Zoo Biology 00: 1–13 (2012)

## RESEARCH ARTICLE

# Variation in Growth and Potentially Associated Health Status in Hermann's and Spur-Thighed Tortoise (*Testudo hermanni* and *Testudo graeca*)

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Captive reptiles often show higher growth rates than in the wild, possibly due to higher feeding intensity. Although health problems are usually linked to inappropriate diets, fast growth itself, such as triggered by appropriate diets fed in high amounts, has traditionally also been considered unfavorable for tortoises. We document growth rates (based on age and mass) from private *Testudo hermanni* and *T. graeca* breeders, which are generally higher than those reported for free-ranging specimens, but show enormous variation. Tortoise patients presented to an exotics clinic also covered the whole growth rate spectrum. To test whether fast growth was associated with diseases, the age–body mass relationship of these patients was tested, in a retrospective evaluation, for additional influence factors, such as dietary history and occurrence of certain diet and growth-related diseases. No indication was found that animals particularly heavy for their age were more prone to diet/growth-related disorders. In general, tortoises fed diets with meat/grain were heavier for their age than tortoises fed more appropriate diets; dietary history was not related to a particular disease. The results suggest the age–body mass relationship may not be suitable for testing effects of fast growth; an age–body length relationship would be more appropriate. Animals presented for a diet/growth-related disorder were younger than animals presented for other reasons; there was a significant negative correlation between the severity of pyramiding and age, suggesting that growth-related

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Received 28 September 2011; Revised 22 November 2011; Accepted 30 November 2011

DOI 10.1002/zoo.21002
Published online in Wiley Online Library (wileyonlinelibrary.com).

disorders may well limit the life expectancy of tortoises. Controlled clinical studies are required to fully test this hypothesis. Zoo Biol. 00:1–13, 2012. 

**Keywords: diet; pyramiding; reptile; herbivory**

## INTRODUCTION

Intensively kept tortoises show growth rates exceeding those of extensively kept or free-ranging animals [Lambert, 1982—*Testudo graeca*; Lambert et al., 1988—*T. graeca*, *T. hermanni*, *T. marginata*; Zwart et al., 1997—*T. hermanni*; Furrer et al., 2004—*Geochelone nigra*; Lapid et al., 2005—*T. graeca*; Ritz et al., 2010a—*G. sulcata*; Ritz et al., 2010b—*G. pardalis*]. Although experimental evidence is mostly lacking, the main cause for the growth discrepancy between captive and free-ranging tortoises is probably the difference in diet, but other factors might also be involved [Andrews, 1982]. Among these are humidity [Wiesner and Iben, 2003], individual temperature optimum [Adolph and Porter, 1996; Avery et al., 1993; Wegehaupt, 2006], availability of drinking water [Lorenzon et al., 1999], and ultraviolet light, or vitamin D supplementation [Heuberger, 2008]. Other nutrients, minerals, or vitamins may also be of importance. Differences in the load of gastrointestinal parasites, other parasites, typhlocolitis due to different reasons or renal diseases may also influence the tortoise's development, especially the constitution of the carapace due to impaired calcium absorption [Häfeli and Zwart, 2000]. Different factors that influence the activity level of a reptile could influence the growth rate as well. Lorenzon et al.'s [1999] results on insectivorous common lizards (*Lacerta vivipara*) showed that a low activity level is associated with a low growth rate. Two theories are discussed for that phenomenon: First, the activity level is directly related to the time spent in a preferred temperature zone and therefore to the time when physiological processes (as food digestion and resulting metabolism and growth) are most efficient; and second, less-active lizards spend less time preying and hence have a lower food intake.

To our knowledge, the only studies providing evidence for an effect of different food compositions on growth in herbivorous tortoises are the ones by Wiesner and Iben [2003], Fledelius et al. [2005] and Diez et al. [2009]. Wiesner and Iben [2003] showed that *G. sulcata* fed a complete diet with low-protein content tended to show less pyramiding than animals on a high-protein diet (but note that humidity was the major factor influencing pyramiding in that study); these findings corroborate the experience of Stearns [1989] that a high-protein diet led to more pyramiding than a low-protein diet (but that the low-protein diet alone did not prevent pyramiding completely). Fledelius et al. [2005] examined the influence of calcium supplementation on the growth rate of *G. pardalis*, and the individuals receiving a calcium dose three times higher than recommended showed the highest growth rate. Calcium absorption in tortoises increases with dietary calcium levels [Liesegang et al., 2001, 2007]. Diez et al. [2009] observed that tortoises that received a high amount of a herb diet grew faster than individuals fed the same diet at restricted amounts. Whether animals underwent hibernation or not also influenced growth in that study, as nonhibernating animals continued to eat and grow during the winter period.

