

Is body shape of mangrove-dwelling monitor lizards (*Varanus indicus*; Varanidae) sexually dimorphic?

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Abstract. In monitor lizards, males are typically larger than conspecific females, but body shape is usually quite similar in both sexes. This not only represents a puzzle worthy of evolutionary explanation, but also makes field sex determination of monitor lizards difficult. We asked whether subtle differences in body shape follow the same pattern as in other sexually dimorphic lizard taxa and thus can be explained by the same selective forces. We tested the hypotheses that (1) females have a longer abdomen due to fecundity selection and (2) males possess bigger heads due to intrasexual selection. We also hypothesised that (3) male monitors show a wider chest and longer upper fore-limbs to win male-male wrestling matches. We monitored ontogeny in 35 mangrove-dwelling monitors (*Varanus indicus*). Seventeen body measurements were taken every three months up to the age of 24-34 months. Sex was determined by an ultrasonographic imaging. We employed multiple approaches to remove the effect of size and used both confirmation and exploratory statistics. The results revealed that sexual differences in body shape were small and emerged after maturity. Females have a relatively longer abdomen while males wider chest and longer upper fore-limbs. Thus, the differences in body shape between male and female varanid lizards may be attributed to both fecundity and sexual selection.

Keywords: allometry, body shape, monitor lizards, sexual dimorphism, SSD, Varanidae.

Introduction

The largest species of extant saurians, including the Komodo dragon, belong to the family Varanidae, commonly referred to as monitor lizards or goannas in Australia. Monitor lizards represent a suitable model for studies of body size (Pianka, 1995, 2004) and scaling of morphological (Christian and Garland, 1996; Thompson and Withers, 1997; Thompson et al., 2008; Packard and Boardman, 2009), life-history (Thompson and Pianka, 2001), physiological (Clemente, Thompson and Withers, 2009; Clemente, Withers and Thompson, 2009) or behavioural (Schuett, Reiserer and Earley, 2009) traits with this variable. Monitor lizards not only exhibit a great variation in body size

along both phylogenetic (Pianka, 1995, 2004) and ontogenetic axes (Auffenberg, 1981), but also vary between the sexes. Fully grown males of most species are larger than the females (Cox, Butler and John-Alder, 2007, for a review see Frýdlová and Frynta, 2010), e.g., the ratio between maximum male and female snout-vent length is 1.39 in *V. salvator* (Shine et al., 1998a), 1.34 in *V. komodoensis* (Lutz and Lutz, 1991), 1.33 in *V. varius* (Carter, 1999), 1.31 in *V. bengalensis* (Auffenberg, Arain and Khurshid, 1991) and 1.30 in *V. indicus* (Wikramanayake and Dryden, 1988).

The difference between male and female body sizes contrasts with only poorly developed sexual dimorphism in body shape. Unlike some other lizard families, the size of the principal body segments follows almost the same allometric relationships in both sexes of varanid lizards (Thompson and Withers, 1997). This unusual pattern generally corresponds with surprising uniformity of varanid body form on among-species (Shine, 1986).

Similarity of male and female body shapes makes morphometric determination of sexes

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difficult (Thompson, 2002; Smith et al., 2007). Sometimes reliable results can only be obtained by dissection, endoscopy, ultrasonographic imaging (Schildger et al., 1999; Horn, 2004) and/or hormonal analyses (Mayes, Bradshaw and Bradshaw, 2005) because methods such as sondage, palpation or visual inspection of hemipenises are not always applicable (Gaulke, 1997). That is why several authors searched for advanced criteria enabling sex determination from simple measurements taken in the field (Thompson, 2002; Smith et al., 2007).

Indiscernible differences between male and female body shape may be revealed using statistical tools. Thompson and Withers (1997) analysed log-transformed measurements of appendages for 17 species of Australian monitor lizards and reported the results of discriminant function analyses (DFA) successfully separating the sexes. Thompson (2002) examined the feasibility of using the ratio of abdomen length to head length (or width) as a priori deduced criterion for sexing monitor lizards. He found significant differences between the sexes in this trait, but the overlap between sexes was often too large to confidently separate sexes for all species. Recently, Smith et al. (2007) tested the ability to predict sex in six species of varanids by a set of a priori models. They adopted generalized linear modelling and most explanatory variables were ratios of particular measurements to snout-vent length. They successfully found a reliable sexually diagnostic feature for *Varanus gouldii*, but emphasised the need for large samples. They also argued against potentially spurious results of earlier analyses performed by multivariate exploratory statistical methods (cf. Thompson and Withers, 1997) and null-hypotheses testing (cf. Thompson, 2002).

