Indian Star Tortoise (*Geochelone elegans*) – Several years of husbandry and breeding experience in Bulgaria

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Introduction and breeding stock

The adult pair of *Geochelone elegans* was obtained in May 2006. At that time they were sexually dimorphic subadults (Fig. 1, 2a–d) showing clear mating behavior, although egg deposition first appeared almost 2 years later. Their initial dimensions and growth rate are recorded in Table 1.

Accompanying paper work attested to their being "Captive Bred" in the Czech Republic, but subsequently the importer was implicated in illegal animal smuggling; my tortoises had been a part of a large group of 200 star tortoises. Unfortunately the Indian Star Tortoise is notoriously popular in the illegal trade of tortoises (Telecky 2001, Zwartepoorte

Fig. 1
By general habitus, coloration and size, my *Geochelone elegans* appear to be of the South Indian form, here my female shortly after arriving at the Gea Chelonia Foundation Tortoise Centre.

Date	Female		Male	
	SCL (mm)	Weight (g)	SCL (mm)	Weight (g)
2006/19/05	137	550	127	380
2006/29/12		710		440
2007/21/05		800		420
2007/25/09		980/840*		450
2008/02/06		950		490
2008/10/09		1070		500
2009/18/10		1150		550
2011/23/12	177	1250	144	550
2012/09/01		1300/1100*		

** After egg deposition*

Table 1
Growth rate of my *Geochelone elegans*.

2005, Vinke & Vinke 2010). I firmly believe that my tortoises had been wild caught and illegally smuggled into Europe, then "laundered" in Czech Republic before re-exportation to western European countries and the U.S.A. Such a large group of captive bred star tortoises is appearing simultaneously on the market is extremely unlikely, as there is no breeder of such numbers in the Czech Republic. The probability of their wild origin is further supported by their behavior and from my activities with Bulgarian tortoise conservation; I was partly involved in stopping the illegal tortoise trade of the dealer mentioned.

Morphological difference between southern and northern populations of *Geochelone elegans* in India are reported by some authors (e.g. Das 1995, Bidmon 2006) and genetically confirmed by Gaur et al. 2005, but further investigation is needed. By general habitus, coloration and size, my star tortoises appear to be of the South Indian form, though this is merely speculative (Bidmon 2006). That the exact origin of my Star tortoises remained unknown complicated my efforts to adapt their housing conditions, in light of the different basic climatic requirements relating to the described morphs of the species (Bidmon 2006, Fife 2007).

2009								
Month	IV	V	VI	VII	VIII	IX	X	XI
Ø Temp. °C	10	7	21	24	22	19	15	10
Max. Temp. °C	23	29	31	35	31	30	28	20
Min. Temp. °C	1	16	11	16	14	8	2	-1
2010								
Month	IV	V	VI	VII	VIII	IX	X	XI
Ø Temp. °C	11	17	21	23	26	20	12	14
Max. Temp. °C	22	30	32	33	35	32	24	24
Min. Temp. °C	3	6	12	15	16	11	-1	5
2011								
Month	IV	V	VI	VII	VIII	IX	X	XI
Ø Temp. °C	10	15	20	24	23	21	12	6
Max. Temp. °C	21	26	32	33	34	30	28	16
Min. Temp. °C	0	4	11	13	14	12	2	-4

Table 2
Temperature records April–November during 2009–2011. These data were kindly provided by Asen Iliev, owner of a meteorological station, http://home.asen.iliev.name/weather/, in the city of Bourgas (40 km southwest of Banya village).

