

Sexual dimorphism in *Pseudopus apodus* (Reptilia: Sauria: Anguidae) from the Steppe Crimea

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Received 11 May 2018 | Accepted by V. Pešić: 5 September 2018 | Published online 11 September 2018.

Abstract

The current paper is focused on sexual dimorphism of a giant glass lizard, or sheltopusik, *Pseudopus apodus apodus* (Pallas, 1775) from its northernmost populations inhabiting the Crimea. In total, 72 *P. apodus* individuals (45 males and 27 females) were collected at the Kerch Peninsula during 2013–2017. To estimate the variability, 13 morphometric parameters and 18 indices characterizing the head and body proportions were used. It was found that males and females differed significantly by means of almost all parameters, except the body and tail sizes. Besides that, the differences by 10 ratios characterizing head proportions were revealed as well. However, a reliable determination of the lizard sex using linear sizes and/or ratios values seems to be impossible because of the strong overlap of the variability ranges in both sexes. At the same time, the use of the canonical discriminant analysis by the complex of morphometric parameters and by ratios has shown that the males and females in both datasets are classified correctly basing on the sex with an accuracy approximating 100%. The differences in the allometric growth of males and females partially define the sexual dimorphism of *P. apodus* on head size and shape. A sex-related differences in the development of at least one pair of parameters (head and snout lengths) were clearly evident, since isometry was established for males, while allometry – for females. Moreover, the systems of correlation between the body and head parts differ in both sexes. Thus, male characteristics correlate significantly, while the female ones were less toughly connected, and some pairs of parameters did not correlate at all.

Key words: sheltopusik, external morphology, morphometry, sex differences, Kerch Peninsula.

Introduction

A giant glass lizard, or sheltopusik, *Pseudopus apodus* (Pallas, 1775) is the biggest representative of Anguidae family in the current fauna of the Western Eurasia with the vast distribution range (Sindaco & Jeremchenko 2008). Recent genetic study basing on the molecular markers allowed to establish that an

eastern part of its range (from the Crimea at the north and west, to Iran at the south and Kazakhstan at the east) is inhabited by a nominative subspecies, while at the Balkan-Anatolian part of the range *P. a. thracicus* (Obst, 1978) resides. In turn, the recently discovered, but still undescribed subspecies dwells on the Eastern coast of the Mediterranean Sea (Jandzik et al. 2018). Therefore, *P. apodus* intraspecific taxonomy is still not studied well enough.

It is noteworthy that F.J. Obst (1978), who studied *P. apodus* intraspecific structure for the first time, believed that the isolated populations of the Northern and Eastern Black Sea Regions belong to *P. a. thracicus*; however, the lack of the studied specimens from those territories makes these conclusions speculative. Later, the taxonomic position of *P. apodus* from the Crimea and Western Caucasus has been discussed repeatedly basing on its external morphology. Some authors believe that the lizards from the former USSR territory, including the Crimea and Caucasus Black Sea coast, belong to the nominative subspecies (Szczerbak & Tertyshnikov 1989; Karmishev 2002; Kukushkin & Sviridenko 2005; Kukushkin & Karmyshev 2008), although others identify these populations as *P. a. thracicus* or intermediate form (Obst 1981; Tuniyev 2007). Recently it was established that *P. a. apodus* resides in the Crimea and at the Caucasus Isthmus, while *P. a. thracicus* distribution range in Anatolia does not reach the southern and western borders of the Caucasus ecoregion (Jandzik et al. 2018).

The morphological differences between the subspecies require clarification (Rifai et al. 2005; Jandzik et al. 2018). The variability of the external morphology characters of this lizard is poorly studied, what emphasizes the need of its precise survey. It is evident that the sexual dimorphism is extremely important for the studies of subspecies and geographic populations.

P. apodus sexual dimorphism has been thoroughly analyzed only by several researchers (Lisičić et al. 2012; Lovrić 2012). In most cases the authors simply claim the presence of the sexual dimorphism basing on the absolute and relative body sizes, head shape and/or some other characters (Skrynnikova 1977; Jablonski 2006; Tuniyev 2007; Scharf & Meiri 2013). In particular, it was noticed that the females had longer body, while shorter tail and more compact head as compared to males (Siroitchkovsky 1958; Obst 1981). Despite the relatively detailed characteristic of the lizards using morphometric parameters, pholidosis and coloration (the Crimean plain and mountain populations are compared) presented in several publications, the sexual dimorphism was out of the research scope (Kukushkin & Sviridenko 2005; Kukushkin 2006; Kukushkin & Karmyshev 2008), or the results were not fully reliable because of the low number of the females in the sample (Karmishev 2002).

It was noticed that the traits of the sexual dimorphism in anguid lizards are relatively weakly expressed, what makes the external morphology-based sex identification to be quite challenging in some cases (Wiens & Slingluff, 2001). This statement is mainly fair in relation to *P. apodus* as well. Undoubtedly, the glass lizard sex usually can be identified during the catching, when the males immediately display their everted hemipenises as a typical behavioral reaction of the species. Furthermore, the old males have the huge and massive head, what excludes the mistake during the sex identification. Nevertheless, males can be very inert and do not show hemipenises during the catching under the low temperature in spring and even in summer at the end of a daily activity in the twilight. Oftenly, in the field conditions the researcher puts all collected lizards into one tissue bag, what complicates the sex identification within the following analysis, especially of small and medium-sized specimens. At the same time, the data on the sex ratio is very important for the understanding of *P. apodus* population structure as well as many aspects of the biology of this poorly studied species. The development of the suitable system of *P. apodus* measurements for the reliable differentiation of males and females might shed some light into this problem.

Therefore, the aims of the current work were to study the sexual dimorphism of the *P. apodus* and to develop the reliable criteria for the sex identification of some individuals basing on the body sizes and their ratios. The detailed analysis of the evolutionary aspect of this issue, i. e. the reasons of the sexual dimorphism origin (see: Cox et al. 2003; Sharf & Meiri 2013), was far beyond of the objectives of our study.

Material and Methods

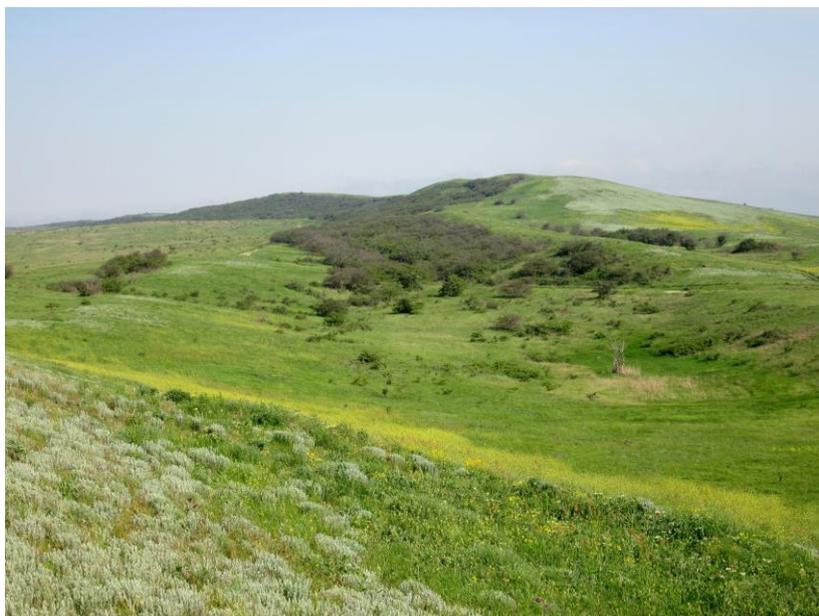
The region of studies and sample

The distribution range of *P. apodus* throughout the Crimean Peninsula is fragmented both because of natural reasons and anthropogenic changes of the landscapes. Currently, two main populations exist at the Crimea separated by the distance of circa 100 km. One large part of the range is attributed to the

Submediterranean forest and forest-steppe regions of the south-western part of the Crimean Mountains, while the second – to the north and eastern coasts of the Kerch Peninsula characterized by the continental dry-steppe climate (Kukushkin & Karmyshev 2008; Kukushkin 2015). In the focus of our paper is the second population at the northern limit of the species range. The Kerch Peninsula was chosen because of the highest density of *P. apodus* as compared to the majority of the Crimean mountain populations – up to 5–11 individuals per 1000 m², sometimes up to 50–75 individuals per a hectare (Kotenko & Kukushkin 2010). It is evident that the catching of the large serpentiform lizard moving rapidly in steppe or semi-desert landscapes requires less efforts, then in the stony mountain terrains.

We have studied *in vivo* 72 *P. apodus* adults (62.5% males and 37.5% females), caught at the coastal strip ranging from the Kazantip Cape (on the Sea of Azov) to the foot of the Mountain Opuk (on the Black Sea) during 2013–2017. More than two thirds of the sample (76.4% of individuals) were the lizards from the Bulganak-Osovinskaya Steppe collected between the Tarkhan Cape (N45.4550, E36.4430) and the Khroni Cape (N45.4406, E36.5771) at two plots of 7–8 and 2–3 km long, respectively (Fig. 1. and Fig. 2). The elevation range of *P. apodus* collection sites varies between 1–2 and 164 m a. s. l.