In many lizard taxa, the relative sizes of the head and abdomen were most frequently reported as sexually dimorphic. Head size (e.g., Vial and Stewart, 1989; Anderson and Vitt, 1990; Castilla and Bauwens, 1991; Mouton and van Wyk, 1993; Vitt and Colli, 1994; Barbadillo et al., 1995; Hews, 1996; Smith, Lemos-Espinal

and Ballinger, 1997; Shine et al., 1998b; Kratochvíl and Frynta, 2002) was usually interpreted as a trait affected by intrasexual selection favouring biting abilities in combating males (Herrel, McBrayer and Larson, 2007; Huyghe et al., 2007). Because male varanids can be mutually aggressive (Horn, Gaulke and Böhme, 1994; Earley, Attum and Eason, 2002), head size was considered in searching for a sex discriminating trait.

Abdomen length has mostly been neglected until Braña (1996) attributed sexual dimorphism in body shape of lacertid lizards to fecundity selection favouring females possessing longer abdomens enabling them to lay more eggs. Later on, Olsson et al. (2002) supported this view for *Niveoscincus*. Kratochvíl et al. (2003) demonstrated that relative abdomen length is capable of explaining sexual differences in the relative size of heads, limbs and tails (scaled to snout-vent length that inherently includes abdomen length) in *Zootoca vivipara*. This conclusion is also applicable to some other lizard taxa in which the head size was reported as a sexually dimorphic trait (but see Vitt and Cooper, 1985; Griffith, 1991; Kratochvíl and Frynta, 2002). Thus, relative abdomen length remains the best candidate as a sex discriminating trait. Sexual size dimorphism (SSD) in this trait may be achieved by two alternative proximate mechanisms: either by structural differences (multiplication of vertebrae, cf. Shine, 2000) or by differential growth (length of the vertebrae, cf. O'Riain et al., 2000).

Combat between male varanid lizards is highly ritualized (Horn, Gaulke and Böhme, 1994) and resembles a wrestling match (Horn, 1985, 1994; Thompson, Withers and Thompson, 1992). Winning of its clinch phase probably requires strong and long forearms rather than a stronger bite. Therefore, we hypothesised that a larger size of this body segment is favoured by sexual selection and we decided to examine sexual differences in the relative width of the chest and the length of the upper forelimbs, measured from elbow to elbow.

In this paper we focus on the mangrove-dwelling monitor *V. indicus* (Daudin, 1802) who belongs to the subgenus *Euprepriosaurus* (cf. Ast, 2001; Böhme, 2003; Ziegler et al., 2007; Koch et al., 2009). *V. indicus* is a 'male larger species' capable of potentially indeterminate (de Buffrénil, Ineich and Böhme, 2004) and rapid growth (de Buffrénil, Houssaye and Böhme, 2008, Frynta et al., in press). Unlike some other varanids, they are active (within relatively small home ranges) throughout the year, and this activity which enables continuous growth is influenced by both sex and body size (Smith and Griffiths, 2009). Males, but not females of the mangrove-dwelling monitor, have been reported to engage in ritualised combat (McCoid and Hensley, 1991).

The aims of this paper were to examine records of body measurements of captive mangrove-dwelling monitor lizards from hatching to adulthood, and to (1) undertake exploratory analyses of size-adjusted data to uncover sexually dimorphic traits; (2) to test sexual dimorphism in a priori selected candidate traits; (3) to examine the utility of body shape parameters and other methods for sexing; and (4) to discuss possible selective forces underlying the observed sexual dimorphism in body shape.