Nevertheless, controlled, experimental studies on the influence of feeds used in captive situations in zoos or by private breeders are mostly lacking—probably due

**TABLE 1. Recommendations From Sequential Issues of a Standard Textbook for the Feeding of Herbivorous Tortoises**

| Year | Recommendation | Source |
|---|---|---|
| 1980–1993 | 80% fruits, 19% meat, 1% minerals; fruit: apple, pear, orange, banana, tomato, greens (fresh grass, clover, salad); meat: muscle, heart—cut to fine pieces—also complete feeds for dogs and cats. If fruit is scarce: oat flakes, rice, dry dog food, steamed potatoes | Meyer et al. [1980, 1989, 1993] |
| 1999 | Leafy greens, vegetables, fruit (apple, banana, pear, grapes, kiwi), sometimes moist dog and cat food, grain products | Kamphues et al. [1999] |
| 2004–2009 | Greens (wild herbs and a small proportion of salad and vegetables), small amounts of fruits (may lead to malfermentation and diarrhea), moist dog and cat foods should not be a major component (cause gout), milk and grain products only in limited amounts, hay always ad libitum, sepia or egg shells as calcium sources | Kamphues et al. [2004, 2009] |

Note that this information is not intended as an actual recommendation, but shows how feeding recommendations for tortoises have changed historically. With respect to the most recent recommendations, note that other textbooks [e.g., Calvert, 2004a; Donoghue, 2006] do not recommend dog or cat food, milk products, or grains.

to the long time periods necessary for such experiments. Recommendations to feed tortoises sparingly and with high-fiber diet items are derived from observations on the natural diet [e.g., El Mouden et al., 2006; Lagarde et al., 2003], anecdotal observations of captive animals [e.g., Stearns, 1989], and common sense. Before making quick judgments on pet owners who feed cat food to their herbivorous tortoises, we should remember that historically the use of diets with animal protein was common and even recommended (see Table 1), that a cat-food based diet has even been recommended recently for fast growth in herbivorous tortoises without mention of potential side-effects [Lapid et al., 2005], and that general recommendations to exclude such items [Calvert, 2004b; Donoghue, 2006; McArthur and Barrows, 2004; Wegehaupt, 2006] are comparatively recent.

With respect to tortoise diets, two different factors need to be considered separately that may, in practice, often occur in parallel: an inadequate diet composition (in terms of diet items and nutrients; in particular high-protein diets due to the use of meat products; calcium deficiency), and a high amount of food offered. In particular, the consequences of feeding a high amount of food will vary between an adequate or inadequate diet. For example, the captive tortoises investigated by Stearns [1989], Furrer et al. [2004] and Ritz et al. [2010a, b] either did not receive any animal protein or only, in the case of *G. sulcata* [Ritz et al., 2010a], at the very beginning of their lives, but nevertheless all showed growth rates exceeding that of free-ranging animals. Hence, it seems possible that even plant food may trigger fast growth in tortoises, especially when offered ad libitum [Diez et al., 2009]. This fast growth, if triggered by high amounts of an adequate diet, must not necessarily be linked to conditions associated with an inadequate diet. For example, Donoghue [2006] suggests that overfeeding per se does not lead to the malformation of the carapace usually termed “pyramiding,” but that nutrient imbalances are responsible for this. An inadequate diet, in contrast, is also often associated with increased growth (because such diets are usually high in energy and protein, feeding them mostly automatically leads to excessive supply), but also with pyramiding (also not as the only reason), bone malformation, or gout [Calvert, 2004b; Donoghue, 2006; Hatt, 2008; Wegehaupt, 2006].

The assumption that fast-growing tortoises show pyramiding growth of the carapace is common, but the consequence of this shell abnormality on the health status of the tortoises has not been investigated systematically. Wegehaupt [2006] distinguishes pyramiding *with an abnormal bone structure underneath the scutes* from pyramiding *without an abnormal bone structure*. He observed that free-ranging tortoises living in arid zones with limited water access often show pyramiding with a normal bone structure, whereas individuals of the same species from habitats with higher environmental moisture develop a smooth carapace. Lambert [1982] also noted that free-ranging *T. graeca* living in arid regions showed uneven carapace scutes compared to individuals from more humid regions. Abnormalities in the bone structure of the carapace, however, are ascribed by Wegehaupt [2006] to an intensive feeding with a high-protein diet. He suggests that the result is a porous and thickened carapace, as is often observed in tortoises kept as pets [Lambert et al., 1988]. Again, data backing these claims are missing.