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Figures 1–2. Typical habitats of *Pseudopus apodus* at Bulganak-Osovinskaya Steppe of the Kerch Peninsula: near the Tarkhan Cape (1), near the Khroni Cape (2).

The sample of females have been collected for 5 years during the expeditions. Such a long time was required because of the shift of the sex ratio in the regional *P. apodus* population, where the males prevail pronouncedly (Kukushkin et al. 2013; Kukushkin & Yaryhin 2013). The sex ratio in our sample (males (1.67) / females (1.0)) is far beyond the real state-of-art, because we strived to have the representative sample of females, while only some of the collected males were measured. In fact, the number of males exceeds the female's one at least in five times. For example, sometimes among 20–30 specimens collected within one day no females were found.

It is supposed that *P. apodus* in the Central Asia become fertile at 3–4 years and body length of 320 mm (Bogdanov 1965). Our observations in the Steppe Crimea revealed that some females of 310–315 mm-long are able to reproduce. Hence, *P. apodus* adults become fertile and mature, when their body length exceeds 310 mm.

Morphometric characters

The body and tail lengths were estimated using the tape-measure with the precision of 1 mm. In turn, the head dimensions were evaluated using the caliper with the error of ± 0.1 mm.

The topography of the head scales in the studied *P. apodus* population is presented on Fig. 3 and Fig. 4. The measurements following the original scheme are listed below:

L. – body length from the tip of the snout to cloacal aperture, along the median line of the body (i.e., snout-vent length);

L. cd. – length of intact tail;

TL – total length (calculated for individuals with an intact tail by the summation of *L.* and *L. cd.* values);

L. c. ot. – head length from the anterior edge of the ear aperture to the tip of the snout;

L. c. lr. – head length from the posterior edge of the last supralabial scute (usually separated from the ear aperture by two small scales) to the tip of the snout;

Pil. – pileus length from the posterior margin of the occipital shield (rounded scute, bordering with interparietal shield by a short seam) to the tip of the snout;

Lt. c. max – maximum head width;

Lt. c. or. – head width at the level of the posterior edge of the eye orbits;

Lt. c. oc. – head width at the level of the seam between the third and fourth supraorbital scutes (i. e., approximately at the level of the posterior edge of the iris); measured perpendicularly to the body axis, because the supraorbitals position on the right and left sides of the head can be slightly assymetrical;

L. on. – distance from the anterior angle of the eye to the posterior edge of the nostril, was measured on the right side of the head;

L. fr. – length of the frontal shield;

Lt. fr. – maximum width of the frontal shield;

L. r. – length of the snout (rostrum) from the front edge of the frontal shield to the tip of the snout;

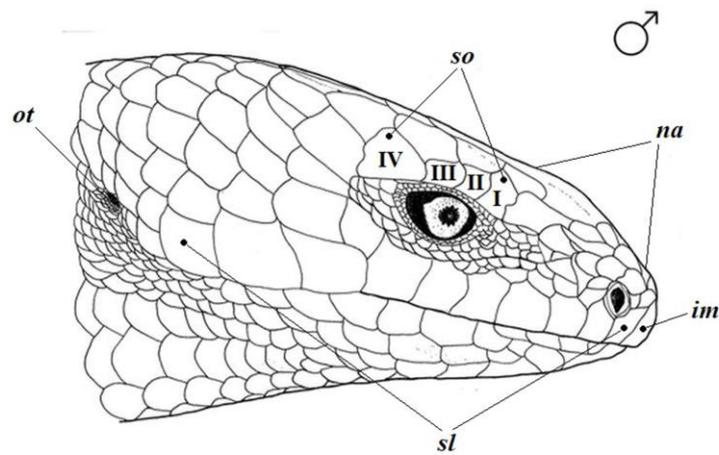
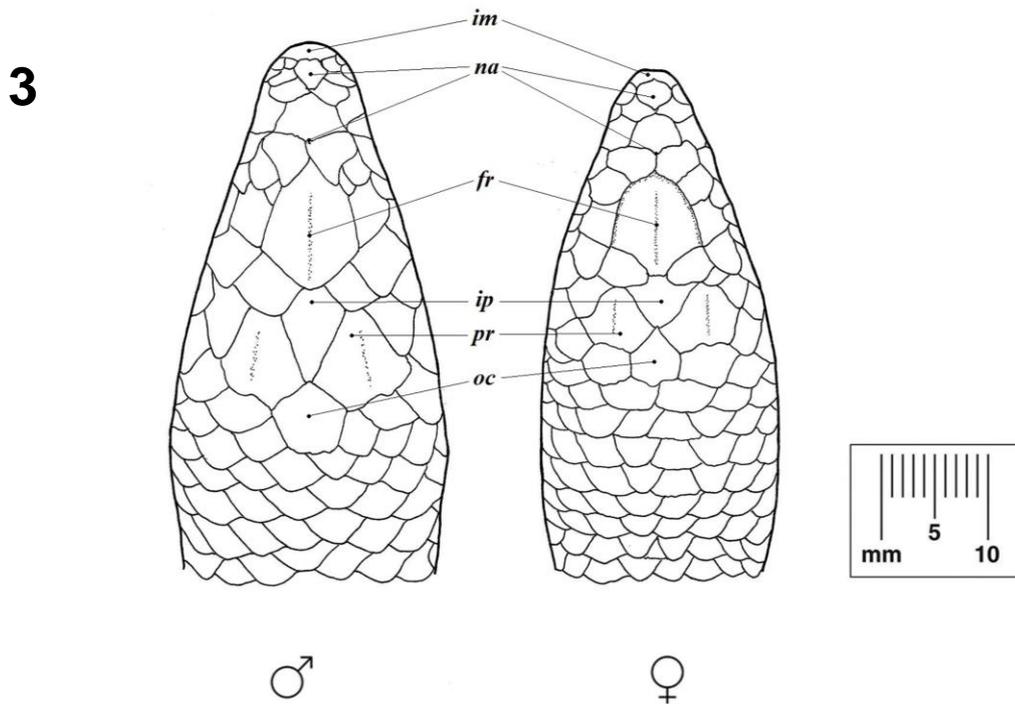
Lt. r. – width of the snout at the level of the nasal apertures (the distance between the inner edges of the nostrils).

These parameters selected for the sex identification can be easily measured in the field *in vivo* without any physical harm to animals. Some valuable parameters, though promising in relation to the studies of sexual dimorphism, were omitted because of the difficulties to measure them precisely: e. g., length of hind limbs rudiments, the maximum height and width of intermaxillar (rostral) scute, and some others.

To characterise the body proportions and the ratio of the linear head sizes 18 indices were used (*L./L. cd.*, *L./L. c. ot.*, *L./L. c. lr.*, *L./Pil.*, *L. c. ot./Pil.*, *L. c. ot./Lt. c. max.*, *Pil./Lt. c. or.*, *Pil./Lt. c. oc.*, *Pil./L. fr.*, *L. fr./Lt. fr.*, *Pil./L. r.*, *L. r./Lt. r.*, *L. r./L. on.*, *L. r./L. fr.*, *L. on./Lt. r.*, *Lt. c. max./Lt. r.*, *Lt. c. or./Lt. r.*, *Lt. c. oc./Lt. r.*). Moreover, the peculiarities of the body coloration, molting stages of both sexes, and some other tiny details were taken into the account as well.

Statistical analysis

The statistical analysis were performed in STATISTICA 6.0 and 10, as well as in PAST 3.11 software packages (Hammer et al. 2001). For each trait the basic statistical parameters were calculated. Since the data were evaluated as normal, the basic parametric statistical methods (correlation analysis and Student's t-test) were selected. The significance of the difference between the means was evaluated using of Student's t-test. The differences were supposed to be reliable at the confidence level of 5% ($P < 0,05$).



Figures 3–4. Topography of *Pseudopus apodus* head shields: view from above, body length is 390 mm in male and 385 mm in female (im: intermaxillar (rostral), fr: frontal, pr: parietal, ip: interparietal, oc: occipital, so: supraoculars) (3), side view (im: intermaxillar (rostral), sl: supralabials, fr: frontal, so: supraoculars, na: nasal area, ot: ear aperture) (4).

For the large-scale comparison of the sex differences following the whole set of the morphological characters a canonical discriminant analysis has been used. Morphological measurements listed above as well as their ratios were applied separately. Characters *L. cd.* and *TL* were omitted here, since 38.9% of individuals in our sample had tails damaged by predators, namely 13 males (28.9%; $n = 45$) and 15 females (55.6%; $n = 27$).

For the analysis of the relative growth of the body and head the regression analysis was used. In turn, allometric equations were used for the approximation. The individuals of both sexes differ by the complex of both the linear sizes and indices. This can be explained by the fact that some organs/body parts develop in different pace regarding the others and the organism as a whole (allometric growth). The degree equation $Y = b \times X^a$ (where Y – organ/body part size, X – the other organs/body part or the organism size, a and b – constants) is used for allometry evaluation (Shebanin et al. 2008). The most important here is an allometry constant a . Thus, if $a > 1$, then Y increases in size faster than X ; if $a < 1$ – *vice versa*; if $a = 1$, then the body parts develop proportionally, i.e. isometrically.