Materials and methods

Thirty five mangrove-dwelling monitors reared at Prague zoo were used in this study. They were siblings belonging to four subsequent clutches hatched at November 2006, January, February and June 2007. The animals were housed individually in terrariums of various sizes (starting from 60 × 30 × 40 cm for hatchlings) and gradually changed for larger ones to satisfy the needs of the growing animals (ending with terrariums 145 × 100 × 130 cm or even 300 × 130 × 130 cm). The ambient temperature in the breeding room varied between 28 to 30°C with hotter basking sites. Food was provided ad libitum, initially every Monday and Thursday until the monitors were approximately two years old, after which it was provided weekly. Hatchlings were fed cockroaches and crickets, and this insect diet was replaced by a vertebrate diet as early as possible (at the age of 1-3 months). Chicken parts (initially predominantly livers, latter on necks), the primary vertebrate diet, were supplemented with vitamins and minerals (Nutri Mix,

Trouw Nutrition Biofactory, Ltd.). Vitamins AD₃ and E were provided monthly. The health of the animals was regularly monitored. On 14th December 2008, 15th February 2009 and 25th April 2009 a veterinary examination using ultrasound imaging of abdominal cavity enabled an unambiguous sex determination for all individuals (cf. Schildger et al., 1999; Horn, 2004).

The experiments were performed in accordance with Czech law implementing all corresponding European Union regulations and were approved by the institutional animal care and use committee.

The experimental animals were measured and photographed (ventral view of the body, dorsal and lateral views of the head) in standardized positions every 3 months from hatching up to the age of 24-34 months. In total, we collected 378 valid records for 22 (235 pseudoreplicates) males and 13 (143) females. In addition, we included 4 adult males (father and uncle of the experimental animals of the age exceeding 17 years and the brothers 6 and 3 years old) and 2 adult females (mother of the experimental animals 9 years old and her sister 6 years old) of mangrove-dwelling monitors. These aged animals were measured only once to provide reference of fully grown individuals.

We adopted and/or modified standard measurements from Thompson and Withers (1997) and Smith et al. (2007). The modifications and adoption of additional measurements were done in order to maximize precision when dealing with live animals and to include putatively dimorphic body segments (e.g., chest and abdomen). We used the following 17 measurements: (1) SVL – snout-vent length; (2) DEX – distance between the extremities (thorax-abdomen length); (3) TL – tail length; (4) TW – tail width (at its base); (5) CFW – chest and upper fore-limb width; (6) LFL – lower fore-limb length (without finger); (7) HHW – hip upper hind-limb width; (8) KHL – knee to heel length; (9) HL – head length (from rostrum to ear); (10) RNL – rostrum to nostril length; (11) NEL – nostril to the middle of eye length; (12) EEL – eye to ear length; (13) RPL – rostrum to parietal-scale length; (14) IOW – interorbital width; (15) INW – internostril width; (16) NMH – nostril to maxilla height; (17) EMH – eye to maxilla height. Measurements 4-8 were taken by digital callipers to the nearest 0.01 mm; the remaining ones were measured by UTHSCSA Image Tool (<http://dtdsdx.uthscsa.edu/dig/itdesc.html>) from digital photographs. LFL and KHL were measured on both left and right sides and the mean values were used in further analyses. For the location of these measurements see figs 1 and 2. In addition, using radiographic images of the body we counted the total number of vertebrae from the first thoracic vertebrae down to the pelvis.

We split the records into following data-sets: (1) Entire data-set – including all available records; (2) Juveniles – records taken up to the age of 546 days, i.e., the inflection point of the logistic growth equation describing relationship between female body weight and age (Frynta et al., in press); (3) Adults – records taken at the age exceeding 546 days; (4) Body size balanced – it includes the last record of each female as well as a single record of each male taken at SVL, most precisely matching the body size of a corresponding female. To reduce possible clutch effects, matching records were selected preferentially from individuals