Some climatic data

From late April/early May to late October/early November my star tortoises are housed outdoors at the Gea Chelonia Foundation Tortoise Centre, located in the most easterly part of the Balkan Mountain range, Eminska Mountain. The area lies within the Black Sea coastal climatic zone with an average annual precipitation of 550–600 mm and an average annual temperature of 12 °C (Ivanchev 2007a,b) (Fig. 3a–c). August to September is the driest period with 20–60 mm precipitation per month. During spring, precipitation goes up to 170 mm monthly. Average temperature during April is 10–10.5 °C and the average night and day temperatures stabilize at over 10 °C in the second half of the month. The warmest period is July to August with average temperatures of 22.5–23 °C and tempera-

Fig. 2a–d
The adult pair of star tortoises soon after acquisition.

ture maximums of about 30–32 °C. Fall around the coast is considerably warmer than spring. For example the average temperature in October is 14–15 °C (4–5 °C higher than during April). The earliest autumn frosts usually occur in late November, but occasional chilly nights may occur even in the beginning of the month. October is somewhat unpredictable, and requires the keeper to be vigilant at all times for tropical tortoises housed outside. For example, the lowest temperatures measured during the month are 1–2 °C below zero, despite which daytime temperatures may reach 33–35 °C during periods of very intense warming.

Some temperature data for 2009–2011 are summarized in Table 2.

Due to its proximity to the Black Sea and comparatively low elevation – 175 m ASL – the absolute humidity at the Centre is high, more so at midday than in the morning and evening hours. The average annual relative humidity is 75–78 %, the highest being experienced during winters, and lowest during the second half of summer. Due to the comparatively high summer humidity the annual amplitude of relative humidity is 10–15 % (see also Bidmon 2011 and videos at http://www.schildkroeten-im-fokus.de/shop/2011_2_01v.html or SIF-Link 110201v).

Outdoor maintenance

From late April/early May to late October/early November, my Star tortoises are kept in a 10 m² outdoor

Fig. 3
The vicinity of Banya village (a) where Mediterranean tortoises *Testudo hermanni boettgeri* and *T. graeca ibera* naturally occur. The Black Sea shore (b) is 4 km east of the Centre. Map of Bulgaria (c), note relative locations of Banya and Sofia, separated by 450 km.

enclosure, with a few artificial hiding places (Fig. 4). Since 2009 I added small greenhouses 2×1×0.5 m for the adults and 1×0.5×0.5 m for the hatchlings and juveniles, in order to extend their outdoor period (Fig.5a–b). Generally they are taken outside when the minimum overnight temperature remains above 9–10 °C and the daily temperature reaches 23–27 °C on bright sunny days. The addition of the greenhouses has allowed a 30- to 40-day extension of the outside period every year. There is no supplementary heating/lighting source inside the greenhouses. The lid is kept open from late June until September, when the temperature inside the greenhouses rises above 35 °C, whereupon the whole greenhouse is covered with camouflage netting (Fig. 5c). This way the interior provides humid, shady and sunny spots which differ from those outside, thus providing more microclimatic options. It is noteworthy to mention that the tortoises tolerate night temperature as low as 7 °C for a few nights without ill effect.

The food staple for all tortoises during the outdoor period is the natural greens growing in the enclosure (Fig. 6a). Here is a partial list of the naturally growing edible plant species in the area, readily consumed by *Geochelone elegans*: Dandelion (*Taraxacum officinale*), Clover (*Triifolium repens*), Plantain (*Plantago* spec.), Dead nettle (*Lamilium purpureum*), Hawksbeard (*Crepis capillaris*), Mallow (*Malva sylvestris*),

Fig. 4
View of the the Gea Chelonia Foundation Tortoise Centre.

Fig. 5a–b
Installing the greenhouses (a,b), greenhouse covered with camouflage net to provide shade during warmest periods (c).

Fig. 6a–d
Natural greens (a) are available in the enclosure during spring and summer. The tortoises feed on earthworms (b,c) whenever they have the chance after a summer rain. Additional food (d, leafy greens) is supplied if the vegetation in the enclosure is too dry to support normal dietary requirements.