Finally, the correlation analysis was used for the evaluation of the strength of linear relationship between the variables (morphometric parameters) (Lakin 1990).

Results

The body and tail lengths

In the studied sample the specimens with the body length from 361 to 420 mm (66.7% males, 81.5% females, 72.2% in total) prevail among the representatives of both sexes. However, 51.1% of males are 381–420 mm-long, while 59.3% of females – 361–400 mm. It can be supposed that these differences represent the real peculiarities of the size and age structure of males and females, though they can be explained by the random factors. The average body length ($L.$) of males and females in our sample were almost identical, while the maximum length ($L. max$) were somewhat higher in males (Table 1).

No significant sex differences in the absolute tail length were revealed, although the maximum values of this parameter in females were significantly lower than in males, while the mean values were just slightly lower (Table 1). At the same time, the relative tail length ($L./L. cd.$) in both sexes is *de facto* equal.

Among the individuals with the intact tail the maximum total length of 1230 mm was recorded in male ($L. 465$ mm, $L. cd. 765$ mm), while the largest female in our sample was 1085 mm-long ($L. 429$ mm, $L. cd. 656$ mm).

The relative size, proportions and shape of the head

The significant differences between the males and females at the absolute values of the head measurements were found for all characters (Table 1). For $Lt. fr.$ character the differences are reliable at $P < 0.01$; the differences for other characters are supposed to be highly reliable ($P < 0.001$).

The comparison using indices (Table 2) revealed the highly reliable differences at the parameters characterizing the head length in regards of the body size: $L./L. c. ot.$, $L./L. c. lr.$ and $L./Pil.$ The reliable differences at $P < 0.01$ were found also at three more indices ($Pil./Lt. c. oc.$, $L. fr./Lt. fr.$, $Lt. c. oc./Lt. r.$), while at $P < 0.05$ – at four ($Pil./Lt. c. or.$, $Pil./L. r.$, $L. r./Lt. r.$, $Lt. c. or./Lt. r.$). Furthermore, the differences at other six ratios are below the reliability level, although in all cases their values are slightly higher in females. Finally, the value of $L. c. ot./Lt. c. max$ ratio has no sex difference at all.

Basing on these data we can conclude that *P. apodus* females, in comparison to males, have almost the same body length, though shorter head and pileus, relatively wider head on the eye level ($Pil./Lt. c. or.$ and $Pil./Lt. c. oc.$), wider frontal shield as well as relatively shorter and narrow snout. In turn, males have relatively bigger (but not wider) head as compared to females; elongated rostrum with the slightly pronounced thickening in nostrils area, which is almost unexpressed in females. The upper surface of male snout frontwards the frontal shield has well-pronounced hump-like “crooky” profile. In general, the male head is more angular than the female one, and is visually more separated from the body. Females have more “compact” heads, evenly convex in the nasal area lacking evident “crook” and unobvious cervical interception. Besides that, males, particularly large ones, have more pronounced supraocular visors.

Table 1. The measurements and t-test results for *P. apodus* males and females from the Kerch Peninsula population*

Measurement	Measurement value (range of variation, mean±error of mean, in mm) of males (n = 45)	Measurement value (range of variation, mean±error of mean, in mm) of females (n = 27)	Student's test (t)	P for t- test
<i>TL</i>	807–1230 967±14.72	848–1085 949±17.88	0.78	> 0.05
<i>L.</i>	310–465 387±4.97	330–429 386±4.28	0.15	> 0.05
<i>L. cd.</i>	497–765 590±9.17	518–656 576±10.82	0.99	> 0.05
<i>L. c. ot.</i>	31.2–55.0 40.5±0.71	31.9–42.6 36.5±0.57	4.39	< 0.001
<i>L. c. lr.</i>	28.4–45.3 37.3±0.60	29.0–37.0 33.2±0.46	5.42	< 0.001
<i>Pil.</i>	30.2–45.5 37.9±0.54	30.0–38.0 34.0±0.38	5.91	< 0.001
<i>Lt. c. max</i>	18.1–31.6 23.6±0.43	18.6–25.1 21.3±0.28	4.48	< 0.001
<i>Lt. c. or.</i>	16.2–23.8 19.0±0.25	15.7–19.1 17.6±0.17	4.63	< 0.001
<i>Lt. c. oc.</i>	14.1–21.7 16.4±0.22	13.6–16.8 15.3±0.17	3.96	< 0.001
<i>L. on.</i>	9.0–12.9 10.8±0.15	8.1–11.3 9.73±0.14	5.22	< 0.001
<i>L. fr.</i>	9.6–18.5 12.4±0.24	9.0–13.1 10.8±0.18	5.33	< 0.001
<i>Lt. fr.</i>	6.8–11.3 9.13±0.15	7.1–9.8 8.56±0.14	2.78	< 0.01
<i>L. r.</i>	11.3–17.6 14.5±0.20	11.4–15.3 13.5±0.19	3.63	< 0.001
<i>Lt. r.</i>	6.0–8.7 7.36±0.10	5.4–7.5 6.49±0.10	6.15	< 0.001

The typical sex differences in relative head sizes and shape of *P. apodus* males and females are presented on Fig. 3 and Fig. 4. Definitely, the listed details favour to some variability and might be expressed in various individuals to different extent (Fig. 5 and Fig. 6).

The analysis of intraspecific allometry

The allometry was assessed on the basis of the analysis of four pairs of characters, at first, the body length as well as head length from the ear to the snout tip (*L.* and *L. c. ot.*), what is expressed as the equation $L = b \times L. c. ot^a$. In frames of the current research the allometry was analyzed in the individuals of both sexes, and the resulted equations were $L = 39.89 \times L. c. ot^{0.61 \pm 0.06}$ (males) and $L = 67.79 \times L. c. ot^{0.48 \pm 0.11}$ (females). Basing on these equations, the constant *a* in both cases differed significantly from 1, what is an

* Statistically significant Student's test values are marked bold.

evidence for unproportional (allometric) growth of the head and body in males and females. However, the allometry constant a (0.61 in males, 0.48 in females) had no significant differences in both sexes ($t = 1.04$; $P > 0.05$).

Table 2. The values of body indices and t-test results of *P. apodus* males and females from the Kerch Peninsula population*

Index	Index value (range of variation, mean±error of mean, in mm) of males (n = 45)	Index value (range of variation, mean±error of mean, in mm) of females (n = 27)	Student's test (t)	P for t- test
<i>L./L. cd.</i>	0.60–0.69 0.64±0.004	0.62–0.68 0.65±0.005	1.56	> 0.05
<i>L./L. c. ot.</i>	7.51–11.3 9.60±0.09	9.37–11.8 10.6±0.12	6.67	< 0.001
<i>L. / L. c. lr.</i>	9.37–12.5 10.4±0.09	10.7–12.6 11.6±0.10	8.92	< 0.001
<i>L./ Pil.</i>	9.41–11.7 10.3±0.08	10.9–12.4 11.4±0.07	10.4	< 0.001
<i>L. c. ot./ Pil.</i>	0.99–1.33 1.07±0.01	0.93–1.22 1.08±0.01	0.71	> 0.05
<i>Lt. c. ot./ Lt. c. max</i>	1.46–2.00 1.72±0.02	1.49–2.00 1.72±0.03	0.0	-
<i>Pil./ Lt. c. or.</i>	1.76–2.21 2.00±0.02	1.75–2.05 1.94±0.02	2.12	< 0.05
<i>Pil./ Lt. c. oc.</i>	2.07–2.67 2.31±0.02	2.00–2.47 2.22±0.02	3.18	< 0.01
<i>Pil./ L. fr.</i>	1.90–3.96 3.09±0.05	2.69–3.62 3.16±0.05	0.99	> 0.05
<i>L. fr./ Lt. fr.</i>	1.14–1.99 1.36±0.02	0.99–1.45 1.27±0.02	3.18	< 0.01
<i>Pil./ L. r.</i>	2.26–2.83 2.62±0.02	2.25–2.94 2.53±0.03	2.50	< 0.05
<i>L. r./ Lt. r.</i>	1.59–2.34 1.98±0.02	1.59–2.44 2.08±0.04	2.24	< 0.05
<i>L. r./ L. on.</i>	1.20–1.53 1.35±0.01	1.13–1.55 1.39±0.02	1.79	> 0.05
<i>L. r./ L. fr.</i>	0.75–1.44 1.18±0.02	0.99–1.61 1.25±0.03	0.08	> 0.05
<i>L.on./ Lt. r.</i>	1.00–1.88 1.44±0.03	1.17–1.76 1.48±0.03	0.94	> 0.05
<i>Lt. c. max./ Lt. r.</i>	2.58–3.89 3.21±0.05	2.91–3.78 3.29±0.05	1.13	> 0.05
<i>Lt. c. or./ Lt. r.</i>	2.14–3.02 2.59±0.03	2.39–3.20 2.72±0.04	2.60	< 0.05
<i>Lt. c. oc./ Lt. r.</i>	1.89–2.64 2.24±0.03	2.12–2.80 2.37±0.03	3.06	< 0.01

* Statistically significant Student's test values are marked bold.