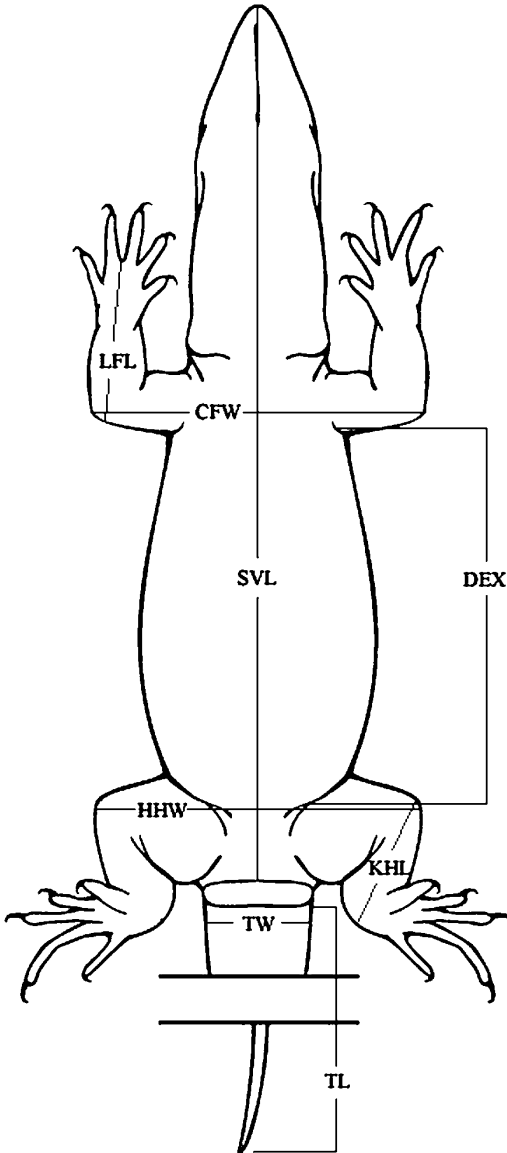


Figure 1. Measurements on the body of the mangrove-dwelling monitor lizard (*Varanus indicus*). SVL: snout-vent length; DEX: distance between the extremities (thorax-abdomen length); TL: tail length; TW: tail width (at its base); CFW: chest and upper fore-limb width; LFL: lower fore-limb length (without finger); HHW: hip upper hind-limb width; KHL: knee to heel length.

hatched from the same clutch. The measurements were log-transformed prior to further analyses. The principal component analysis (PCA) was used to visualise relationships among studied variables and to quantify contribution of PC1 interpretable mainly as size component of variation (including contribution of allometric relationships). Next, we performed size-adjustment of the original variables. For this

purpose, we used Mosimann's method (Mosimann, 1970) as well as the residuals from regression of each measurement on PC1, SVL and HHW. Mosimann's method was used because it allows precise correction for isometric growth. The use of residuals is the most appropriate method for size adjustment, because it corrects not only isometric growth, but also considers allometric relationships (cf. Bookstein, 1989). The disadvantage of this approach is the difficulty in estimating the allometric slopes in heterogeneous samples of limited size.

As an alternative, we adopted a method published by Somers (1986, 1989) as implemented in the Size analysis v02 (Thompson and Withers, 2005a, 2005b, 2005c). This software computes from original untransformed measurements not only generalised (multivariate) isometric size, but also partial isometric size-adjusted measurements. These size-free data were further analysed in the case of a balanced data-set where isometric size adjustment is relevant due to a relatively narrow range of size variation.

Sex differences in size-adjusted data were further examined either by *t*-tests (when treating a priori hypotheses concerning single trait) or by a multivariate exploratory statistics – discriminant function analysis (DFA). The results comparing the residuals between the sexes were nearly the same as those obtained for ANCOVAs testing sex differences of original variables and adopting body size (SVL or HHW) as a covariate. We included DFA as an exploratory method performing visualisation of multivariate relationships. This procedure was not used for testing purposes and thus there was no need to account for pseudo replications.

The data (both transformed and size-adjusted) were checked for normality prior to the statistical analyses. Deviations from normality were small, and most distributions were both unimodal and symmetrical as required for the used multivariate procedures. STATISTICA, version 6.0 (StatSoft Inc., 2001) was used for most calculations.