Bindweeds (Convolvulaceae), Mulberry (*Morus* spec.), White thorn (*Silybum* spec.), Grape leaves, Common Morning Glory (*Ipomea purpurea*), Blackberry (*Rubus* spec.), Wild lettuce (*Lactuca serriola*), and Radish (leaves) (*Raphanus sativus*). Extra items like fruit and cultivated vegetables are given occasionally. After summer rain the juveniles, the male and especially the adult female readily eat earth worms when findable on the surface of the ground (Fig. 6b–c). If during the warmest months – July and August – the vegetation in the enclosure dries out (Fig. 7), and the preferred vegetation is being overgrazed, fresh greens are picked on a daily basis and offered to the tortoises (Fig. 6d). Fresh water is always available in a dish which provides the opportunity for soaking. One peculiarity observed during the outdoor season is the search for earthworms by the female which she eats eagerly even during the pre-nesting period.

Fig. 7
View of the Centre in August – the driest period of the year.

Indoor maintenance

During November to April the tortoises are kept indoors. For the first few years the adult pair inhabited a 75×35×20 cm plastic tank (Fig. 8a), but due to growth and lack of space, especially for egg deposition, this was switched to a larger plywood tub measuring 120×50×40 cm (Fig. 8b). I would emphasize that the latter proved to be a poor choice due to the difficulty in maintaining good hygiene and disinfection when necessary.

No additional UV light source has been used

Initially I used a mixture of peat, garden soil and perlite as a primary substrate, covered with a mat of grass or hay. Now the substrate has been changed to garden soil, as this creates less dust than the fast-drying peat, which resulted in an irritation of the nasal mucus membranes of the adults. Frequent signs of RNS and sneezing, even when the tortoises were resting, was observed. The substrate depth gradually increases throughout the enclosure from 5 to 25 cm. A wooden hiding box 35×25×20 cm

Fig. 8a–b
75×35×20 cm plastic tank (a) where hatchlings and juveniles are maintained, previously also used for the adults. Plywood tub (b) measuring 120×50×40 cm, currently used for the adult pair.

