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TECHNICAL REPORT

Body Size Development of Captive and Free-Ranging Leopard Tortoises (*Geochelone pardalis*)

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The growth and weight development of Leopard tortoise hatchings (*Geochelone pardalis*) kept at the Al Wabra Wildlife Preservation (AWWP), Qatar, was observed for more than four years, and compared to data in literature for free-ranging animals on body weight or carapace measurements. The results document a distinctively faster growth in the captive animals. Indications for the same phenomenon in other tortoise species (Galapagos giant tortoises, *G. nigra*; Spur-thighed tortoises, *Testudo graeca*; Desert tortoises, *Gopherus agassizi*) were found in the literature. The cause of the high growth rate most likely is the constant provision with highly digestible food of low fiber content. Increased growth rates are suspected to have negative consequences such as obesity, high mortality, gastrointestinal illnesses, renal diseases, ''pyramiding,'' fibrous osteodystrophy or metabolic bone disease. The apparently widespread occurrence of high growth rates in intensively managed tortoises underlines how easily ectothermic animals can be oversupplemented with nutrients. Zoo Biol 29:517–525, 2010.

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INTRODUCTION

The Leopard tortoise [*Geochelone pardalis*, Bell, 1827], one of the largest mainland tortoise species, ranges from Eastern to Southern Africa [Iverson, 1992]. Despite its wide distribution, the knowledge about this species, particularly its growth and development, is limited. Available data from literature are primarily concerned with patterns of the body mass and the body size, correlating weight and length measurements in free ranging [Lambert, 1995; Lambert et al., 1998; Hailey and Coulson, 1999; Kabigumila, 2000, 2001] or captive specimens [Wilson, 1968; Rall, 1988]. Although such information emphasizes the consistency of these correlations, they offer little guideline for the husbandry of the species, because the most important question for raising tortoises—the correlation of body mass and age—cannot be addressed. The only study providing information about the body mass development with age in Leopard tortoises is by Wilson [1968], who kept animals in confinement but did either not offer food or just supplement some greens in addition to the natural vegetation. Additionally, Hailey and Coulson [1999] and Hailey and Lambert [2002] presented data on the total length of free-ranging Leopard tortoises in relation to age.

A growth rate exceeding that of natural populations is suspected to occur in many captive and pet tortoises, with potential pathological consequences such as obesity, high mortality, gastrointestinal illnesses, renal diseases, "pyramiding," fibrous osteodystrophy or metabolic bone disease [Häfeli and Schildger, 1995; McArthur, 2004a; McArthur and Barrows, 2004; Donoghue, 2006; Hatt, 2008]. On the one hand, empirical studies on the correlation of fast growth with any of these conditions are lacking; on the other hand, growth curves for natural or captive tortoises that relate age to other parameters are rare. This lack of guidelines induces a component of uncertainty in tortoise husbandry. To our knowledge, the only published data on a comparison of age-related growth in intensively kept and extensively kept, respectively free-ranging herbivorous land tortoise species are on Galapagos giant tortoises (*Geochleone nigra*) by Furrer et al. [2004] and on Spur-thighed tortoises (*Testudo graeca*) by Lapid et al. [2005].

In this contribution, we present data on the growth of Leopard tortoises kept at the Al Wabra Wildlife Preservation (AWWP), Doha, State of Qatar, and compare the data with the specimens managed by Wilson [1968] on natural vegetation only and to free-ranging individuals investigated by Hailey and Coulson [1999] and Hailey and Lambert [2002].