Results

Size and shape components

The first principal components revealed by PCAs from both entire and adult data-sets were strongly positively correlated with all analyzed traits and thus reflect predominantly the multivariate body size (for loadings computed for adults see table 1). Nearly all variances of original variables were explained by this size component (including allometric change in shape): 98.48% for entire data-set and 92.73% for records measured in adults. The HHW and HL had the highest correlation with the multivariate body size (PC1) in both analyses. The PC2s contributed for just 0.38% and 1.81% for

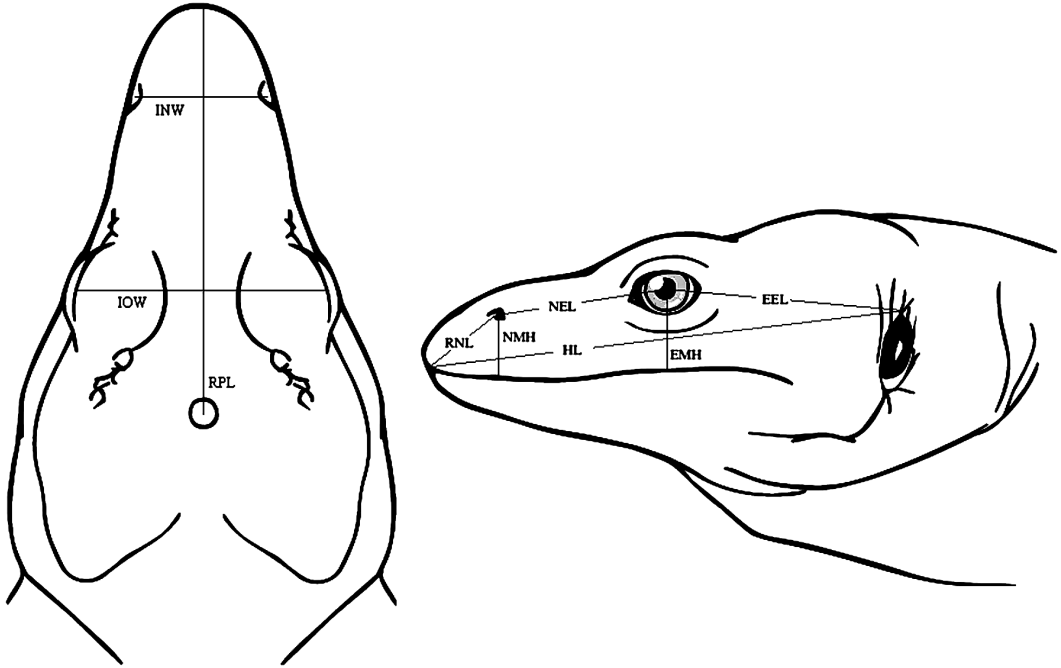


Figure 2. Measurements on the head of the mangrove-dwelling monitor lizard (*Varanus indicus*). RPL: rostrum to parietal-scale length; IOW: interorbital width; INW: internostril width; HL: head length (from rostrum to ear); RNL: rostrum to nostril length; NEL: nostril to the middle of eye length; EEL: eye to ear length; NMH: nostril to maxilla height; EMH: eye to maxilla height.

Table 1. Correlations between log-transformed original variables and principal components (PC) in records concerning adult mangrove-dwelling monitor lizards (*Varanus indicus*). Sex was included as supplementary variable only.

Variable	PC1	PC2
SVL	-0.9747	0.1637
DEX	-0.9156	0.2955
TL	-0.9526	0.1777
HHW	-0.9843	0.0493
CFW	-0.9778	0.0121
KHL	-0.9796	0.0575
LFL	-0.9684	0.0478
TW	-0.9494	-0.0282
RPL	-0.9398	0.1002
IOW	-0.9713	-0.0420
INW	-0.9831	0.0060
HL	-0.9834	-0.0963
RNL	-0.9417	-0.1755
NEL	-0.9559	-0.1941
EEL	-0.9770	-0.0333
NMH	-0.9757	-0.1119
EMH	-0.9364	-0.2218
*Sex	-0.5900	-0.4086

the entire data-set and adults, respectively. In adults especially, DEX and EMH contributed to PC2, which was somewhat associated with sex (Mann-Whitney test computed from mean PC2 of each individual: $z = -2.92$, $P = 0.0036$, $n_{\text{males}} = 24$, $n_{\text{females}} = 15$).

