

Captive breeding of *Dipsochelys* giant tortoises

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Abstract: The Seychelles Giant Tortoise Conservation Project captive breeding programme for the Seychelles tortoises *Dipsochelys arnoldi* and *D. hololissa* is described. Successful hatching occurred in 2002 and the reasons for this success discussed. Important factors are enclosure design, social structure and the use of artificial incubation. Methods for sexing hatchlings are discussed. There may be great potential in manipulating social structure to encourage breeding in otherwise difficult taxa, such as the Galapagos tortoise *Chelonoidis nigra*.

Key words: anatomy, conservation, giant tortoise, social structure

Introduction

Indian Ocean giant tortoises have a long history in captivity, having been kept since the 1600s. Despite this history captive breeding of the surviving Aldabra-Seychelles genus *Dipsochelys* remains relatively rare, with occasional breeding in Britain, the U.S.A., Australia and Japan. The only regular breeding occurs in Mauritius and Seychelles. Even in Seychelles the vast majority of captive tortoises do not breed.

The rediscovery of the Seychelles giant tortoises *D. hololissa* (Günther, 1877) and *D. arnoldi* Bour, 1982 led to the creation of the Seychelles Giant Tortoise Conservation Project by the Nature Protection Trust of Seychelles in 1997. The project brought together the few surviving individuals of these species and housed them in large, semi-natural enclosures. The experiences of other *Dipsochelys* tortoise keepers were compiled through direct discussions and other sources (Ebersbach 2001; Schils & Smeets 2001). This resulted in successful captive breeding in 2002. The methods used to achieve this success are described below.

Enclosures and social organisation

The captive breeding project is based in three large enclosures on Silhouette island. Each enclosure measures approximately 30x40m, housing 13 tortoises. These comprise 3 adult male and 3 adult female *D. arnoldi*; 3 adult male, 1 subadult male and 2 adult female *D. hololissa*; and a juvenile *D. dussumieri*. The enclosures contain natural plants, trees, shelters, muddy wallows and supplies of clean drinking water (Fig. 1).

From 1997 to 2001 the species were kept separate with *D. hololissa* (and the *D. dussumieri* juvenile) in one enclosure and the *D. arnoldi* in another. The third enclosure was only used seasonally, when females were separated from the males in order to encourage mating during the breeding season. From 2002 all tortoises were allowed free movement between the enclosures following advice that successful breeding was only likely with a large group, preferably of at least 12 tortoises (O. Griffiths pers. comm.). Mating success appeared to improve after this change and fertile eggs were produced for the first time.



Fig. 1. *D. hololissa* (right) and *D. arnoldi* (left) in enclosures on Silhouette island

Incubation

Since the first eggs were laid in 1999 most clutches were incubated artificially. In 2002 three alternative incubation methods were tried: artificial incubation, reburial in a secure site and natural, undisturbed incubation. This year saw the first hatchlings, all from eggs incubated artificially. None of the eggs incubated in the ground hatched; there was no sign of development in reburied eggs and most of the natural nests were destroyed by crabs.

Successful artificial incubation was achieved using an incubator with over 80% humidity and set at 29°C (28-30°C). The 2001 temperature resulted in hatchlings after 125-136 days which would be expected to be males. The temperature was altered in 2003 to over 30°C (30-32°C) to produce females, and hatching occurred at 90-94 days (Fig. 2).

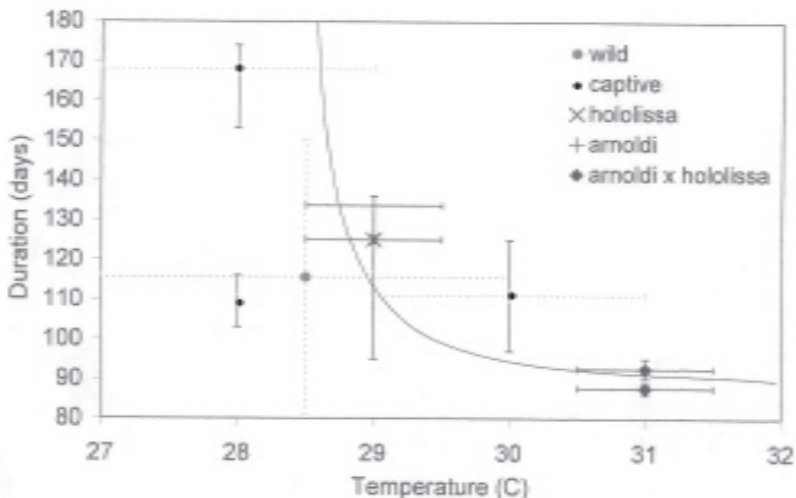


Fig. 2. Results of artificial incubation (based on published data for *D. dussumieri* and new data on *D. arnoldi* and *D. hololissa*).



Fig. 3. *Dipsochelys hololissa* (left) and *D. arnoldi* (right) hatchlings

Hatchling morphology

The 2002 hatchlings comprised both *D. arnoldi* and *D. hololissa* (Fig. 3). The external morphology was compared to investigate species differences (Gerlach & Bour 2003). The first 2003 hatchlings represented hybrids between these two species, and accordingly they show variable external morphology. In 2002 one *D. hololissa* full-term embryo died prior to hatching and in 2003 one of the hybrids died during the hatching process. Both of these were dissected to investigate the internal anatomy and to confirm the presumed sexes of the clutches.