Faster growing individuals reach sexual maturity earlier [Jackson et al., 1976; 1978; Lambert et al., 1988; Ritz et al., 2010a], which could help saving years in restocking programs of highly endangered land tortoise species [Aresco and Guyer, 1999; Ritz et al., 2010a]. Pees et al. [2010] suggest that intensive feeding might trigger an early sexual maturation and egg production for which the body is “not yet prepared.” Again, data or references that back these claims are missing. If a faster growth leads to an earlier sexual maturity, problems should only occur if reproductive activity occurs disproportionately early in faster growing individuals. Evidence for this is, to our knowledge, lacking so far. Fast growth is also traditionally associated with other health problems in the literature on tortoise husbandry, leading to higher mortality and also reduced life spans [Furrer et al., 2004; McArthur and Barrows, 2004; Wegehaupt, 2006]. In the opinion of Wegehaupt [2006], offspring of fast-growing individuals may be infertile already in the second generation; these claims are, however, not backed by data.

We investigated historical records of tortoises presented as patients to our clinic in order to test for potential evidence that individuals for which a fast growth can be suspected were particularly prone to disease, and whether associations between fast growth and husbandry information provided by owners could be detected. In addition, we also surveyed private tortoise breeders for growth records of their animals.

## METHODS

Private owners of *T. hermanni* and *T. graeca* were contacted by an appeal in *Testudo*, the journal of the community of interest in tortoises and turtles in Switzerland (Schildkröten-Interessengemeinschaft Schweiz, SIGS) to collect data on the age and body mass of their animals. Only data from tortoises were used that were, in the opinion of their owners, free of health problems. Data for 65 *T. hermanni* of 11 different owners and data of 21 *T. graeca* of 6 owners were available. Comparative data were also collected from the literature [Kirsche, 1971; Lapid et al., 2005; Wegehaupt, 2006].

Case histories of the years 2000–2009 from the archive of the Clinic of Zoo Animals, Exotic Pets and Wildlife of the Vetsuisse Faculty of the University of Zurich were evaluated. Only cases were selected where the owner had provided an age of the animal. This information had to be taken at face value; individual cases where the veterinarian on duty had made a note that the age information appeared questionable (by adding a question mark on the medical history sheet) were not included in the analysis. Animals had been weighed as part of the routine clinical examination.

Data on the age, body mass, sex, feeding history, and health problems were available for 539 animals of *T. hermanni*, *T. graeca* and tortoises of unknown species (but, most likely, of either one). Age was recorded in days and the body mass in grams. The information on the diet given by the owner was qualitative (i.e., no proportions or quantities were given); this information was used to classify animals into three diet categories: (1) animals were only fed extensively with hay, grass, herbs, and salad; (2) animals received in addition vegetables, fruits, and/or pellets; (3) animals were fed intensively with meat and/or grain products.

In reptile medicine, various types of "metabolic bone disease (MBD)" have been described [Mader, 2006]. In the clinical reports, the terms "MBD," "pyramiding," and "fibrous osteodystrophia" were the most prominent ones that might have been used, by the various veterinarians, to describe a similar problem. In order to preserve the original data structure, we included both the notes "MBD" (presumably a finding mainly based on history, radiographs, palpation, and supported by blood mineral analysis) and "pyramiding" (presumably based on a visual impression) among the health problems of the animals that were included in this study. These two observations were included, together with the less-frequently noted categories of obesity, renal problems (suggesting gout), and fibrous osteodystrophia, in the general category of "dietary/growth disorders."