Testing a priori predictions

In order to test a priori hypotheses we avoided pseudo replications and selected a body size balanced data-set concerning 23 males and 14 females measured at comparable body sizes. We hypothesised that females possess relatively longer DEX and males longer CFW and HL. Because HHW appeared to be the most highly correlated with the multivariate size, we further examined residuals of the allometric relationships between the presumably sexually dimorphic variables and HHW. The results (fig. 3a, b) confirmed sexual dimorphism in DEX ($t = -6.17$, $P < 0.0001$) and CFW ($t = 3.64$, $P =$

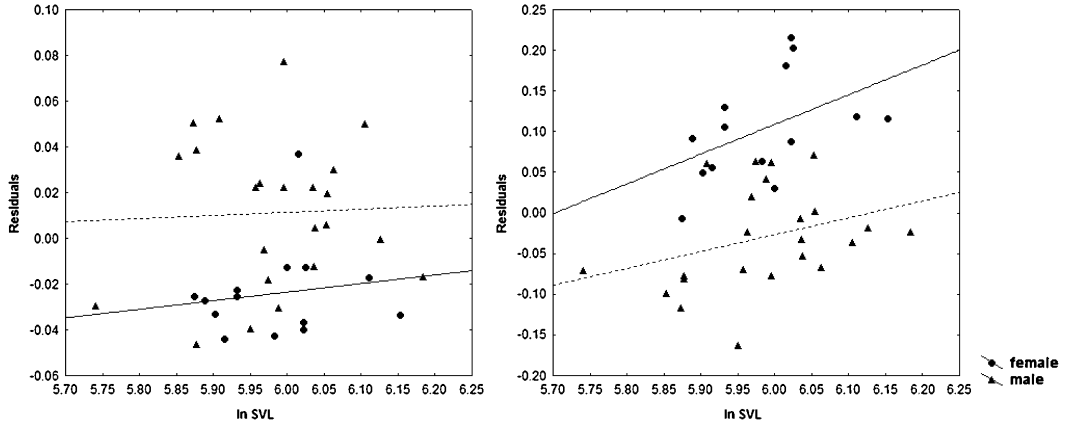


Figure 3. Sex differences in the size adjusted chest and upper fore-limbs (CFW; left) and distance between the extremities (thorax-abdomen length, DEX; right) – computed as the residuals from the allometric relationships of the above variables and hip upper hind-limb width (HHW). Snout-vent length (SVL) is given on x -axis to provide traditional scale of body size. The variables were log-transformed prior the analysis. Full and dotted lines denote linear fit computed for females and males, respectively.

0.0009), but not HL ($t = -1.09$, $P = 0.2837$). The results remained virtually unchanged when size-free measurements (adjusted to isometric multivariate size) instead of original ones were used: DEX ($t = -5.68$, $P < 0.0001$), CFW ($t = 4.50$, $P < 0.0001$) and HL ($t = 0.32$, $P = 0.7535$).

Exploratory analyses

Next we size-adjusted the original log-transformed data-set and performed DFAs to uncover those combinations of traits best predicting the sex. Moreover, to the Mosimann method (MOSIMANN), Somers method (SOMERS) and residuals from allometric relationship on PC1 (RESPC1) and SVL (RESSVL), for size adjustment we also adopted corresponding residuals from HHW (RESHHW). The analyses concerning records collected at youth and adulthood were performed separately.

In the case of juveniles, DFAs revealed only poor discrimination success but still a highly significant result (all P s < 0.0001). The classification success was 74.3% for MOSIMANN (Wilks' Lambda = 0.694, $F_{16,174} = 4.80$), 80.6% for SOMERS (Wilks' Lambda = 0.606, $F_{16,174} = 7.07$), 79.6% for RESPC1 (Wilks' Lambda = 0.603, $F_{16,174} = 7.15$),

78.0% for RESSVL (Wilks' Lambda = 0.603, $F_{16,174} = 7.17$) and 78.5% for RESHHW (Wilks' Lambda = 0.602, $F_{16,174} = 7.20$). SVL and/or DEX versus head dimensions (e.g., HL) contributed most to explaining variance.