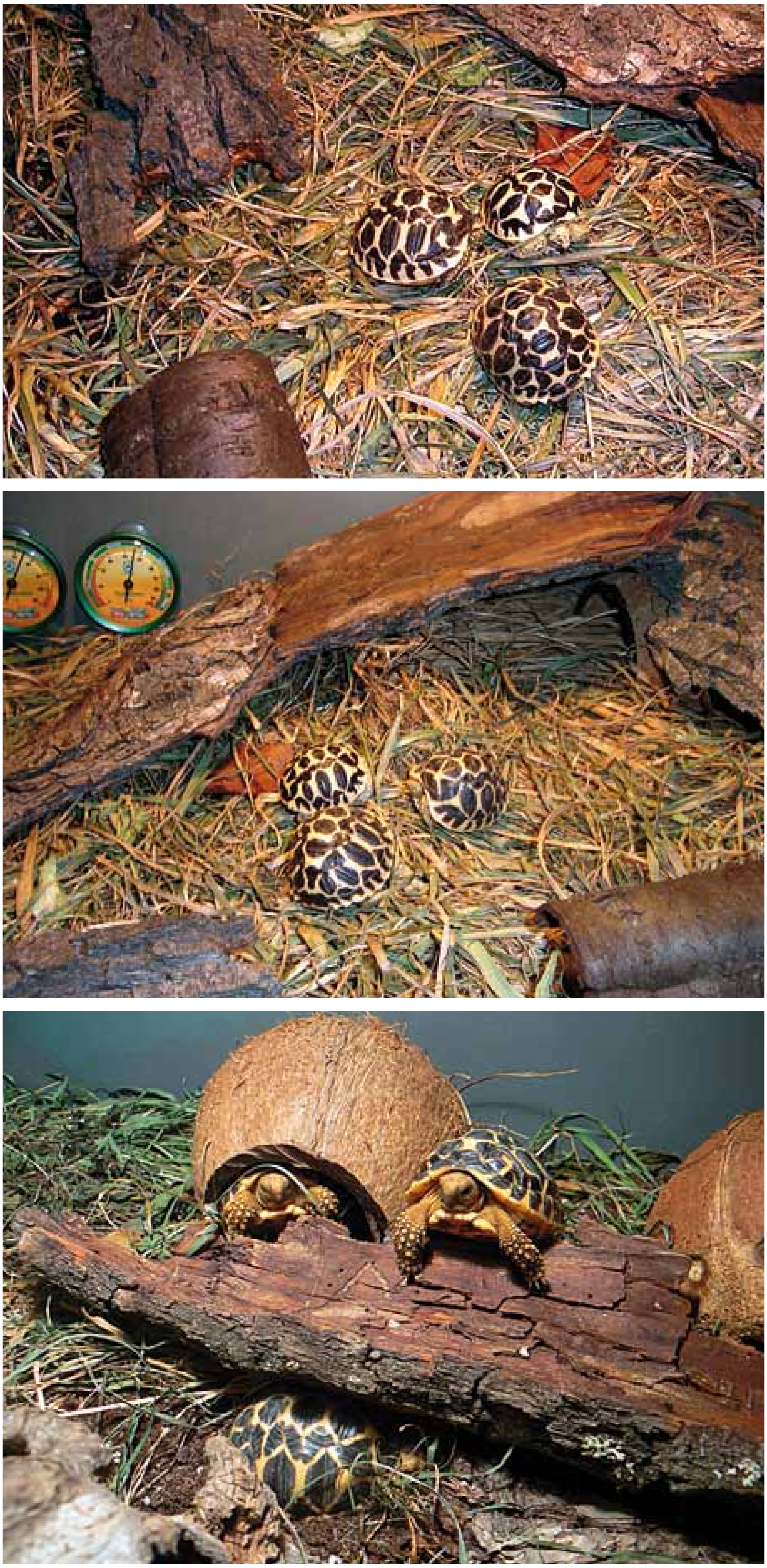

Fig. 9a–c
Indoor enclosures for hatchlings and juveniles.

is located at the opposite side of the heated spot.

The light source is a 100 W halogen spot light, with glass cover removed, mounted at one end of the enclosure, adjusted to create a 34–35 °C hot spot. It is on for 9 hours daily: 8–11 h; 12–14 h; 16–20 h. Different on-and-off schedules were performed by closely observing the tortoises' behavior until finding the optimum schedule. On overcast days, when not enough natural light enters the window, the room light source is on throughout the day 7:30–20:30 h. Otherwise it goes on in the evening so a natural day length of 10–12 h is achieved.

It may be interesting to other keepers that no additional UV light source has been used. So far, even the egg-laying female seems to tolerate the 5–6 month indoor period with no apparent calcium metabolic problems. One reason could be the favorable climatic conditions which prevail between April to November, enabling tortoises to store enough vitamin D_3 reserves. However, halogen bulbs provide a partial UV spectrum. Beginning in January 2012, a 300 W Osram Ultra-Vitalux power lamp, twice a week – 30 min was included in the indoor set up.

A heating cable (20 W) is used in one side of the adults' tank, under the thickest substrate layer and it goes on and off with the light source as the substrate temperature reaches 23–25 °C.

Around 0.7 l of hot water is poured into the tank twice per month and the substrate is sprayed almost every other day to limit the dust and attain optimum humidity. Sometimes a grass tussock is placed in the enclosures, which stores humidity and becomes a preferred resting place. Spraying the enclosures is often done in the evening after the lights are off. In nature humidity increases during the night as the temperature gradually goes down and dew forms, thus in early morning, the ground is wet. However, the tortoises having found their overnight resting places before nightfall, remain dry underneath, even in case of rain.

Hatchlings and juveniles are kept under virtually identical conditions. The differences are: the plastic tank size is only 75×35×20 cm, the substrate layer is 3–5 cm thick, and there are no additional heating cables. For hiding places coconut shells, roof tiles and pieces of bark are provided depending on the size and number of tortoises (Fig. 9a–c). Owing to the thin substrate layer, little or no water is poured inside, but spraying is done more often, depending on a daily monitoring of the conditions, taking care that young tortoises always have a humid sanctuary available.