Further information was collected on parasite occurrence in the feces, whether or not the owner allowed the animal to hibernate, and the outcome of the visit to the Clinic (treated and returned home, or euthanized/died during treatment). If latero-lateral radiographs were available in the archive, the status of carapace deformities was noted. On the one hand, a five-step categorical classification was used (ranging from 0 = no pyramiding to 4 = extreme pyramiding); on the other hand, pyramiding was quantified as a ratio of measurements. On the radiographs, the distance between centers of the third and the fourth central scutes and the depth between the humps of these two scutes was measured (Fig. 1). The ratio of the depth to the distance was

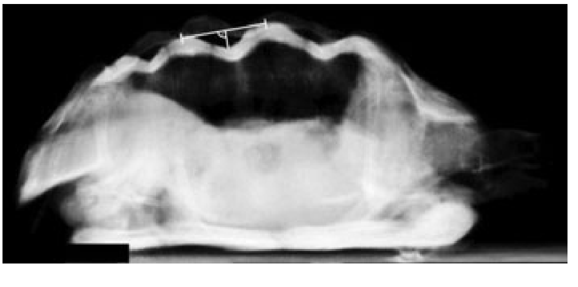

Fig. 1. Quantification of the hump formation of the carapace of herbivorous tortoises (*Testudo* spp.) on laterolateral radiographs.

then used as measurement of the extent of the carapace deformation. The correlation between the categories and the quotient was highly significant (Spearman's $\rho = 0.865$, $P < 0.001$).

Data on age and body mass were ln-transformed prior to further analyses. The effects of various factors on the fundamental relationship between age and body mass were evaluated by General Linear Models (GLMs). Because not all data were available for all animals, sample size *n* varied between different analyses. Interaction terms between factors and measurements were included in the GLMs when appropriate. Correlations were tested using nonparametric tests if data were not normally distributed. Relationships between categorical variables (e.g., hibernation, diet, parasite status, and disease status) were tested by chi-square tests. The significance level was set at 0.05. All tests were performed in PASW 18.0 (SPSS Inc., Chicago, IL).

## RESULTS

The evaluation of the growth data of *T. hermanni* and *T. graeca* kept by private owners in Switzerland showed a broad range of body mass development, although only data from individuals without obvious health problems were investigated (Fig. 2A, B). Available data from the literature on free-ranging or extensively kept animals fell within the range observed in private breeders, indicating that at least some breeders actually provided conditions that mimicked the natural habitat in their effects on growth (Fig. 2C, D); however, in general it seemed that free-ranging animals were at the lower part of the range, especially in *T. graeca* (Fig. 2D). Data from *T. graeca* kept on cat food from Lapid et al. [2005] showed a faster growth rate than that achieved by most breeders (Fig. 2D).

When the data from apparently healthy animals were compared to those of animals presented as patients to our clinic, it was evident that most patients fell into the same growth range, with some outliers (Fig. 2E, F). In particular, the *T. hermanni* patients appeared to be divided into old animals that were comparatively heavy, and those that were comparatively light for their age (Fig. 2E).

The relationship between age and body mass was highly significant ($n = 539$, $F_{1,537} = 1{,}247.122$, $P < 0.001$). Species (*T. hermanni* or *T. graeca*) did not affect this relationship significantly ($n = 147$, overall model: $F_{2,144} = 254.378$, $P < 0.001$; cofactor species: $F_{1,144} = 0.061$, $P = 0.805$); subsequent analyses, therefore, do not differentiate between the species. Instead, both sex (male/female) and the sex–age interaction were significant ($n = 348$, overall model: $F_{3,344} = 145.220$, $P < 0.001$; cofactor sex: $F_{1,344} = 9.911$, $P = 0.002$; sex–age interaction: $F_{1,344} = 12.983$, $P < 0.001$)—in the dataset, younger males were heavier, and older males were lighter, than similar-aged females (Fig. 3A). Whether animals were made to hibernate or not did not affect the age–mass relationship ($n = 211$, overall model: $F_{2,208} = 222.841$, $P < 0.001$; cofactor hibernation: $F_{1,208} = 0.002$, $P = 0.964$). The effect of diet (categories 1–3) on the age–mass relationship was significant ($n = 416$, overall model: $F_{3,412} = 402.722$, $P < 0.001$; cofactor diet: $F_{2,412} = 3.566$, $P = 0.029$), with animals from diet category 3 (intensive feeding) having slightly higher body masses for their age. If diet categories 1 and 2 were combined and compared only against diet category 3, the difference was even clearer ($n = 416$, overall model: $F_{2,413} = 265.240$, $P < 0.001$; cofactor diet: $F_{1,413} = 5.422$, $P = 0.020$). Note that the difference was, however, even if significant, not particularly pronounced (Fig. 3B). Whether animals had parasites also had a