METHODS

Leopard tortoises have been kept at AWWP since 1999. Juveniles hatched each year from May to October (between 2002 and 2007). Animals were kept in enclosures with a natural vegetation of grasses and small shrubs with a regular supplement of a variety of vegetables (tomato, carrot, bell pepper, zucchini, cucumber and pumpkin), fruits (melon, papaya, grapes, apple, pear, berries, banana and cactus fruits), fresh lucerne (*Medicago sativa*), fresh grasses, browse (*Ziziphus spina-christis*), flowers and grass hay ad libitum. Absolute amounts ingested, and the nutritional composition of the diet, were unknown. Hatchings were repeatedly weighed and measured several times per year in varying intervals between 2002 and 2008 (age groups 2002–2006 consisting of 3–50 animals). The investigations included totally 109 Leopard tortoises. Fecal samples were taken regularly, most of the cases without parasite findings. In positive cases the treatment of choice was Fenbendazole (50 mg/kg) for 2 days every other week for 3 weeks or Prazinquantel (8 mg/kg) for 1 day every other week for 3 weeks. The animals included in this study were assessed until two to nearly four and a half years of age. Apart from body mass, measurements included the total length (straight carapace length), the plastron length and the height of the tortoises, measured by callipers (straight measurements) and the curved carapace length and width measured by a soft tape (curved measurements). Data were recorded to the nearest millimeter or the nearest gram, respectively.

RESULTS

The animals of all investigated age groups showed a regular allometric body form development similar to previously published patterns in the same species [Wilson, 1968; Rall, 1988; Lambert, 1995; Lambert et al., 1998] (Fig. 1). Therefore, the relationship of body proportions and body weight are consequently the same in the captive animals and in the free living or not artificially fed individuals.

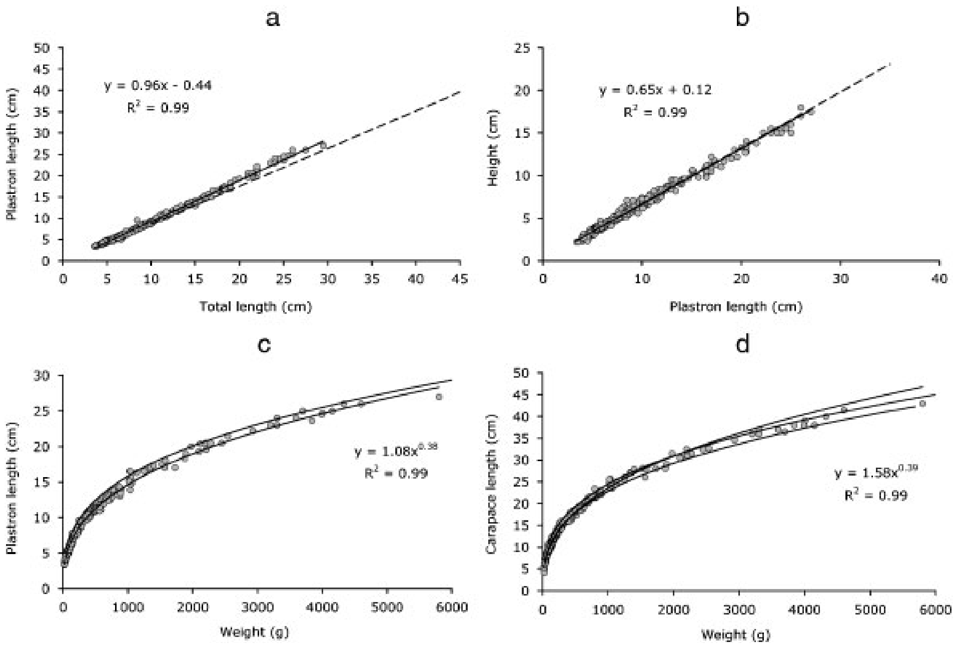

Fig. 1. The allometric relationship between (**a**) total length and plastron length from the Leopard tortoises (*Geochelone pardalis*) at AWWP (data points and solid line) compared to literature [Lambert, 1995, interrupted line, $y = 0.88x{-}0.17$], (**b**) plastron length and height from the Leopard tortoises at AWWP (data points and solid line) compared to the data from Lambert et al. [1998, interrupted line, $y = 0.66x{+}0.17$], (**c**) weight and plastron length from the Leopard tortoises at AWWP compared to the data from Wilson [1968, upper regression line, $y = 1.45x^{0.35}$] and (**d**) weight and carapace length from the Leopard tortoises at AWWP compared to literature [Wilson, 1968, middle regression line, $y = 2.31x^{0.34}$ and Rall, 1988, lower regression line, $y = 1.97x^{0.35}$].