Discrimination success was higher for the adults-only data. Classification success was 92.9% for MOSIMANN (Wilks' Lambda = 0.318, $F_{16,137} = 18.38$, $P < 0.0001$), 92.9% for SOMERS (Wilks' Lambda = 0.333, $F_{16,137} = 17.17$, $P < 0.0001$), 94.2% for RESPC1 (Wilks' Lambda = 0.332, $F_{16,137} = 17.23$, $P < 0.0001$), 92.8% for RESSVL (Wilks' Lambda = 0.326, $F_{16,136} = 17.56$, $P < 0.0001$) and 92.2% for RESHHW (Wilks' Lambda = 0.329, $F_{16,137} = 17.49$, $P < 0.0001$). Irrespective of the method used for the size adjustment, the shape difference between the sexes was determined mostly by relatively longer DEX, SVL and TL in females and relatively longer CFW, NMH, EMH and some other head dimensions in males (see table 2 for CVA loadings). Next, we performed backwards selection to reduce the number of variables included in our analysis. The reduced DFA included CFW, TW, NMH and EMH for MOSIMANN (Wilks' Lambda = 0.408, classification success = 87.0%); CFW, LFL,

Table 2. Correlations between individual variables and the first canonical axes (CV1) discriminating sexes in adult mangrove-dwelling monitor lizards (*Varanus indicus*). Canonical variate analyses (CVA) were performed with size-adjusted measurements. Methods of size-adjustment were Mosimann method (MOSIMANN), Somers method (SOMERS), residuals from allometric relationships on PC1 scores (RESPC1), snout-vent length (RESSVL) and hip upper hind-limb width (RESHHW). For the measurements see under Materials and methods.

	MOSIMANN	SOMERS	RESPC1	RESSVL	RESHHW
SVL	-0.320	-0.529	-0.518	—	-0.289
DEX	-0.265	-0.490	-0.490	-0.255	-0.320
TL	-0.283	-0.400	-0.395	-0.028	-0.225
HHW	0.127	-0.169	-0.185	0.296	—
CFW	0.458	0.161	0.142	0.559	0.430
KHL	0.136	-0.117	-0.132	0.295	0.059
LFL	-0.096	-0.117	-0.122	0.213	0.021
TW	0.266	0.049	0.071	0.297	0.167
RPL	-0.302	-0.145	-0.154	0.126	-0.039
IOW	—	—	—	0.372	0.182
INW	-0.054	0.210	0.200	0.472	0.241
HL	-0.014	0.199	0.187	0.477	0.238
RNL	-0.001	0.131	0.114	0.357	0.172
NEL	-0.136	-0.047	-0.057	0.255	0.061
EEL	0.189	0.315	0.316	0.511	0.322
NMH	0.324	0.357	0.364	0.513	0.332
EMH	0.267	0.383	0.405	0.519	0.408

TW, INW, RNL, EEL, NMH and EMH for SOMERS (Wilks' Lambda = 0.351, classification success = 94.16%); CFW, LFL, TW, INW, RNL, EEL, NMH and EMH for RESPC1 (Wilks' Lambda = 0.348, classification success = 93.51%); DEX, TW, CFW, RNL, NEL, NMH for RESSVL (Wilks' Lambda = 0.394, classification success = 89.5%) and DEX, TW, CFW and NMH for RESHHW (Wilks' Lambda = 0.449, classification success = 87.0%).

In order to graphically demonstrate the discrimination power of two body segments that consistently contributed to the above DFAs and thus sex differences, we plotted CFW against DEX in all records measured in adults (fig. 4).

We found no sexual differences in vertebral counts; all the examined individuals (20 males and 11 females) had a uniform 22 trunk vertebrae.

Comments on sexing methods

We examined 35 individuals of which 27 everted their hemipenises and/or hemiclitorises. The morphological distinctness between hemipenises and hemiclitorises is sufficient for successful sexing. All specimens determined as

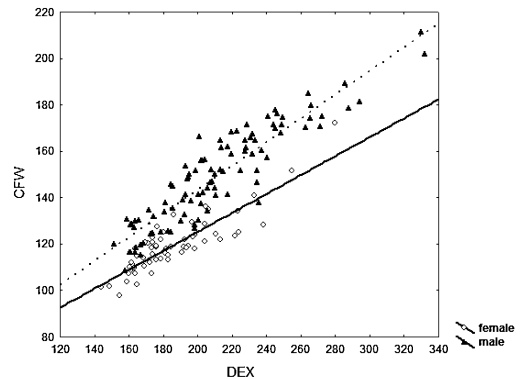


Figure 4. Biplot of the chest and upper fore-limbs (CFW) and the distance between the extremities (thorax-abdomen length; DEX) in the mangrove-dwelling monitor lizards (*V. indicus*). Only the records (pseudoreplicates) taken at adulthood (the age exceeding 546 days) were included. The scales refer to the original not transformed data. Full and dotted lines denote linear fit computed for females and males, respectively.