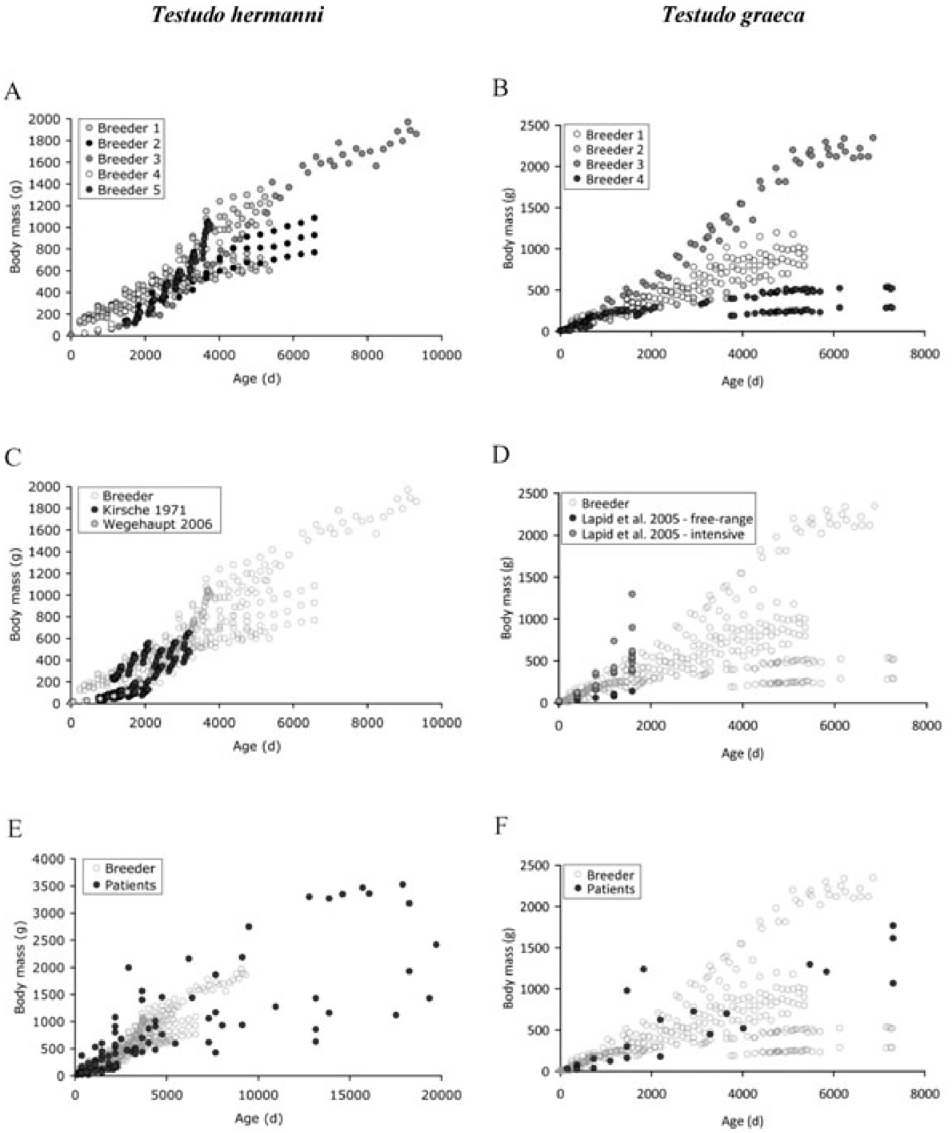


Fig. 2. Relationship between age and body mass in *Testudo hermanni* and *T. graeca* from private breeders (**A** and **B**), compared to data from free-ranging, extensively kept or intensively kept individuals (**C** and **D**), and compared to the data for the tortoise patients of this study (**E** and **F**).

significant effect on their age-specific body mass ($n = 150$, overall model: $F_{2,147} = 158.621$, $P < 0.001$; cofactor parasites: $F_{1,147} = 6.325$, $P = 0.013$) (Fig. 3C). The presence of diet/growth disorders in general ($F_{1,536} = 2.167$, $P = 0.142$), pyramiding deformations ($F_{1,536} = 0.033$, $P = 0.856$), MBD ($F_{1,536} = 3.028$, $P = 0.082$), or both ($F_{1,536} = 1.091$, $P = 0.297$) did not have a significant effect (Fig. 3D). Among females, animals with dystocia did not differ from other animals ($n = 177$, overall model: $F_{2,174} = 129.052$, $P < 0.001$; cofactor dystocia: $F_{1,174} = 1.092$, $P = 0.297$). The