Figure 5. Variability of the head shape in *Pseudopus apodus* from the Kerch Peninsula, view from above: left column – males, right column – females.

The same results were obtained for another pairs of characters. Thus, the allometry constant was 0.68 for the ratio $Lt. c. or. = b \times Lt. c. max^a$ (head width on the level of the posterior orbital margin and maximum head width) without the differentiation of sexes (following the common matrix), what indicates the allometry. In the same time, the similar values were obtained also for males ($a = 0.68$) and females ($a = 0.62$). The difference between these indices is insignificant ($t = 0.64$; $P > 0.05$). The male and female allometric constants for the equation $Lt. c. oc = b \times Lt. c. max^a$ (head width at the level of the posterior edge of the iris and maximum head width) were practically identical to the constant values of the previous pair of characters (0.62 in males, 0.61 in females; $t = 0.55$; $P > 0.05$). Therefore, as a result of three equation analyses mentioned above, the allometric constant essentially differs from 1 in all cases, what proves that allometric development of the body and head is typical both for males and females.

However, other data were obtained as a result of the analysis of the relation between $L. c. lr.$ и $L. r.$ parameters (head length from the snout tip to the last supralabial and snout length). In the allometric function $L. c. lr = b \times L. r^a$ the allometry constant corresponded to the isometric growth ($a = 0.98$) in the analysis of both sexes altogether. The same results were for males ($a = 0.97$), although for the females it was different ($a = 0.55$), what corresponded an allometric growth. It is noteworthy that the differences between the constants in males and females were statistically reliable ($t = 2.21$; $P < 0.05$).



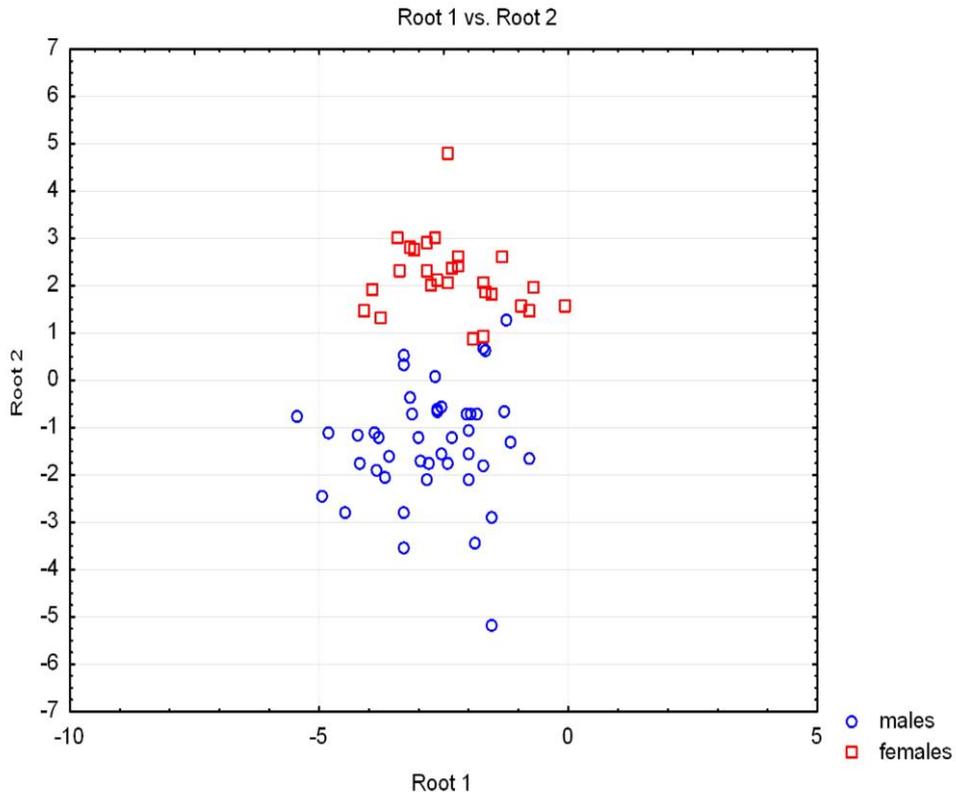
Figure 6. Variability of the head shape in *Pseudopus apodus* from the Kerch Peninsula, side view: left column – males, right column – females.

Therefore, *P. apodus* has evident sex-related features of the relative development of at least one pair of studied parameters, which indicates the isometry in males and allometry in females. This feature might be probably expressed at the remarkable sex differences in the relative length of the rostral part of the head and the snout outlines (Fig. 3–6).

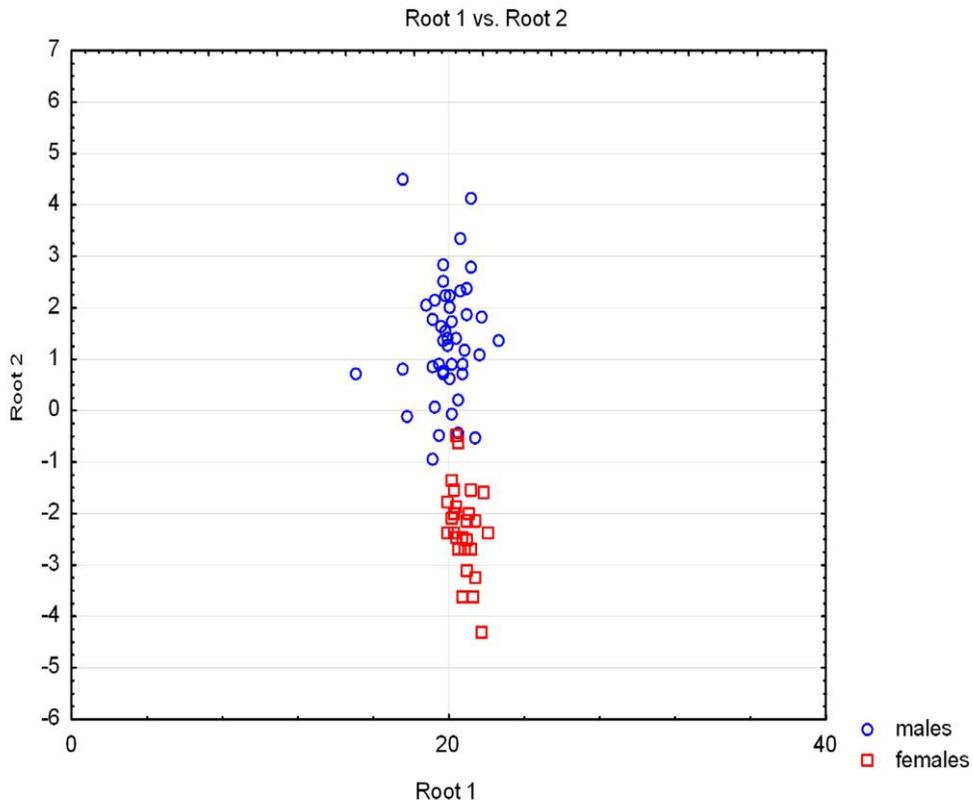
The discriminant canonical and correlation analyses

The distribution of individuals within the two canonical axes according to the absolute values of the dimensional features is shown on Fig. 7. The matrix of sex-based classifications suggests that 42 out of 45 males (93%) fit their group, while the rest 3 individuals better fit to females in the set of characters. In turn, 100% of the females fit their own group. A sex-based discrimination is provided by the first canonical axis by all the measurements (Table 3). Thus, the whole set of measurement characters can be used in the studies of sexual dimorphism in *P. apodus* populations. However, the overlap of the variability ranges makes the sex identification using linear sizes and their ratios impossible.

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Figures 7–8. Scatterplot of canonical scores computed for dimensions of head and body (7) and indices of body and head proportions (8) of *Pseudopus apodus* males and females (results of discriminant analysis).

Table 3. Correlations between *P. apodus* males and females measurements and canonical scores (results of discriminant analysis). Correlations marked bold are significant at $P < 0.05$.

Character	Root 1	Root 2
<i>L.</i>	-0.99	0.03
<i>L. c. ot.</i>	-0.97	-0.12
<i>L. c. lr.</i>	-0.97	-0.14
<i>Pil.</i>	-0.98	-0.13
<i>Lt. c. max</i>	-0.97	-0.12
<i>Lt. c. or.</i>	-0.99	-0.08
<i>Lt. c. oc.</i>	-0.99	-0.07
<i>L. on.</i>	-0.98	-0.12
<i>L. fr.</i>	-0.95	-0.16
<i>Lt. fr.</i>	-0.97	-0.06
<i>L. r.</i>	-0.98	-0.08
<i>Lt. r.</i>	-0.98	-0.15

The similar results were obtained using indices (Fig. 8). The matrix of classifications suggests that both sexes reveal almost absolute (100%) sex-based discrimination: 95% of males and 96% of females were identified correctly. In this case, the best discrimination was also observed at the first canonical axis, and the correlation coefficients between the indices and the canonical axes were statistically significant for all indices (Table 4). The variability range of the both sexes overlaps substantially. Hence, there is no reliable value for a single index, which allows to identify correctly the sex of each individual. At the same time, the discriminant analysis revealed a relatively significant differences in the complex of characters and indices.