Among the animals raised at AWWP, differences in the body weight development between the different year cohorts are evident (Fig. 2a). In particular, animals hatched in 2002 and one group of animals from 2003 showed a slower body weight increase than the other animals. No difference in husbandry conditions could be elucidated in retrospect to which this difference could be attributed.

When the growth patterns of Leopard tortoises from AWWP are compared with the data from Wilson [1968], Hailey and Coulson [1999] or Hailey and Lambert [2002], a distinctive difference is evident (Fig. 2b). The animals kept at AWWP grew much faster than all the other individuals studied.

DISCUSSION

The captive population of Leopard tortoises at AWWP showed a dramatically faster growth pattern than conspecifics from the wild or kept in natural enclosures with hardly any food supplementation (Fig. 2). In this respect, the data for this species reveal the same pattern that can also be found in other tortoise

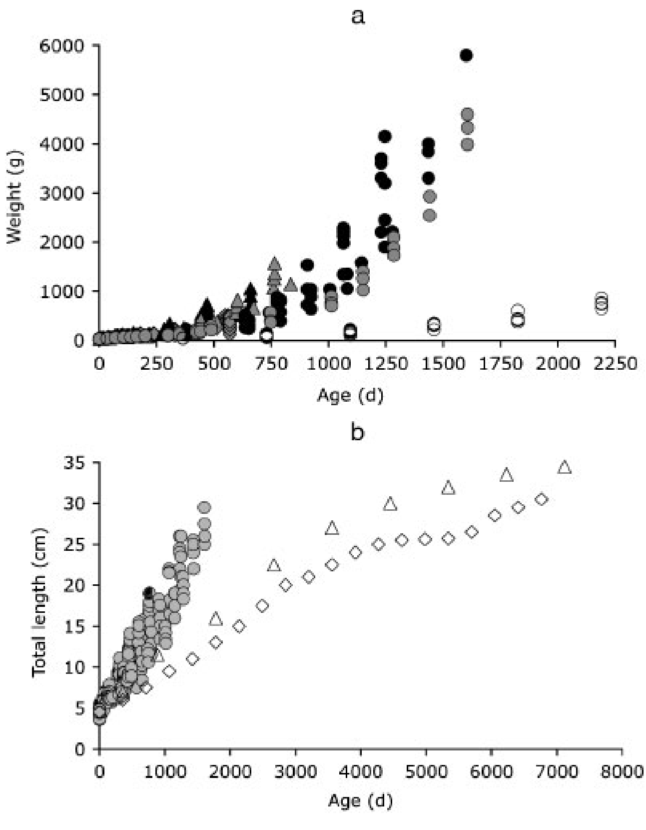

Fig. 2. Data showing (**a**) the weight development from the Leopard tortoises (*Geochelone pardalis*) at AWWP separated by birth years (2002 gray circles, 2003 black circles, 2004 gray triangles, 2005 black triangles, 2006 rhombs) compared with literature [Wilson, 1968, open circles] and (**b**) the growth of the total length from the Leopard tortoises at AWWP (gray circles) compared with literature [Hailey and Coulson, 1999, triangles; Hailey and Lambert, 2002, rhombs].

species—either in direct comparisons of captive and free-ranging populations, or when data from different publications are combined (Fig. 3). Free-ranging or extensively kept animals always grow much slower than intensively kept individuals.