All the tanks (adult and juveniles) are placed on Styrofoam plates for insulation. Under the described conditions during the day the temperature gradient in the enclosures is 20–35 °C, 50–60 % humidity, and 13–18 °C and 70–90 % humidity at night.

Fig. 10a–e
During winter, when available, fresh greens are always preferred (a,b). Green lettuce is the chief alternative food staple (c,d). Other vegetables and fruits are given only occasionally. Twice per month a mixture of Sera raffy P, ground carrots and cucumbers powdered with cuttlebone are offered to all star tortoises (e).

Fig. 11
Obvious mating behavior was often observed almost two years before the first egg deposition.

All tortoises are fed daily. Fresh greens, picked outside when available, are the main food (Fig. 10a–b), supplemented by leafy greens. Some vegetables and fruits are given only occasionally (Fig. 10c–d). Twice per month a mixture of Sera raffy P, ground carrots and cucumbers, powdered with cuttlefish bone is given exactly in the manner described by (Bidmon 2006) (Fig. 10e). When crushed parts of cuttlefish bone are available in the enclosures, the mixture is not additionally powdered.

Nesting season	Date	Clutch size	Days between clutches	Number of hatchlings
1	2007/25/09	3		2
	2007/10/11	4	46	1
2	2009/18/01	5		
	2009/06/03	3	46	-
3	2009/19/10	4		3
	2009/08/12	4	50	4
4	2010/15/08	5*		2
	2010/01/10	5	45	4
	2010/07/12	4	67	4
	2011/23/01	6	47	4
5	2011/30/09	4*		4
	2011/24/11	6	55	4
	2012/08/01	4	45	4

** Eggs laid outdoors in the green house.*

Table 3
Summarized nesting data.

A small water dish is nearly always available with the adults, especially before and after egg deposition. Water regimes of the juveniles are described below.

Mating and egg deposition

The adult pair exhibited clear mating behavior shortly after they were acquired (Fig. 11), although the first clutch of eggs was produced in September 2007. Mating behavior continues throughout the year but is most frequent in April–May, when the tortoises are placed outside. Spring and summer rainfalls, spraying or pouring water into the tank, and soaking the tortoises in tap water (during indoor maintenance) stimulate courtship behavior. It is worth mentioning that the male got horny, continuously following and mounting the female several days before egg laying during the last two nesting seasons – behavior previously not observed. This behavior is a reliable sign that the female is ready to lay eggs. As soon as the male was separated, she almost immediately began to dig a nest.

It must be stressed that references to courtship or mating stem entirely from observing the male's sexual behavior. Whether the female experiences real mating, unless eggs are laid afterwards, remains rather speculative.

The female weighed 980g before producing the first clutch, and 840 g afterwards (Table 1). She started digging in the outdoor enclosure, but after a few days of unsuccessful efforts, she was placed inside. However, she remained unable to deposit her eggs. After 10 days she was injected with calcium 50 mg/kg and Oxytocin 5 IU to induce oviposition (Fig. 12a). The three eggs were relatively large and one was deformed (pear shaped, Fig. 12b, 14h), possibly the cause of the laying problem. The second clutch of 4 eggs was deposited after 46 days without

Fig. 12a–c
First clutch (a) was induced after injection with calcium 50 mg/kg and Oxytocin 5 IU. Three relatively large eggs were deposited and one was deformed (b) possibly responsible for the female's inability to lay for 10 days. Twice an egg was broken (c), most probably due to lack of experience and/or localized under-calcification of the eggshell.

Fig. 13a–f
Most eggs are laid indoors (a–c) and preferred nesting time is late afternoon and evening. Only two clutches were laid outdoors in August and September in the greenhouse (d,e). The temperature during nesting fell gradually from 27 °C at the onset, to 22 °C upon having covered up the eggs (d). Ignore the humidity readings as it is measured from the box outside the green house.