Table 4. Correlation between the body indices of *P. apodus* males and females and canonical scores (results of discriminant analysis). Correlations marked bold are significant at $P < 0.05$.

Index	Root 1	Root 2
<i>L./L. c. ot.</i>	0.98	-0.15
<i>L. /L. c. lr.</i>	0.98	-0.17
<i>L./ Pil.</i>	0.98	-0.15
<i>L.c.ot./ Pil.</i>	0.98	-0.01
<i>Lt. c. ot./ Lt. c. max</i>	0.98	0.01
<i>Pil./ Lt. c. or.</i>	0.99	0.06
<i>Pil./ Lt. c. oc.</i>	0.98	0.07
<i>Pil./ L. fr.</i>	0.97	-0.03
<i>L. fr./ Lt. fr.</i>	0.96	0.12
<i>Pil./ L. r.</i>	0.99	0.06
<i>L.r./ Lt. r.</i>	0.97	-0.07
<i>L. r./ L. on.</i>	0.98	-0.04
<i>L. r./ L. fr.</i>	0.96	-0.09
<i>L.on./ Lt. r.</i>	0.95	-0.03
<i>Lt. c. max./ Lt. r.</i>	0.97	-0.02
<i>Lt. c. or./ Lt. r.</i>	0.98	-0.07
<i>Lt. c. oc./ Lt. r.</i>	0.98	-0.08

Undoubtedly, the sheltopusik body parameters correlate between themselves. It is assumed that the correlation systems of males and females may differ. To test this hypothesis, the correlation analysis of all

measurements of the lizard body was performed for the whole sample and also for males and females separately. As a result, the reliable correlations between all measurements were obtained for the whole sample (Table 5), in which the sex differences were neglected. All male characters correlates significantly as well (Table 6). Despite that, the results of the correlation analysis of the female group were diverse, since the strength of the relationship between the characters were somewhat lower than in males, and totally absent between some pairs of characters (Table 7). Therefore, the representatives of both sexes have certain differences in the correlation system between the individual body parts, what presumably allows to discriminate sexes qualitatively.

Table 5. Correlations between body and head sizes of *P. apodus* (disregarding sex differences). All correlations are significant at $P < 0.05$ ($n = 72$).

Characters	<i>L.</i>	<i>L.c.ot.</i>	<i>L.c.lr.</i>	<i>Lt.c.</i> <i>max</i>	<i>Pil.</i>	<i>Lt.c.</i> <i>or.</i>	<i>Lt.c.</i> <i>oc.</i>	<i>L.on.</i>	<i>L.fr.</i>	<i>Lt.fr.</i>	<i>L.r.</i>	<i>Lt.r.</i>
<i>L.</i>	1.00	0.74	0.76	0.75	0.74	0.73	0.67	0.64	0.55	0.81	0.71	0.49
<i>L.c.ot.</i>	0.74	1.00	0.90	0.82	0.82	0.82	0.68	0.82	0.61	0.81	0.78	0.58
<i>L.c.lr.</i>	0.76	0.90	1.00	0.87	0.90	0.88	0.79	0.87	0.64	0.81	0.82	0.65
<i>Lt.c.max</i>	0.75	0.82	0.87	1.00	0.84	0.93	0.86	0.75	0.62	0.77	0.82	0.68
<i>Pil.</i>	0.74	0.82	0.90	0.84	1.00	0.86	0.80	0.79	0.66	0.81	0.84	0.68
<i>Lt.c.or.</i>	0.73	0.82	0.88	0.93	0.86	1.00	0.86	0.75	0.59	0.77	0.79	0.67
<i>Lt.c.oc.</i>	0.67	0.68	0.79	0.86	0.80	0.86	1.00	0.69	0.59	0.68	0.76	0.64
<i>L.on.</i>	0.64	0.82	0.87	0.75	0.79	0.75	0.69	1.00	0.60	0.69	0.74	0.62
<i>L.fr.</i>	0.55	0.61	0.64	0.62	0.66	0.59	0.59	0.60	1.00	0.66	0.56	0.58
<i>Lt.fr.</i>	0.81	0.81	0.81	0.77	0.81	0.77	0.68	0.69	0.66	1.00	0.73	0.58
<i>L.r.</i>	0.71	0.78	0.82	0.82	0.84	0.79	0.76	0.74	0.56	0.73	1.00	0.67
<i>Lt.r.</i>	0.49	0.58	0.65	0.68	0.68	0.67	0.64	0.62	0.58	0.58	0.67	1.00

Table 6. Correlations between body and head sizes in males (before slash) and females (after slash) of *P. apodus*. Correlations marked bold are significant at $P < 0.05$.

Charac- ters	<i>L.</i>	<i>L.c.ot.</i>	<i>L.c.lr.</i>	<i>Lt.c.max</i>	<i>Pil.</i>	<i>Lt.c.or.</i>	<i>Lt.c.oc.</i>	<i>L.on.</i>	<i>L.fr.</i>	<i>Lt.fr.</i>	<i>L.r.</i>	<i>Lt.r.</i>
<i>L.</i>	1.00	0.82/0.67	0.87/0.79	0.80/0.81	0.85/0.85	0.78/0.81	0.71/0.68	0.68/0.85	0.63/0.46	0.84/0.81	0.80/0.62	0.57/0.55
<i>L.c.ot.</i>	0.82/0.67	1.00	0.91/0.65	0.83/0.48	0.80/0.59	0.85/0.40	0.69/0.22	0.78/0.68	0.50/0.44	0.78/0.74	0.74/0.66	0.49/0.22
<i>L.c.lr.</i>	0.87/0.79	0.91/0.65	1.00	0.87/0.65	0.87/0.76	0.88/0.66	0.78/0.55	0.83/0.79	0.49/0.61	0.79/0.79	0.82/0.57	0.57/0.20
<i>Lt.c.max</i>	0.80/0.81	0.83/0.48	0.87/0.65	1.00	0.80/0.71	0.92/0.83	0.85/0.71	0.66/0.74	0.57/0.19	0.74/0.70	0.83/0.57	0.60/0.51
<i>Pil.</i>	0.85/0.85	0.80/0.59	0.87/0.76	0.80/0.71	1.00	0.83/0.73	0.78/0.62	0.67/0.83	0.53/0.49	0.81/0.72	0.81/0.71	0.54/0.45
<i>Lt.c.or.</i>	0.78/0.81	0.85/0.40	0.88/0.66	0.92/0.83	0.83/0.73	1.00	0.84/0.76	0.65/0.74	0.49/0.31	0.76/0.62	0.81/0.47	0.57/0.51
<i>Lt.c.oc.</i>	0.71/0.68	0.69/0.22	0.78/0.55	0.85/0.71	0.78/0.62	0.84/0.76	1.00	0.57/0.73	0.51/0.35	0.66/0.47	0.83/0.26	0.56/0.45
<i>L.on.</i>	0.68/0.85	0.78/0.68	0.83/0.79	0.66/0.74	0.67/0.83	0.65/0.74	0.57/0.73	1.00	0.45/0.48	0.62/0.72	0.69/0.60	0.44/0.44
<i>L.fr.</i>	0.63/0.46	0.50/0.44	0.49/0.61	0.57/0.19	0.53/0.49	0.49/0.31	0.51/0.35	0.45/0.48	1.00	0.63/0.54	0.53/0.12	0.48/0.12
<i>Lt.fr.</i>	0.84/0.81	0.78/0.74	0.79/0.79	0.74/0.70	0.81/0.72	0.76/0.62	0.66/0.47	0.62/0.72	0.63/0.54	1.00	0.70/0.60	0.57/0.30
<i>L.r.</i>	0.80/0.62	0.74/0.66	0.82/0.57	0.83/0.57	0.81/0.71	0.81/0.47	0.83/0.26	0.69/0.60	0.53/0.12	0.70/0.60	1.00	0.67/0.27
<i>Lt.r.</i>	0.57/0.55	0.49/0.22	0.57/0.20	0.60/0.51	0.54/0.45	0.57/0.51	0.56/0.45	0.44/0.44	0.48/0.12	0.57/0.30	0.67/0.27	1.00

Other features and body coloration

The head relative size and shape are not the only sex-specific habitual characters. For instance, the presence of hemipenises makes the tail base to be more massive as compared to females. Moreover, in males the transition between the body and the tail base is unpronounced, while females have noticeable tail narrowing right after the cloaca (Fig. 9 and Fig. 10). Besides these characters, some other features typical for males and females were registered, and they will be only shortly mentioned here, though require more detailed analysis. Thus, the rudiments of the hind limbs in males in average are somewhat longer (more than 4 mm) as compared to females (less than 4 mm). Intermaxillar shield is much narrower, more convex and slightly protruding in females than in males. Furthermore, the sex-dependent differences in shape of pupil of the eye is also observed: in males, especially big ones, its margin is mostly sharply scalloped, while in females – more roundish (Fig. 6).



11



12



Figures 9–12. General view of *Pseudopus apodus* from the Kerch Peninsula: male from Karalarskaya Steppe, May 2015 (9), female from the Khroni Cape, July 2017 (10), male from the Tarkhan Cape, May 2014 (11), female from the Kazantip Cape, June 2004 (12).