Anatomy

The anatomy of *Dipsochelys* giant tortoises is described in detail in Gerlach (2003). Hatchling anatomy is identical to that of the adults in most respects. Partial musculoskeletal dissections are shown in Fig. 4. The only feature of the internal anatomy not previously figured is the brain (Fig. 4), this closely resembles that of other tortoise species. The skull is notably poorly developed, with no mandibular denticles and no supra-occipital crest. It is notable that the skull at this stage is very similar to that of the Madagascar spider tortoise (*Pyxis arachnoides*), a genus which is closely related to *Dipsochelys*, and may be a paedomorphic derivative from a Madagascan common ancestor (Palkovacs *et al.* 2002).

The dermal components of the carapace are not ossified in the hatchling material, with the carapace being composed of the dorsal vertebrae and ribs only. The vertebrae are all distinct and the 8th dorsal vertebra 75% of the length of the 7th (similar to adult *D. hololissa* but distinct from *D. dussumieri*).

Sexing the embryos proved to be less clear than published accounts imply (Swingland & Coe 1979). Both dissections revealed identical reproductive tract morphology despite the clear differences in incubation time and duration, factors which are expected to result in different sexes. The cloaca of both embryos contained a distinct penis-like structure. This was relatively small but structurally identical to the adult male penis. The gonads were elongate, brown structures positioned dorsally to the kidneys. No clear internal structure could be discerned. From these dissections it appears that the reproductive tracts of male and female tortoises is not differentiated until after the hatchling stage. It is probable that

the penis precursor does not develop any further in the female, remaining a small area of erectile tissue, developing into the full penis structure in subadult males. Gonad differentiation may also take place relatively late. This late differentiation means that embryonic and hatchling tortoises cannot be sexed on the basis of reproductive tract morphology, despite published reports of hatchling sex ratio determined by dissection (Swingland & Coe 1979). An alternative sexing method may be possible using the external morphology of the tail. This is distinctly longer in adult males than in females, but no such difference is present in hatchlings. As the tail elongates males do not grow additional scales but expand the existing scales, thus the number of tail scales gives an indication of the adult tail length (I.R. Swingland pers. comm.). The embryo and hatchling tail scale counts are shown in Table 1. These support the expectation that the low temperature 2002 hatchlings are male whilst the higher temperature 2003 hatchlings are female.

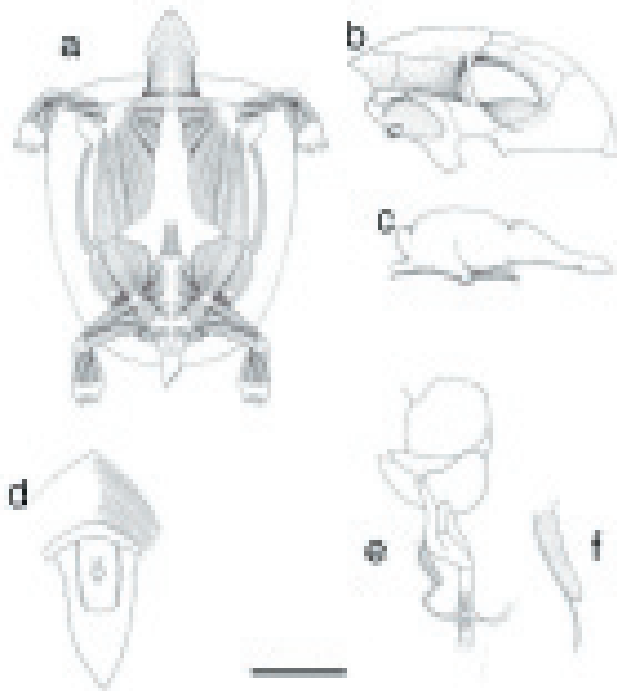


Fig. 4. Hatchling *D. hololissa* anatomy. a) superficial musculature ventrally; b) skull laterally; c) brain laterally; d) sectioned cloaca dorsally, showing erectile organ; e) urogenital system; f) detail of gonad. Scale bar: a - 15mm; b&f - 3mm; c&d - 2mm; e - 10mm

Table 1. Tail scale counts of artificially incubated hatchlings (range and mean)

Species	Incubation temperature	N	Tail scales	Presumed sex
<i>D. arnoldi</i>	28-30	3	12-(13.8)-14	male
<i>D. hololissa</i>	28-30	2	14	male
<i>D. arnoldi</i> x <i>hololissa</i>	30-31	7	8-(9.0)-11	female

Discussion

The successful captive breeding of both *D. hololissa* and *D. arnoldi* in 2002 are the result of providing the adult tortoises with suitable conditions. These comprise large, varied enclosures, plentiful natural foods (notably high in calcium) and an appropriate social grouping. The combination of spatial and social variability enables the females to avoid the males when they wish to do so and reduces tensions in the captive group. A relatively large group (12 or more individuals) encourages some degree of competition between the males which seems to be needed to stimulate successful mating. Under captive conditions (where a full selection of nest sites cannot be provided) artificial incubation is the most effective method. This requires high humidity levels (over 80%), the critical temperature for sex determination is believed to be 29°C.

These methods have been developed specifically in order to achieve successful captive breeding of *Dipsochelys* giant tortoises but they may also have application to other species. The social aspect of tortoise behaviour is often overlooked, although it is known to be vitally important in the breeding of the plough-share tortoise *Astrochelys yniphora* (Vailant, 1885) (McKeown *et al.* 1982) and is significant in the Galapagos tortoises *Chelonoidis nigra* (Quoy & Gaimard, 1824). Stimulating male-male competition in tortoise breeding has only been explicit in the Seychelles Giant Tortoise Conservation Project and in projects to breed the plough-share tortoise but could be the key to successful breeding of other Critically Endangered taxa. The most famous tortoise needing such a novel approach, and perhaps the most likely to respond, is the last surviving male Pinta Galapagos tortoise *C. nigra abingdoni* (Gunther, 1877) ‘Lonesome George’.

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