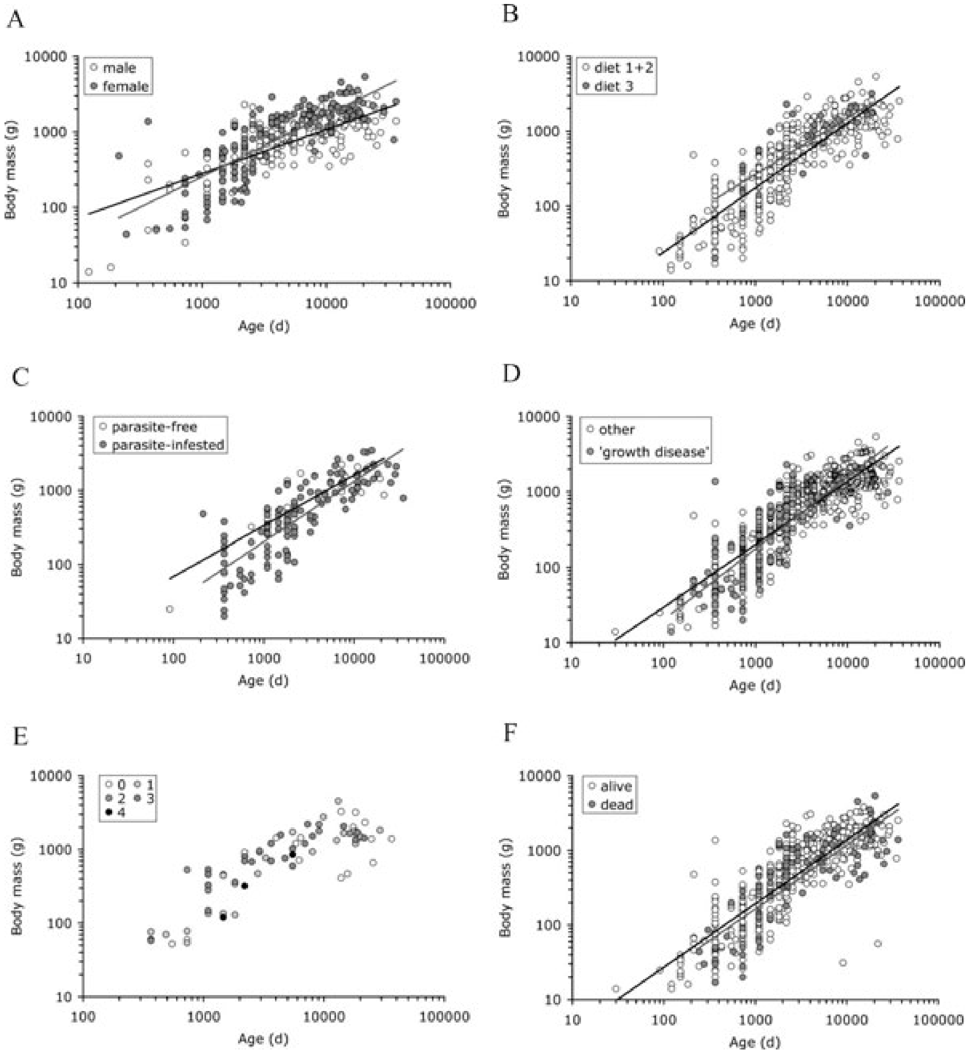


Fig. 3. Relationship between age and body mass in the tortoise patients of this study, as separated by (**A**) sex, (**B**) diet, (**C**) parasite status, (**D**) the presence of the "diet/growth disorders" complex or other reasons for presentation as patients, (**E**) the degree of pyramiding (from 0 = absent to 4 = extreme), (**F**) whether the patient survived or not.

pyramiding category (based on the x-rays) had a significant effect ($n = 75$, overall model: $F_{5,68} = 39.100$, $P < 0.001$; cofactor pyramiding category: $F_{4,68} = 2.561$, $P = 0.046$), and the pyramiding quotient (based on the x-rays) was close to being a significant covariable ($n = 75$, overall model: $F_{2,72} = 90.545$, $P < 0.001$; covariable pyramiding quotient: $F_{1,72} = 3.401$, $P = 0.069$). Pair-wise comparisons using Sidak adjustment for multiple testing, however, did not reveal any significant difference in the age–mass relationship between the five pyramiding categories (Fig. 3E). Whether animals left the clinic alive, or died/were euthanized had a significant effect on their age-specific body mass ($n = 536$, overall model: $F_{2,533} = 620.845$, $P < 0.001$; cofactor ending:

$F_{1,533} = 4.097$, $P = 0.043$), with surviving animals generally having a higher body mass (Fig. 3F).