The differences between *P. apodus* males and females in body coloration is not so evident as in other representatives of Anguidae family (Fitch 1989; Sos 2011) and, especially, Gerrhonotinae (Dashevsky et al. 2012). Nevertheless, it is possible to distinguish some diversifications in *P. apodus* body coloration in the studied population related with the specificity of the phenocomplex of each sex. At late May – early June, the gray-olive or yellowish dorsal body surface in males is noticeably lighter than in females, which is reddish-brown. Moreover, females have pronounced white spots and patchy plots on the back forming recognizable “speckled” type of coloration (Fig. 9–12). Hence, it is possible to differentiate rather reliably the representatives of both sexes at the peak of their seasonal activity in late spring – early summer on the basis of different coloration patterns.

The observed sex-dependent differences in coloration of the background might be defined mainly by the moulting stage, i. e. features of lizard phenology. For example, at the Kerch Peninsula, an overall moulting of males was observed at early–mid-May before the mating period, while non-gravid females usually prevailing in the population moult from late-July to mid-August (Kukushkin & Yaryhin 2013). According to our observations, the moulting of pregnant lizards takes place at late June – early July approximately 2–3 weeks before the egg laying, which lasts the whole July in the Kerch Peninsula populations (Szczerbak 1966; Kukushkin et al. 2013; our unpublished data).

Discussion

The body sizes

Among the various representatives of Anguidae the males regarding the body length can be significantly smaller (Sos & Herczeg 2009) or bigger than females (García-Bastida et al. 2013), while sometimes both sexes are equal-sized (Dashevsky et al. 2013). Usually, males of anguid lizards seem to be bigger (Cox et al. 2007). In our *P. apodus* sample males and females have almost the same mean body lengths, but the differences in the mean tail lengths are insignificant ($P > 0.05$).

The data characterising the dimensions of *P. apodus* from the Kerch Peninsula (Kazantip Cape and Karalarskaya Steppe) at late 1990’s were obtained: *L.* is 392 ± 11.13 mm (limits are 320–450 mm; $n = 33$) in males, and 360 ± 30.82 mm (limits are 310–450 mm; $n = 4$) in females; *TL* is 1011 ± 14.22 (limits are 910–1140; $n = 19$) in males, and 933 ± 77.62 (limits are 850–1150; $n = 4$) in females; *L. cd.* is 621 ± 9.01 (lim. 560–700 mm; $n = 19$) in males and 573 ± 42.70 (520–700 mm; $n = 4$) females (Yu. Karmyshev, personal communication). This dataset has higher maximum values of all size characters in females than in our sample (Table 1), while the *TL* and *L.* mean values are substantially lower. Undoubtedly, these results supplement the morphological descriptions of *P. apodus* from the Kerch population, however, the small number of females in the sample do not allow to evaluate the sex differences adequately.

In a very large *P. apodus* sample from Turkmenistan (225 males and 115 females), the maximum body length was 460 mm for both sexes (Bogdanov 1962). At the same time, in the sample of 28 males and 22 females from the Northern Caucasus, the maximum and average body lengths in females were somewhat higher than in males: 444 mm (373.5 mm in average) and 418 mm (367.1 mm in average) respectively (Siroitchkovsky 1958). This might be related to the reproductive function of females and “the necessity to bear numerous eggs” (Siroitchkovsky 1958, P. 43). On the contrary, other authors indicated larger male sizes (*L.* and/or *TL*) for the Central Asian and Pre-Caucasian populations (Bogdanov 1960; Yakovleva 1964; Skrynnikova 1977), although in all cases there were a few females in the samples, what might affect the reliability of the conclusions. It seems to be correct that *P. a. apodus* males and females have no significant differences in the body length (Yakovleva 1964).

It is known that the body size variability in males and females within the same Squamata species may be complex depending on the geographical location and habitat conditions of a particular population: in one part of the range the larger males can prevail significantly, while in another – the larger females (Cox et al. 2007; Maliuk & Peskov 2011). In regards of the aforementioned data, it can be added that the sizes of *P. a. thracicus* males from two Croatian populations in Cres Island and Split environs varied. Thus, they had larger maximum sizes in both populations, while their average sizes were slightly larger than in females in the first locality, though smaller in the second one (Lovrić 2012).

The relative tail length

Some authors studying sheltopusiks noticed that the mean tail length in males is somewhat bigger than in females at relatively equal maximum indices (Siroitchkovsky 1958; Lovrić 2012). At the Crimea *L./L. cd.* ratio comprised 0.55–0.64 in males and 0.57–0.67 in females (Szczerbak 1966). In Kyrgyzstan *P. apodus* males have 1.52–1.72-fold longer tails as compared to the body, while in females – only 1.36–1.49-fold; hence, there was no overlap in the variability ranges (Yakovleva 1964).

Our results clearly confirm that both maximum and mean tail lengths in males is bigger than in females, although the sex differences on this parameter are not reliable (Table 1). At the same time, no sex differences basing on *L./L. cd.* were found (Table 2), what corroborates the data obtained in 1990's: *L./L.cd.* index value in males comprised 0.63 ± 0.01 (limits are 0.59–0.69; $n = 19$), in females – 0.63 ± 0.02 (limits are 0.57–0.65; $n = 4$) (Yu. Karmyshev, personal communication). It is noteworthy that in the sample collected at the end of 1990's, 36.8% of individuals have the damaged tail – this finding is very close to the recent ones (see above).

The head relative sizes and proportions

According to Yu. Karmyshev, the comparative analysis of both sexes established sexual dimorphism at two indices – “a relative head width” (the definition is not described in details) and “a relative height of intermaxilar shield” (the shield is relatively narrower in females) (Karmyshev 2002). Two indices, (1) the ratio of the maximum head width to the head length from the mouth corner to the snout tip, and (2) the ratio of the head length to the body length, revealed the highly reliable differences (at $P < 0.001$) at the comparison of 24 males and 5 females in the jointed sample from the Mountainous and Plain Crimea (Yu. Karmyshev, personal communication). As far as we know, there are no any other data characterizing head proportions of *P. a. apodus* of both sexes.

In males and females of *P. a. thracicus* from the Northern Adriatic (Cres Island) population the sexual dimorphism has been revealed on the snout width (internostril distance), head length (from the snout tip to the cervical interception) and some others size parameters (Lovrić 2012). Unfortunately, the measurements and ratios used by this researcher distinguish from ours, what excludes the possibility of thorough comparison of two northern populations of different *P. apodus* subspecies.

As it was mentioned above, the observed sex differences in the relative head length of *P. apodus* from the Kerch Peninsula population are not related to the allometric growth specificity in males and females. At the same time, our data suggests that such a specificity defines the sex differences in the ratio between the different head parts and, to some extent, its outlines.

The putative issue of allometric growth specificity has been discussed earlier for the representatives of the sister genus *Anguis* Linnaeus, 1758: “*Slow warms exhibit a distinct sexual dimorphism in body proportions. In equal-sized individuals, always the males have a bigger and wider heads. Relative to the body, their head growth is much more positively allometric than that of the females...*” (Böhme 2006, P. 243). It is noteworthy that the developmental patterns are even more complex for other anguids. Thus, both *Gerrhonotus infernalis* Baird, 1859 and *P. apodus* have significant sex-dependent differences in head size. *G. infernalis* females reveal negative allometric growth pattern for the head length, and isometric growth for the parameters, characterizing head width and height. In turn, males of this lizard show isometric growth for the head length character, while for the head width and height – positive allometric one (García-Bastida et al. 2013).

As it was mentioned above, *P. apodus* males and females have differences in correlations between the body parts. It has to be taken into account that the correlations systems are dependent on the environmental conditions. It is assumed that in other *P. apodus* populations the sex differences might be expressed in similar manner, though the regional peculiarities may not be excluded as well because of some indirect evidence. Thus, in *P. a. thracicus* sample from Cres Island comprising 21 males and 14 females, males showed higher absolute values at the majority of the parameters than females, what indicates the strong expression of sex dimorphism in this population. In turn, in the coastal Croatian sample consisting of 16 males and 11 females sex dimorphism is less pronounced (Lisičić et al. 2012). Hence, it is the issue of a high interest to study *P. apodus* sexual dimorphism in biogeographical aspect.

Among the possible reasons of the head size increase in males of anguid lizards as compared to females, at first, the sexual selection has to be mentioned, what might occur due to male – male combats and mating rituals common among the anguids, while the head elongation and widening are related with the development of strong jaw muscles and the increase of the biting force (Fitch 1989; Böhme 2006; Sos &

Herczeg 2009; Dashevsky et al. 2013; García-Bastida et al. 2013; Sharf & Meiri 2013). The same tendency was registered to other Sauria systematic groups: males with evidently bigger heads might have advantages in aggressive interactions and mating as compared to males with the smaller heads (Kratochvíl & Frynta 2002; Maliuk & Peskov 2011). It has to be noticed in this regards that the brutal and prolonged combats of *P. apodus* males are quite common during the reproductive season (Jablonski, 2018), while males tightly hold the females with the jaws during the copulation (Kukushkin et al. 2013).