Fig. 14a–h
Interior view of the incubator (a). Hatchlings from the first nesting season (b-h). Even though the first three eggs were induced with Oxytocin, two of them hatched. The third one(misshapen) was infertile.

complications, but one egg was broken while laying (Fig. 12c).

Nesting data is summarized in Table 3. Note that after three seasons depositing two clutches, the female shifted to four clutches per season. There was no intermediate season of three clutches which came latter in season №5. The mean clutch number per season is 2.6 (range 2–4 clutches, n=5), but this value could be increasing due to fewer clutches produced during the first three seasons after reaching sexual maturity. The mean clutch size is 4.4 (range 3–6 eggs, n=13). Mean number of days between clutches of the same season is 51 (range 45–67 days, n=7). Egg size varies from 38–53 mm in length, 23–32 mm in width and 17–22.3 g weight (n=57).

Until now nesting appears throughout August–March with a peak during September–January (Table 3). The preferred nesting time is late afternoon and evening (Fig. 13a–c). Sometimes nesting will continue as late as 23:30 h before the nest is completely covered and camouflaged. Usually the female is very choosy, sometimes digging test nests for up to 10 consecutive days before actual deposition. Normally, this period lasts 2–3 days. Only twice were eggs deposited outdoors in the green house when the ambient temperature was only 22–25 °C (Fig. 13d–f). Most of the eggs are laid indoors under the hot spot, which creates an air temperature of 27–30 °C and a substrate temperature of 23–25 °C (at 10 cm depth). Excavation, laying and camouflaging the nest take from 1.5 h up to 3.5 h.

Problems associated with eggs breaking during nesting were experienced twice in November 2007 and January 2009, when an egg cracked during deposition (Fig. 12c). In my opinion this was due to lack of experience (occasionally young *Testudo hermanni boettgeri* females are observed to experience the same accidents)