Animals that received a diet comprising meat/grain (diet category 3; $n = 36$; median = 4,380 days, range = 365–18,260 days) were, on average, older than animals not receiving these items (diet category 1 + 2; $n = 380$; median = 2,190 days, range = 91–36,500 days) (*U*-test, $P = 0.021$); there was, however, no age difference between animals receiving diet category 1 and diet category 2 ($P = 0.857$). Animals with diet/growth disorders in general were, on average, younger ($n = 272$; median = 2,190 days, range = 122–36,500 days) than animals without such problems ($n = 267$; median = 2,555 days, range = 30–29,200 days) (*U*-test, $P = 0.016$). The same was the case for animals with ($n = 38$; median = 1,095 days, range = 244–36,500 days) or without MBD ($n = 501$; median = 2,555 days, range = 30–36,500 days; *U*-test, $P < 0.001$), and for animals with ($n = 123$; median = 1,095 days, range = 122–27,375 days) and without pyramiding ($n = 416$; median = 3,285 days, range = 30–36,500 days; *U*-test, $P < 0.001$). There was a negative correlation between the pyramiding quotient and age ($n = 75$, Spearman's $\rho = -0.243$, $P = 0.035$), indicating that particularly pronounced cases of pyramiding were mainly seen in younger tortoises.

Using the chi-square test, there was no evident risk, for any disease, outcome, or husbandry factor linked to sex. Neither whether animals were allowed to hibernate, nor whether they had parasites, was linked to any other disease, outcome, or husbandry factor, with the only exception that animals that received diet categories 1 + 2 had parasites significantly less frequently (14 out of 110 cases) than animals that received diet category 3 (4 out of 10; $P = 0.021$). There was no evident risk due to diet categories 1 + 2 vs. category 3 for diet/growth disorders ($P = 0.783$) or pyramiding deformations ($P = 0.795$). There was no single case of MBD in animals receiving diet category 3; all cases of MBD occurred in animals on diet categories 1 + 2 (chi-square $P = 0.050$). Diet did not relate with whether animals survived or died/were euthanized ($P = 0.484$).

## DISCUSSION

The results of this study underline the high degree of phenotypic flexibility in herbivorous tortoises with respect to growth. This is evident from comparisons between animals raised under different conditions, both between the wild and captivity, between intensive and extensive husbandry systems, between breeders, and between animals kept at the same breeder (Fig. 2A–D). While differences between the wild and captivity, and between different husbandry regimes, may well be mainly due to differences in diet composition and amounts of diets offered (for other reasons see Introduction), the findings also suggest that under one husbandry regime, individual differences in growth can occur that are less easily explained. Dickinson [1985] and Lambert et al. [1988] already remarked that the growth development of tortoises between and within clutches differs remarkably even if the animals were kept under the same conditions. Differences between individuals, such as related to the part of the diet actually ingested in group-fed animals, or the microclimate that individuals in a group are exposed to, could potentially help explain such variation to a certain degree. In our case, such information was not available for the individuals investigated.

The results from the analyses of our clinic's patients are less clear-cut. Evidently, the major limitation of a survey like this one is the absence of data for the control group—those animals kept by private owners that are considered healthy and not presented for examination and treatment. To a certain degree, the data from private breeders, who all considered their animals healthy, could act as such a control. Additionally, a retrospective evaluation like this one necessarily lumps not only information by various owners but also measurements and diagnoses made by various veterinarians; the data will therefore contain a large margin of inconsistency.

Both *T. hermanni* and *T. graeca* are species known for their sexual dimorphism, with females attaining larger body masses than males [Willemsen and Hailey, 2003]—a pattern also reflected in the patients of this study (Fig. 3A). Interpretations on the associations of body mass with other factors are difficult to translate into conclusions about husbandry and disease in tortoises. On the one hand, a comparatively lower body mass was associated with parasite infestation (Fig. 3C) and a fatal condition (Fig. 3F), which suggests that parasite infestations and or any other condition related to a fatal outcome were mainly chronical conditions, which led to reduced body masses. The finding that conditions summarized as "diet/growth disorders" were not associated with body masses that were high for the animals' age can, in this respect, not contradict the idea that high growth rates can lead to disease in tortoises, but rather suggest that in order to thoroughly collect evidence for the damaging impact of high growth rates, carapace measurements rather than weighing of animals are required. If any condition of the animal leads to chronic illness, body mass will decrease [Jackson, 1980]—which means that, in our retrospective study that focuses on the age–body mass relationship, animals suffering from intensive diets and/or fast growth cannot be properly identified. Carapace length measurements would allow a doubtless identification of animals with high growth rates, and deviation from the typical carapace length–body mass relationship would additionally indicate animals with chronic weight loss [Jackson, 1980]. Therefore, while this study cannot provide evidence for negative effects of fast growth on tortoise health, future data collections should focus on collecting age, body mass, and body length information together as routine measurements/questions in the clinical investigation of tortoises.