Among the other reasons for the sexual dimorphism in head shape and size, the nutritional preferences of males and females can be mentioned. In the diet of this big lizard the invertebrates with the hard integuments prevail: mollusks, big Orthoptera and Coleoptera, fresh-water crabs, etc. (Siroitchkovsky 1958; Szczerbak 1966; Rifai et al. 2005; Tuniyev 2007; own observations). The data on the diet of *P. apodus* representatives of both sexes is still scarce (Çiçek et al. 2014), and, as far as the evidence will be accumulated, the sex differences in the intensity and the nutritional spectrum might be found in future. To strengthen this assumption, the observations that *P. apodus* females have more secretive lifestyle and shorter distance of activity than males have to be mentioned. Probably, some differences in daily activity of *P. apodus* males and females also exist. Altogether, the aforementioned differences might affect the spectrum of lizard feeding.

Taxonomical aspect of morphometric studies

At the conclusive part, the taxonomical aspect of *P. apodus* morphological studies has to be discussed. F.J. Obst (1978) had subdivided sheltopusik on 2 subspecies: a nominative one, widespread mainly in Asiatic part of the species range, and a Balkan's one (*P. a. thracius*), which inhabits South-Eastern Europe and Western Anatolia. Both subspecies were identified on the basis of the geographical pattern of the external morphology characters variability including one morphometric parameter, namely "head length to width ratio". In the original paper it was defined as "...Kopflänge von der Schnauzenspitze bis einschließlich Occipitalschild im Verhältnis zur Kopfbreite in Höhe des hinteren Augenrandes..." ("...the ratio of the head length from the snout tip to the occipital shield to the head width at the level of the posterior eye edge...") (Obst 1978, S. 130), though it is not clear from the context, whether the eye itself or the orbital fossa has been mentioned. The average value of this ratio was 1.93 (variation range is 1.72–2.12; n = 33) in *P. a. thracius*, while in *P. a. apodus* – 2.16 (variation range is 1.88–2.33; n = 38) disregarding the lizard sex.

The *Pil./ Lt. c. or.* ratio used in our work is supposed to be equivalent to "head length to width ratio", which has the diagnostic significance for *P. apodus* subspecies distinguishing. It was mentioned before that sheltopusiks from both Crimean populations are fully corresponding the description of a nominative subspecies by the pholidosis characters, while the coloration specificity and the head ratio mentioned above have intermediate character and is more in accordance with *P. a. thracius* description (Kukushkin & Sviridenko 2005; Kukushkin & Karmyshev 2008). In the sample from the Kerch Peninsula (n = 72), what is the basis for the current research, value of the ratio *Pil./ Lt. c. or.* comprised 1.97 ± 0.01 (limits are 1.75–2.21).

Recently, the division of the species into eastern and western subspecies was confirmed by the molecular and genetics methods (Jandzik et al. 2018). Nevertheless, the morphological differences between the subspecies and population still remain unclear, and the taxonomical revision of *P. apodus* intraspecific systematics on the basis of morphological data is strongly required. Moreover, the sexual dimorphism might be considered as well. At the initial stages of the research, the unification of the *P. apodus* measurement scheme will be rather important because of the incomparability of the published data on species morphology. Furthermore, a geometric morphometry approach can be also helpful at the comparative studies of sexes, populations and/or subspecies of *P. apodus* (Kaliontzopoulou 2011).

Conclusions

No significant sex differences in *P. a. apodus* body and tail sizes were found in the population from the Kerch Peninsula, although the values of the maximum body lengths as well as the maximum and average tail lengths in males were somewhat higher than in females. At the same time, the relative size and shape of the head were considerably different in both sexes. However, it seems impossible to identify correctly the sheltopusik sex basing only at the linear head sizes and/or ratios characterizing the head proportions of both sexes because of the significant overlap of their variability ranges of the morphometric parameters and the

derived ratios. Nevertheless, the use of the canonical discriminant analysis with the complex of absolute values of the morphometric parameters allowed to identify reliably 93% of males and almost 100% of females, while the same analysis using ratios – 95% males and 96% females. Thus, the proposed set of measurements can be used for the sexual dimorphism assessment in *P. apodus* populations.

The observed sex differences in head size and shape might be partially explained by the peculiarities of its growth in general as well as its parts. It is noteworthy that the sex differences in *P. apodus* relative development of *L. c. lr.* and *L. r.* characters (isometric growth in males and allometric – in females) might be partially responsible for an easy distinguishing between males and females in the head outlines. Besides that, the representatives of both sexes show some differences in the correlation systems between the morphometric parameters. However, the obtained results could not be directly extrapolated to other populations, since the absolute and relative size characters are highly dependent on local habitat conditions such as the duration of the activity period, growth rate, nutritional spectrum, etc.

Sex differences of the body coloration are not much pronounced, and are defined mostly by the time of moulting of males and females. The background color of the dorsal body side is recommended to be used only as an extra “field” character for the rapid preliminary sex identification.

In *P. apodus* from the Steppe Crimea the diagnostic character for the subspecies identification, so called “head length-width ratio”, is intermediate between the values known for the nominative subspecies and *P. a. thracius*, according to F.J. Obst (1978). In general, *P. apodus* intraspecific taxonomical revision basing both on recent molecular data and external morphology characters considering sexual dimorphism is highly required. Furthermore, the development of a unified system of measurements is desirable for this purpose.

Acknowledgements

The authors are sincerely thankful to Yuri Karmyshev (Melitopol, Ukraine), who collected data on *P. apodus* morphology from the Kerch population in 1990s, which we have used for the comparative analysis. Andrey Tupikov (Kharkiv, Ukraine), Pavel Moroz, Aleksandr Yaryhin, Yevgen Pysanets, Olga Manuilova, Yuliya Krasylenko (Kyiv, Ukraine), Ivan Blokhin (Moscow, Russia), Natalia Litvinyuk (Kazantip Nature Reserve, Schelkino, Crimea), Roman Zimmukhov (Karalarsky Regional Landscape Park, Bagerovo, Crimea), Vladimir Pletyuk and Vera Gasymova (Opuk Nature Reserve, Yakovenkovo, Crimea) are highly appreciated for their kind help during the field observations and collections at protected territories of the Kerch Peninsula during 2010–2014. Some animal's photos were prepared by Andrey Tupikov, Aleksandr Yaryhin, Larisa Znamenskaya and Mikhail Beskaravaynyi (Karadag Nature Reserve, Theodosia, Crimea) in 2003–2012. Ilya Turbanov (I.D. Papanin Institute for Biology of Inland Waters of Russian Academy of Sciences, Borok, Russia) substantially assisted in the preparation of illustrations. We highly appreciate scientific illustrator Kateřina Janošíkova (Centre for Science Communication, Palacký University in Olomouc, Olomouc, Czech Republic) for the graphical drawings of *P. apodus* from the Crimea. Igor Doronin (Department of Herpetology, Zoological Institute of Russian Academy of Sciences, Saint Petersburg, Russia) proofread the draft of manuscript and provided some valuable references.

O.V. Kukushkin has been partially working within the framework of the research topic AAAA-A17-117030310017-8 at the Zoological Institute of Russian Academy of Sciences. I.V. Dovgal worked within the framework of the research topic #AAA-A18-118020890074-2.

Our paper is dedicated to Yuri Karmyshev (November 25, 1963 – March 25, 2017) – the Ukrainian herpetologist, who input significantly into the research of the Crimean reptiles.

References

- Bogdanov, O.P. (1960) Fauna of Uzbekskaya SSR, 1. *Amphibians and reptiles*. Tashkent: Publishing house of Academy of Sciences of Uzbekskaya SSR, 259 pp. (in Russian).
- Bogdanov, O.P. (1962) *Reptiles of Turkmenia*. Ashkhabad: Publishing house of Academy of Sciences of Turkmenkaya SSR, 232 pp. (in Russian).
- Bogdanov, O.P. (1965) *Ecology of reptiles of Middle Asia*. Tashkent: Publishing house “Nauka” of Uzbekskaya SSR, 260 pp. (in Russian).