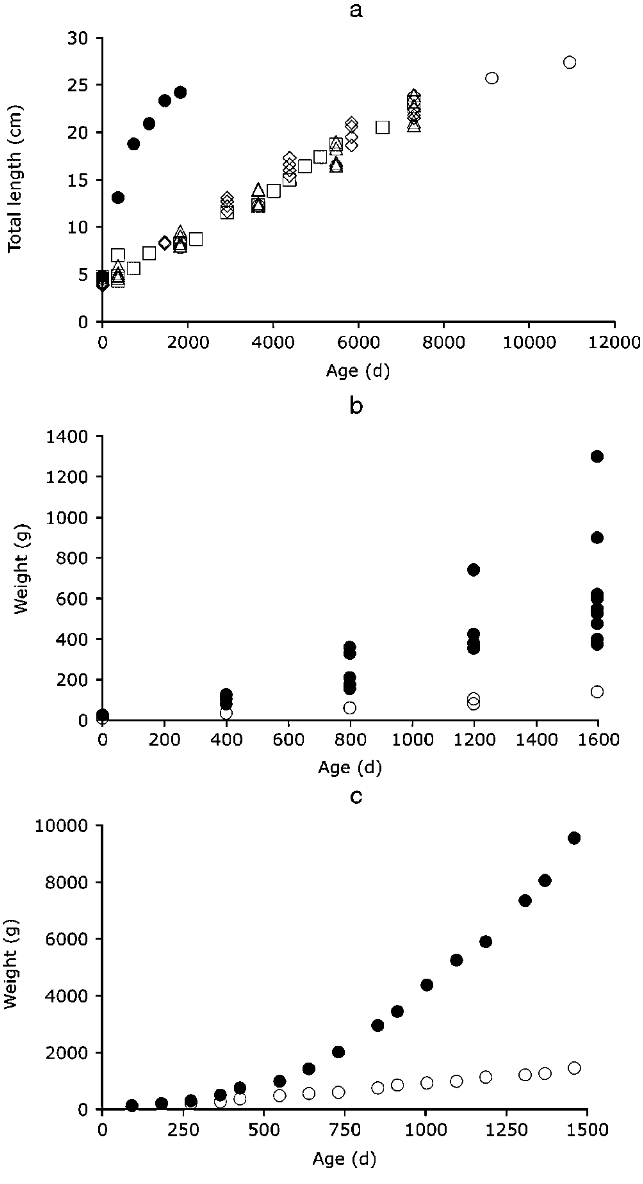

Fig. 3. Comparison of the different development of intensive and extensive nourished land tortoise species. (**a**) Age to total length of Desert tortoises (*Gopherus agassizi*) fed intensive [points, Jackson et al., 1976, 1978] and free-ranging [triangles, Germano, 1992; rhombs, Germano, 1994] or with a rather extensive feeding [squares, Miller, 1932, 1955; circles, Patterson and Brattstrom, 1972]. (**b**) Age to weight of captive Spur-thighed tortoises (*Testudo graeca*) fed with a high-energy diet (points) and free-ranging animals (circles) in Israel by Lapid et al. [2005]. (**c**) Age to weight of the Galapagos giant tortoises (*Geochelone nigra*) at the Zurich Zoo (points) and on Galapagos (circles), Furrer et al. [2004].

Similarly, McArthur [2004b] had presented qualitative evidence, in the form of photographs of two similar-aged Leopard tortoises from the wild and from captivity, respectively, that documented a faster growth in the captive individual.

In tortoises, growth patterns can be influenced by sexual dimorphism, or by environmental conditions. Growth patterns also vary between different populations of free-ranging individuals, most likely due to differences in habitat quality [Aresco and Guyer, 1999]. In the case of the Leopard tortoise, conflicting results have been published with respect to sexual dimorphism—some studies found sexual dimorphism in the species, with females being larger [Lambert et al., 1998; Kabigumila, 2000, 2001; Mason et al., 2000], but another study did not find evidence for it [Lambert, 1995]. The discrepancy is most likely explained by differences in environmental conditions between the study populations, because Hailey and Coulson [1999] noted differences in the degree of sexual dimorphism in Leopard tortoises between various geographic areas. Lambert et al. [1998] also remarked that growth varied geographically, probably due to environmental conditions such as differences in climate, bushfire incidence and predation pressure. For example, wet summers may increase activity and stimulate a higher food intake which leads to faster growth, whereas lower temperatures in winter reduce the activity, may even cause a hibernation, and thus slow down growth [Lambert, 1995]. Of course, these seasonal influences also have an effect on quality and abundance of food. The variation observed in the growth patterns between hatchling cohorts at AWWP is most likely explained by such (unnoticed) changes in environmental conditions.