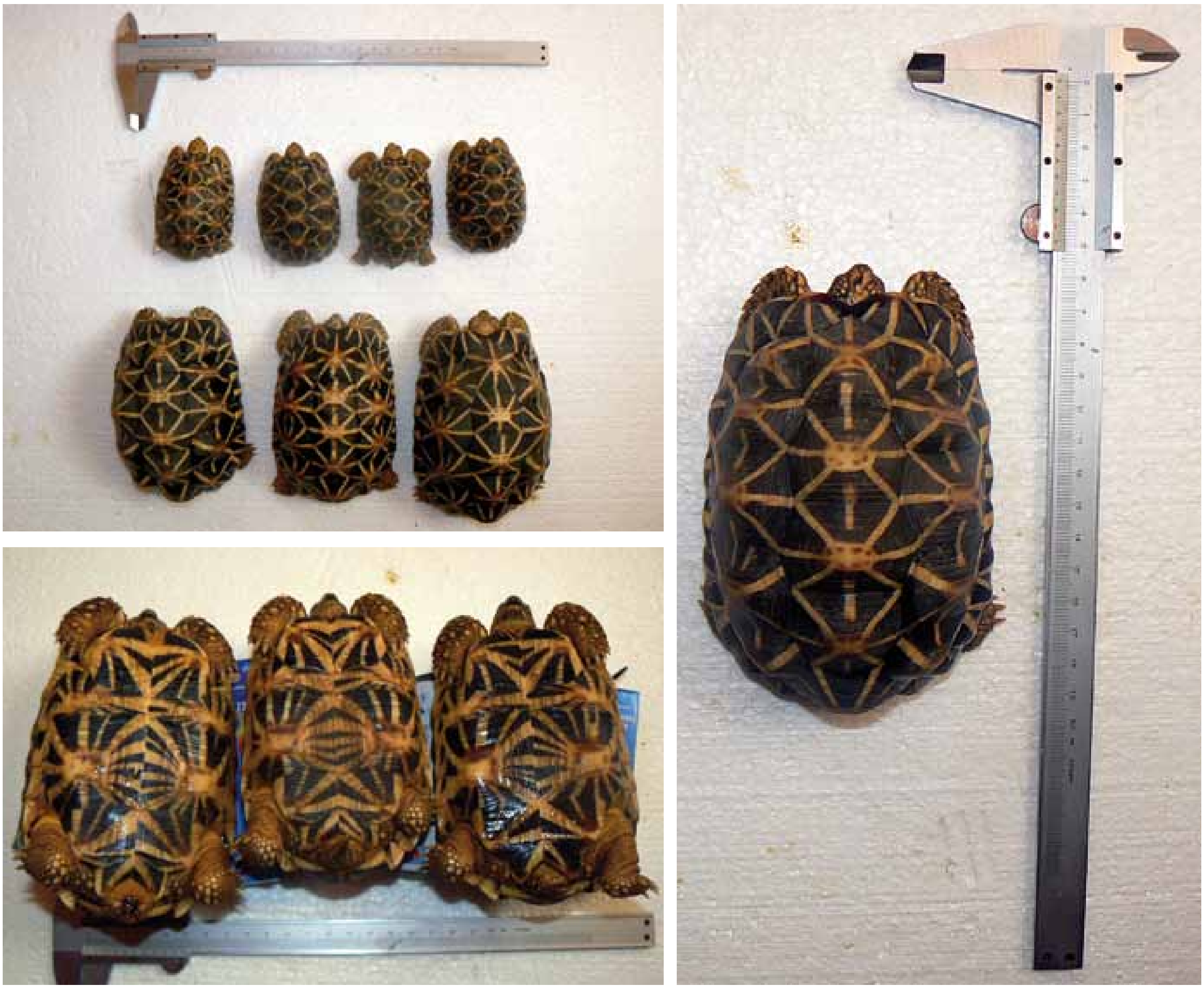

Fig. 15a–c
Two and four year-old juveniles (a). The three subadults (b), the male is in the middle. Young female with five costal scutes on each side (c).

and/or to inadequately calcified egg shells. Also the intensive growth of the female during this early stage most probably led to some minor calcium insufficiency which was later corrected with supplementary calcium added to the diet.

Incubation

Eggs are dug out immediately after deposition and placed in the incubator in plastic containers half buried in 3–4 cm deep vermiculite. The incubator I use is a simple set-up which includes Styrofoam box, 20W silicon heating cable and ELV Universal thermostat. Humidity is maintained with sponges in the 70–80 % range (Fig. 14a).

Eggs incubated at 31–32 °C will hatch after 97–101 days and at 29–29.5 °C after 104–124 days of incubation (Fig. 14b–h). The only three individuals identifiable so far by gender were incubated at the higher temperature, and interestingly one of them is male. This finding is contrary to the well-documented temperature dependant sex determination (TDSD) for *G. elegans*, according to which at these temperature female-biased clutches are prevalent (Fife 2007). Other keepers report females hatching at 28 °C (Bidmon pers. communication). Supposedly pivotal temperature might vary or other factors play a role in the embryonic sex determination like for example the CO_2 level in the breeding environment, described for *Graptemys kohnii* and *Trachemys scripta* (Etchberger et al. 2002).

An interesting observation which might be useful and reassuring for other keepers involves the long-distance transport of eggs at various stages of incubation, with no perceptible effect on hatching success. Star tortoises and their eggs had to be transported by car during winter, for a distance of almost 500 km, a 5 to 6 hour drive. The egg containers were filled to the top with vermiculite, and closed to prevent rotation. A hot water bottle was placed inside of the cotton stuffed incubator with clothing on top. The eggs were transported at nearly all stages of incubation and the hatching rate of the transported eggs was an astonishing 100 %.

In 2010, due to improper use of new hygrometer device, the relative humidity in the incubator reached high levels for prolonged period – over 90 % for more than two weeks. Although fertile eggs are very unlikely to mold, the latest appear in the incubator and some viable eggs were also affected. They were carefully picked up and cleaned with cotton soaked with 3 % hydrogen peroxide (H_2O_2) solution. This treatment helped and further incubation and hatching was successful.