- Böhme, W. (2006) Notes on the combat behaviour of male slow worms, *Anguis fragilis*. *Zeitschrift für Feldherpetologie*, 13(2), 117–118.
- Çiçek, K., Tok, C.V., Hayretdağ, S. & Ayaz, D. (2014) Data on the Food Composition of European Glass Lizard, *Pseudopus apodus* (Pallas, 1775) (Squamata: Anguidae) from Çanakkale (Western Anatolia, Turkey). *Acta zoologica bulgarica*, 66(3), 433–436.
- Cox, R.M., Kelly, S.L. & John-Alder, H.B. (2003) A comparative test of adaptive hypotheses for sexual size dimorphism in lizards. *Evolution*, 57(7), 1653–1669.
- Cox, R.M., Butler, M.A. & John-Alder, H.B. (2007) The evolution of size dimorphism in reptiles. Chapter 4. In: Fairbairn, D.J., Blanckenhorn, W.U. & Székely T. (Eds.). *Sex, Size and Gender Roles: Evolutionary Studies of Sexual Size Dimorphism*. Oxford University Press, pp. 38–49.
- Dashevsky, D., Meik, J.M., Mociño-Deloya, E., Setser, K. & Schaak, S. (2013) Patterns of sexual dimorphism in Mexican alligator lizards, *Barisia imbricata*. *Ecology and Evolution*, 3(2), 255–261.
- Fitch, H.S. (1989) A field study of the Slender Glass Lizard, *Ophisaurus attenuatus*, in Northeastern Kansas. *Occasional papers of the Museum of Natural History the University of Kansas Lawrence*, 125, 1–50.
- García-Bastida, M., Lazcano, D., McBrayer, L.D. & Mercado-Hernández, R. (2013) Sexual dimorphism in the alligator lizard *Gerrhonotus infernalis* (Sauria: Anguidae): Implications for sexual selection. *The Southwestern Naturalist*, 58(2), 202–208.
- Hammer Ø., Harper D. A. T., Ryan P. D. (2001) PAST: Paleontological statistics software package for education and data analysis. *Palaeontologica Electronica*, 4(1), 1–9.
- Jablonski, D. (2006) *Pseudopus apodus* (Pallas, 1775) v prírode a v teráriu. *Fauna*, 17(4), 14–17. (in Slovakian).
- Jablonski, D. (2018) Male-male combat in *Pseudopus apodus* (Reptilia: Anguidae). *Russian Journal of Herpetology*. – In press.
- Jandzik, D., Jablonski, D., Zinenko, O., Kukushkin, O.V., Moravec, J. & Gvoždíc, V. (2018) Pleistocene extinctions and recent expansions in an anguid lizard of the genus *Pseudopus*. *Zoologica Scripta*, 47, 21–32.
- Karmishev, Yu.V. (2002) Reptiles of the south of Steppe zone of Ukraine (distribution, variability, systematics, and peculiarities of biology). *Synopsis of PhD thesis*. Kyiv, 17 pp. (in Ukrainian).
- Kotenko, T.I. & Kukushkin, O.V. (2010) Annotated lists of amphibians and reptiles of the Crimean nature reserves. *Scientific Notes of the “Cape Martyan” Nature Reserve*, 1, 225–261 (in Russian).
- Kratochvíl, L. & Frynta, D. (2002) Body size, male combat and the evolution of sexual dimorphism in eublepharid geckos (Squamata: Eublepharidae). *Biological Journal of the Linnean Society*, 76, 303–314.
- Kukushkin, O.V. (2006) Materials to the study of herpetofauna of the Cape Kazantip. *Biodiversity of Nature Reserves of Kerch Peninsula: Collection of scientific papers*, 126. Yalta: State Nikita Botanical garden, 234–246 (in Russian).
- Kukushkin, O.V. (2015) Giant legless lizard *Pseudopus apodus* (Pallas, 1775). In: Ivanov, S.P., Fateryga, A.V. (Eds.). *Red Data Book of the Republic of the Crimea*. Simferopol: Publishing and printing house “Aryal”, pp. 291 (in Russian).
- Kukushkin, O.V. & Karmyshev, Yu.V. (2008) The notes on interpopulation variability and taxonomy of the armoured glass lizard, *Pseudopus apodus* (Pallas, 1775) (Reptilia: Sauria: Anguidae), from the Crimea. In: *Alive objects in conditions of anthropogenic press (Proceedings of scientific-practical ecological conference, Belgorod, 15–18 September 2008)*. Belgorod: “POLYTERRA”, pp. 107–108.
- Kukushkin, O.V., Karmyshev, Yu.V., Yaryhin, A.N. & Sharygin, S.A. (2013) A state of the knowledge about reproductive biology of giant legless lizard (Reptilia, Sauria, Anguidae) in the Crimea. *Bulletin Samarskaya Luka: Problems of regional and global ecology*, 22 (2), 114–125 (in Russian).
- Kukushkin, O.V. & Sviridenko, E.Yu. (2005) About morphological variability of sheltopusik (Reptilia, Sauria, Anguidae) in the Crimea. In: *Current problems of ecology and zoology (Proceedings of International scientific memorial conference, Odessa, 22–25 April 2005)*. Odessa: Phoenix, pp. 142–145 (in Russian).
- Kukushkin, O.V. & Yaryhin, A.N. (2013) Reproductive biology of sheltopusik (Reptilia, Sauria, Anguidae) at the northern limit of its range in the Crimea: first results and challenges in the study. In: *Biological diversity of the Caucasus and South of Russia (Proceedings of 15th International Scientific Conference, Makhachkala, 5–6 November 2013)*. Makhachkala: Printing house of Institute of Applied Ecology of Republic of Dagestan, 2013, pp. 151–153 (in Russian).

- Lakin, G.F. (1990) *Biometry. Fourth edition, revised*. Moscow: “Vysshaya shkola”, 352 pp. (in Russian).
- Lisičić, D., Lovrić, V., Počanić, P., Derežanin, L. & Tadić, Z. (2012) Biometrical character displacement in populations of *Pseudopus apodus* from the island of Cres and vicinity of Split. In: *11th Croatian Biological Congress with International Participation (Proceedings of Abstracts, Šibenik, 16–21 September 2012)*. Zagreb: Croatian Biological Society, 2012, pp. 89.
- Lovrić V. (2012) Biometrijske značajke blavora (*Pseudopus apodus*, Pallas 1775) na području Splita i otoka Cresa. *Diplomski rad (Sveučilište u Zagrebu, Prirodoslovno-matematički fakultet)*. Zagreb, 75 pp. (in Croatian).
- Maliuk, A.Yu. & Peskov, V.N. (2011) Sex differences in linear size and body proportions of sand (*Lacerta agilis*) and green (*Lacerta viridis*) lizards (Squamata, Lacertidae). *Zbirnyk praz' Zoologichnogo museyuu (Kyiv)*, 42, 100–111. (in Russian)
- Obst, F.J. (1978) Zur geographischen Variabilität des Scheltopusik, *Ophisaurus apodus* (Pallas) (Reptilia, Squamata, Anguinae). *Zoologische Abhandlungen Staatliches Museum für Tierkunde in Dresden*. 35(8), 129–140.
- Obst, F.J. (1981) *Ophisaurus apodus* (Pallas, 1775) – Scheltopusik, Panzerschleiche. In: Böhme, W. (Ed.). *Handbuch der Reptilien und Amphibien Europas, 1. Echsen (Sauria) I*. Wiesbaden: Akademische Verlagsgesellschaft, pp. 259–274.
- Rifai, L., Abu Baker, M., Al Shafei, D., Disi, A., Manashen, A. & Amr, Z. (2005) *Pseudopus apodus* (Pallas, 1775) from Jordan, with notes on its ecology. *Herpetozoa*, 18 (3/4), 133–140.
- Scharf, I. & Meiri, S. (2013) Sexual dimorphism of heads and abdomens: Different approaches to “being large” in female and male lizards. *Biological Journal of the Linnean Society*, 110, 665–673.
- Sindaco, R. & Jeremchenko, V.K. (2008) *Reptiles of the Western Palearctic*. Latina: Editioni Belvedere, 579 pp.
- Siroitchkovsky, E.E. (1958) Materials on the biology of *Ophisaurus apodus* Pall. *Bulletin of the Moscow Society of Naturalists (MOIP), branch Biology*, 63(4), 43–48 (in Russian).
- Shebanin, V.S., Melnik, S.I., Kramarenko, S.S. & Ganganov, V.M. (2008) *Analysis of structure of populations*. Mykolaiv: Mykolaiv State Agrarian University, 240 pp. (in Ukrainian).
- Skrynnikova, L.N. (1977) To the issue of biology of the sheltopusik. *Fauna of Stavropol Region: Collection of scientific papers, 2*. Stavropol: Stavropol Pedagogical Institute, pp. 69–70 (in Russian).
- Sos, T. & Herczeg, G. (2009) Sexual size dimorphism in Eastern slow-worm (*Anguis fragilis colchica*, Reptilia: Anguinae). *Russian Journal of Herpetology*, 16(4), 304–310.
- Sos, T. (2011) Spot polymorphism in *Anguis colchica* Nordmann, 1840 (Reptilia: Anguinae): inter-size class variation. *North-Western Journal of Zoology*, 7(1), 171–175.
- Szczerbak, N.N. (1966) *Amphibians and reptiles of the Crimea (= Herpetologia Taurica)*. Kiev: Naukova dumka, 240 pp. (in Russian).
- Szczerbak, N.N. & Tertyshnikov, M.F. (1989) About systematic position of the sheltopusik (*Ophisaurus apodus*) from the territory of USSR. *Vestnik zoologii*, 5, 35–37. (in Russian)
- Tuniyev, B.S. & Tuniyev, S.B. (2007) Thracian (western) giant glass lizard, *Pseudopus apodus thracicus* (Obst, 1978). In: Zamotayilov, A.S. (Ed.). *Red Data Book of Krasnodarsky Krai (animals)*. Krasnodar: Centre for the Development of Press, Television and Radio of Krasnodarsky Krai, pp. 338–339 (in Russian).
- Wiens, J.J. & Slingluff, J.L. (2001) How lizards turn into snakes: a phylogenetic analysis of body-form evolution in anguid lizards. *Evolution*, 55(11), 2303–2318.
- Yakovleva, I.D. (1964) *Reptiles of Kirgizia*. Frunze: Ilim, 270 pp. (in Russian).