males according to visual inspection of their copulatory organs were later confirmed as males. Only one male was erroneously classified as a female. Success of the method was 96%; however, it falls to 77% if individuals not everting their organs were included. Thus the method is limited especially by low willingness

to everted, especially in females (six of eight cases). Ultrasonographic imaging method was applied to sexually matured individuals and produced unequivocal results. We met no problems associated with its application.

Discussion

Despite the extensive research devoted to morphological criteria enabling sex determination in varanid lizards, only subtle sexual differences in body shape were reported by previous authors (Thompson and Withers, 1997; Thompson, 2002; Smith et al., 2007). Thus, our finding that the vast majority of morphometric variation is attributable to size component and that the shape variation (including sexual differences) is even hard to detect was not very surprising.

Nevertheless, we succeeded to demonstrate sexual differences in the relative size of two body segments predicted by a priori hypotheses. The mean relative width of chest and upper forelimbs (CFW) was smaller in adult females than in males of comparable body size (cf. fig. 3). We can speculate that this trait contributes to winning of the wrestling phase of male combats and thus it is favoured by intrasexual component of sexual selection in varanids. Although the observed sexual dimorphism in CFW seems to indirectly support this hypothesis, field empirical data concerning CFW and relationship of this trait to fighting success are not available yet.

Inversely, the mean relative thorax-abdomen length (DEX) was larger in females than in males of comparable size. This difference can be easily explained by fecundity selection and it is widespread among lizard taxa (Braña, 1996; Olsson et al., 2002; Kratochvíl et al., 2003). Fixed vertebral numbers of the thoracic/abdominal segment suggest that the observed elongation of the thorax-abdomen length (DEX) is not a result of structural changes.

In contrast, we failed to demonstrate sexual differences in head size within the balanced data-set. Because sexual differences in body size were efficiently controlled in this compar-

ison, the absence of sexual differences in head size is reliable. Head size was the trait most frequently reported to be sexually dimorphic in lizards (see Introduction) including some varanids (Smith et al., 2007). This disagreement may be attributed to the allometric relationship between head and body size and the methodological difficulties associated with scaling head size to snout-vent length including dimorphic thorax-abdomen length and/or use of proportions (see Kratochvíl et al., 2003).

The results of exploratory analyses confirmed the above conclusions. The multivariate axes describing sexual differences are associated with the relative width of chest and upper forelimbs (CFW), traits comprising abdomen size (DEX, SVL), tail width (TW) and also some partial dimensions on the head.

Although sexual differences in the body shape are obviously small enough to provide an efficient tool for field sex determination of *V. indicus*, our results clearly suggest that subadults of these monitor lizards can be easily sexed by visual inspection of everted hemipenises/hemictitorises. Unfortunately, this method is not applicable to juveniles up to the age of nine months as well as to adults. Our results confirmed that the sex of mature females can easily be determined by ultrasonographic method, moreover adult males are distinctive by their large asymptotic body size/weight (Frynta et al., in press).

In conclusion, the differences between male and female body shapes are small and emerged only after maturity in *V. indicus*. It is the larger relative width of chest and upper forelimbs of the male and the larger thorax-abdomen length of the female that contribute to these differences. Female monitor lizards of mangrove-dwelling monitors, as well as females of some other lizard taxa, possess a longer abdominal body segment than conspecific males, however, this difference is only slight and it is not the result of an increased number of vertebrae. Bigger chest and upper forelimbs of male mangrove-dwelling monitors may suggest that ritualised

combat prioritises wrestling over biting has led to an increase of this segment for males instead of head size as in other lizard taxa. It would also be of interest to assess the sexual size dimorphism in this trait in another species of giant monitor lizard.

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