Regardless of these factors that can influence a tortoise's development, the differences between intensively kept and free-ranging/extensively kept animals (Figs. 2 and 3) are of a dramatically higher magnitude than differences found in the wild due to environmental conditions or sexual dimorphism. In these cases, it seems obvious that the different living conditions of the populations—particularly the food offered to them—influence the growth considerably. Although direct experimental evidence for this assumption is mostly lacking, other authors also contributed the difference in growth between intensively kept and free-ranging/extensively kept animals to the feeding regime [Jackson et al., 1976, 1978; Furrer et al., 2004; Lapid et al., 2005]. To our knowledge, the only study that provided controlled evidence for an influence of the diet on growth in tortoises is the one by Fledelius et al. [2005], who investigated the influence of calcium supplementation on growth rates in Leopard tortoises. The animals with a daily calcium dose three times higher than recommended had the highest growth rate, whereas individuals receiving less calcium grew slower. A similar effect was reported in soft-shelled turtles [Huang et al., 2003]. In other reptiles, differences in growth rate due to differences in the provision with energy and nutrients have been described repeatedly [Statoh et al., 1990; Donoghue, 1994; Baer et al., 1997; Donoghue et al., 1998; Madsen and Shine, 2000; Rich and Talent, 2008]. These reports document a considerable potential of reptiles to accelerate or decelerate growth in reaction to the supply of food; we can only presume that this plasticity is more pronounced than in the case of the endotherm mammals or birds in which growth rates are probably less flexible. The combination of small initial body size, dramatically lower energy and nutrient requirements in ectotherms as compared with endotherms, lack of an increase in metabolic rate in growing as compared with adult tortoises [Brown et al., 2005], availability of food in captivity, and habituation to feeding (and consuming) amounts adequate for endotherm maintenance on the side of animal keepers, makes an oversupplementation of food to tortoises likely whenever no special attention is paid to restrict this amount.

In addition to differences in the feeding regime, differences in the load of pathogenes and/or commensals, in particular gastrointestinal parasites, might play a role. In free-ranging tortoises, a variety of parasites have been reported [Jacobson, 1994] that will potentially reduce the amount of energy and nutrients available for growth in their hosts. Standard veterinary care for captive individuals, such as the regular parasitic control and treatment in the Leopard tortoises used in this study, could thus also contribute to faster development. To our knowledge, however, this has not yet been investigated in controlled studies.

Whether faster growth rates are actually linked to health problems can, so far, only be speculated upon. Although there appears to be a consensus in this respect in the reptile literature (see Introduction), experimental evidence is lacking. On an anecdotal level, Jackson et al. [1976, 1978] observed not only a dramatically faster growth in their intensively kept Desert tortoises as compared with free-ranging specimens (Fig. 3), but also noted that their animals showed a pyramiding growth pattern. Pyramiding has, so far not been observed in the Leopard tortoises at AWWP. In order to reduce the growth rate of hatchings at AWWP, and presumably contribute to a higher health standard of the following hatching cohorts, vegetables and fruits were excluded as a result of this study at AWWP, so that the current diet only includes the natural enclosure vegetation of grasses and shrubs, and additionally offered grass and lucerne hays. Future years will show whether this change in diet regime will reduce the growth rate of AWWP Leopard tortoises to levels reported in free-ranging specimens.

CONCLUSIONS

1. Intensively managed Leopard tortoise hatchlings showed a faster growth rate (as assessed by the development of body weight or body length over time) as compared with free-ranging or extensively kept specimens.
2. Similar observations were reported in the literature for Spur-thighed tortoises (*T. graeca*), Galapagos giant tortoises (*G. nigra*), and can also be made when comparing literature data on the growth of free-ranging and captive Desert tortoises (*G. agassizi*).
3. The literature reports on the influence of feeding on growth in reptiles make an intensive dietary supplementation in captivity the most likely explanation for this effect.
4. Although experimental evidence for a negative effect of fast growth on health of tortoises or reptiles is lacking, these observations suggest that in order to mimick conditions in the wild, feeding regimes in captivity should be restricted.

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