In this retrospective analysis, diet could only be evaluated in terms of its composition, but not in terms of amounts fed. Although animals receiving diet category 3 (including meat/grain products) had significantly higher mean body masses for their age, they were well within the range observed in tortoises fed either diet category 1 (hay, grass, herbs, green vegetables) or 2 (including fruits, vegetables, pellets). Diet category did not relate with growth diseases or pyramiding—in this respect, qualitative dietary information is probably not sufficient to evaluate a correlation. Rosskopf and Shindo [2003] also commented anecdotally that an evident relationship between the dietary history of animals and their shell health is not always evident. Diet category 3 was predominantly used in older animals, which suggests that the historical development outlined in Table 1 is mirrored in the fact that owners keeping animals since more recent times avoid meat/grain products in general. The relationship between diet 3 and the presence of parasites, even though based on a small sample size, could also indicate that owners feeding diet 3 are generally less informed or concerned about their tortoises' health. However, the findings also indicate that feeding fruits and nongreen vegetables is still common practice, although it is generally discouraged in scientific texts [Calvert, 2004b; Donoghue, 2006; McArthur and Barrows, 2004; Wegehaupt, 2006]. To prove direct effects of diet on growth, pyramiding, disease, and survival in tortoises, long-term feeding experiments are required.

While our retrospective study cannot provide direct evidence for a correlation of growth rates with growth diseases, including MBD or pyramiding, or of the presence of pyramiding with disease and survival, the age distribution of patients suffering from these growth diseases represents some indirect evidence. These problems were significantly more frequent in younger than in older tortoises; in the case of quantitative pyramiding data, there was even a negative relationship between the severity of pyramiding and age, indicating that more severe cases occur in younger animals. It is known that growth diseases such as MBD predominantly affect younger animals [Mader, 2006]. The scarcity or absence of older animals in this disease group suggests that health problems either dissolve (with or without treatment), or that these health problems lead to a low survival, so that animals with these health problems appear in older age classes less frequently. Especially in the case of pyramiding, dissolution of the condition appears unlikely, and the results of this study thus could suggest that pyramiding in pet tortoises indeed reduces their longevity. However, in the absence of controlled studies, these interpretations remain speculative.

The question whether inappropriate amounts and/or an inappropriate composition of the diet causes malformation, disease, and low survival in tortoises remains unanswered. However, even in the absence of evidence gained from controlled studies, husbandry practices should be followed that appear logical, when compared to the conditions the animals live under in the wild, and in consideration of the anatomy and physiology of their digestive tract. For future studies, the documentation of not only age and body mass, but also of carapace length and ideally the pyramiding quotient (measured easily in live animals) is recommended in tortoises presented to veterinary consultation.

## CONCLUSIONS

1. Tortoises show great plasticity in growth rates, which are often linked to intensive feeding (of both appropriate or inappropriate diets).
2. The relationship between age and body mass did not indicate a particular susceptibility of relatively heavier animals presented to an exotics clinic for diet- or growth-related disorders.
3. This may be due to the chronic nature of disease processes in tortoises, which are often linked to weight loss. For a proper evaluation of an increased susceptibility of relatively fast-grown individuals to certain diseases, carapace length measurements should be recorded routinely in tortoise patients.
4. Growth-related disorders, in particular pyramiding, occurred more frequently in younger tortoise patients. This might indicate that such conditions limit the life expectancy of the tortoises, but cannot be considered conclusive evidence.
5. To correctly assess the health risks related to fast growth (as triggered by high amounts of an appropriate diet) in tortoises, controlled clinical studies are required.

## ACKNOWLEDGMENTS

We thank the anonymous tortoise breeders for sharing their data on age and body mass of their animals; in the Clinic for Zoo Animals, Exotic Pets and Wildlife of the Vetsuisse Faculty, University of Zurich, we thank the treating veterinarians of the last decade, as well as our animal care team, for recording the animals' conditions.

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