Hatchling and juvenile care and development

Normally it takes a few (2–5) days before the hatchlings are ready to leave the incubator. After they are placed in their tank it may take up to 10 days before they start feeding. Regular soaking in shallow slightly warm water is provided every few days for the first month. After that, regular baths are provided every week or 10 days. Water trays are not kept in the indoor setup, to minimize the risk of drowning, and because in few hours young tortoises can create a real mess. Sometimes a water dish is provided for a day or two prior to changing the substrate. In the outdoor enclosure clean water is constantly available. Some juvenile growth data is provided in Table 4.

My three first-born subadults (2 female and 1 male, Fig. 15a–c) hatched in January 2008 began to show clear courtship behavior around 33 months of age. It is worth mentioning that one of the young females has five symmetrical costal scutes on each side (Fig. 15c). Exactly the same malformation appeared on a juvenile hatched two years later.

Age	Sex	SCL mm	Max. Wide mm	Max. Height mm	Weight g
Hatchling	Unknown	30	19	22	11.0
	Unknown	33	31	22	11.6
	Unknown	33	31	23	12.3
	Unknown	30	31	23	11.4
2 Years old	Unknown	69	50	43	83
	Unknown	70	54	42	89
	Unknown	70	54	44	85
	Unknown	69	52	41	85
4 Years old	Male	124	80	66	365
	Female	133	90	73	491
	Female	122	83	74	412

Table 4
Growth rate of selected juveniles (Fig. 15a).

Health care

So far my star tortoises have not experienced any serious disease problems. As mentioned in the literature (Bidmon 2002, 2006) the adult pair occasionally shows signs of Runny Nose Syndrome (RNS). This was noted as soon as I obtained them in 2006, and is more pronounced in spring and autumn after their transfer from indoor to outdoor enclosures and vice-versa. However, occasionally bubbly nares are noted at other times of the year. Attempts to pinpoint the cause of this phenomenon have not been successful. In my case, this problem is most probably associated with acclimatization rather than infection with *Mycoplasma* spp. (Brown et al. 2001, Mohammadpour et al. 2010). Other causes described by Bidmon (2002) for such symptoms including grain mites (*Acarus siro*) or mold mites (*Tyrophagus longior*) were never detected. Recently peat dust was discovered to provoke an allergic reaction which is followed by such symptoms. None of the juveniles being raised under identical conditions to those of the adults has ever showed signs of RNS.

Occasionally embryonic death during the final stage of development has occurred (Fig. 16a–b). A possible reason is the development of an overly thick eggshell. Supporting this hypothesis is my experience that when some of the "late" eggs were carefully punctured manually, a living but weakened hatchling could be removed and revived. Another possible reason is yolk sack infection due to the tiny cracks in the egg shell (Hans-Jürgen Bidmon, personal communication). However, mortality of embryos at term and/or their failure to hatch "on time" remain inadequately understood problems requiring further investigation.

Fig. 16a–b
Occasional embryonic death occurs late during development.

In regard to ectoparasites, ticks (*Hyalomma aegyptium*), widely abundant in the area, occasionally are found and removed manually with forceps and the irritated skin treated with 3% hydrogen peroxide (H_2O_2). Endoparasites such as nematode worms (order Oxyurida: *Tachygonetria* spec., Fig. 17) are treated when found with oral 50–100 mg/kg Fenbendazol (Panacur paste) twice in 14–21 day period.

Acknowledgments

I would like to express my gratitude to my parents Daria and Evstati and my girlfriend Iva for sharing all the care and responsibility of the tortoises during my absence, James Buskirk for his support in improving my bumpy original English draft, and Gerhard Jennemann, for teaching me how to identify common endoparasites. My biggest Star tortoise "Thanks" go to Hans-Jürgen Bidmon, always there to

provide me with the right expert advice.

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Fig. 17
Feces. Oxyurid worms (*Tachygonetria* spec.) are clearly visible.

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