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Morphological and reproductive traits of the insular population of *Podarcis siculus* (REPTILIA: LACERTIDAE) from Krk Island (Croatia)

Morfološke i reproduktivne karakteristike otočne populacije *Podarcis siculus* (REPTILIA: LACERTIDAE) sa otoka Krka (Hrvatska)

MARTINA RADOČAJ[1], DUŠAN JELIĆ[2], DEAN KARAICA[1], SVEN KAPELJ[1]

[1] Croatian Herpetological Society HYLA, Radučka 15, 10000 Zagreb, Croatia

[2] State Institute for Nature Protection, Trg Mažuranića 5, 10000 Zagreb, Croatia

Corresponding author: DUŠAN JELIĆ**,** State Institute for Nature protection**,** Trg Mažuranića 5, 10000 Zagreb, Croatia**,** dusan.jelic@dzzp.hr

SUMMARY:

Today, lizards of the genus *Podarcis* are one of the most important representatives of Mediterranean herpetofauna, primarily because of their great variability in islands. We studied a population of *Podarcis siculus* (REPTILIA: LACERTIDAE) from Krk Island (Northern Adriatic) and compared the results to other lacertid species of the Mediterranean Basin. The study was carried out using live lizards that were maintained in terrariums under natural conditions of light and temperature, where they produced egg clutches which were incubated until hatching. The eggs were incubated for average of 31 days and hatching took place from late July to mid of August. The average adult female body size (SVL) was 61,88 mm. Out of 10 females, 9 produced egg clutches with average of 5.3 and the maximum of 7 eggs. The knowledge of reproductive potentials and life traits of this species is significant for further monitoring plans of this invasive species in these areas.

Key words: reproductive characteristics, Krk Island, *Podarcis siculus*

SAŽETAK:

Gušteri roda *Podarcis* su danas jedni od najvažnijih predstavnika mediteranske herpetofaune, prvenstveno zbog velike varijabilnosti na otocima. Proučavali smo populaciju *Podarcis siculus* (REPTILIA: LACERTIDAE) s područja otoka Krka (sjeverni Jadran), te usporedili dobivene rezultate sa ostalim vrstama lacertidnih gušterica na Mediteranu. Istraživanje je provedeno na živim gušterima koji su držani u terarijima pod prirodnim uvjetima svijetla i temperature, gdje su polegli jaja koja su inkubirana do izlijeganja. Jaja su inkubirana prosječno 31 dan, te se izlijeganje odvijalo od kraja srpnja do sredine kolovoza. Prosječna veličina tijela ženke (SVL) iznosila je 61,88 mm. Od ukupno 10 ženki, 9 je poleglo jaja, s prosjekom od 5,3 jaja, a najviše 7 jaja u leglu. Znanje o reproduktivnom potencijalu i životnim navikama ove vrste je bitno radi daljnjih planova monitoringa populacija ove invazivne vrste na navedenom području.

Ključne riječi: reproduktivne karakteristike, otok Krk, *Podarcis siculus*

INTRODUCTION

Today, lizards of the genus *Podarcis* are one of the most important representatives of Mediterranean herpetofauna, primarily because of their great variability on islands, and are the most dominant genus of reptiles in southern Europe (PODNAR LEŠIĆ, 2005). The genus is distributed in Northern Europe reaching up to the Southern part of the Netherlands, Rhine Valley, Czech Republic, Slovakia, Hungary, Romania and Crimea. Also, the genus appears in northwest Africa (Morocco, north Algeria, Tunisia), northwest Asiatic Turkey and islands in the Mediterranean Sea eastward to the Cyclades (ARNOLD, ET AL., 2007). There are 21 species in total in the genus today, and some are endemic to the Mediterranean islands (UETZ ET AL., 2011).

As an autochthon species, the Italian Wall Lizard (*Podarcis siculus,* Rafinesque-Schmaltz, 1810) inhabits the Apennine Peninsula, as well as a large number of islands and islets in the Tyrrhenian and Adriatic Sea and spreads along the Adriatic coast in Croatia. It is primarily insectivorous, heliothermic, widely foraging, oviparous lizard, polygynous and highly territorial, with SVL (snout-vent length) up to 9 cm. It is first active during March, in higher temperatures (16 ºC - 18ºC), but it can be seen also in January or February during warm days. It dominates in competition with autochthonous species and reduces their distribution area by competitive exclusion (BÖHME, 1986, DOWNES AND BAUWENS, 2002A). Up to now there were few studies dealing with reproductive characteristics of *P. siculus* (HENLE, 1988; CAPULA ET AL., 1993, DOWNES AND BAUWENS, 2002A, DOWNES AND BAUWENS, 2002B).

A species life-history is characterized by variables such as age and size at maturity, frequency of reproduction, clutch size, and egg and hatchling size. These variables profoundly affect the species fecundity and survival (BAUWENS, 1999). The relationships between the female body-size, clutch size, egg dimensions, hatchling size and mass can add to our knowledge of reproductive potential and life habits of species. Island populations of lizards have fewer terrestrial predators, therefore attain high densities but face high intraspecific competition and low food availability. Therefore, to insure better survival, island populations have shown to produce few clutches with larger eggs (CARRETERO, 2006). Our aim was to determine the morphological and reproductive characteristics of *Podarcis siculus* population from Krk Island. These data could be the base for further analyses of the variation in morphological and reproductive characteristics of the Italian Wall Lizard.

MATERIALS AND METHODS

STUDY AREA – The study was conducted on a population of *Podarcis siculus* at the beginning of June 2010 (17 males and 9 gravid females), taken from two localities on Krk Island: Punat (X - 5471691, Y - 4986202, elevation of 50 m, 5 males and 3 females) and Ponikve lake (X - 5466810, Y - 4992182, elevation of 20 m, 12 males and 6 females). Krk Island belongs to a group of islands in Kvarner area in the Northern part of Croatian coast, with the Mediterranean sub-tropic climate type (RIĐANOVIĆ, ET. AL., 1975.). The average temperature measured on the nearest meteorological station (Rijeka city) was 13,98 °C (January 5,7°C, July 23,3 °C). Average precipitation was 116, 03 mm (November 183,3 mm, July 77, 8 mm).

MORPHOLOGY AND SEXUAL DIMORPHISM—For all specimens (17 males, 9 females), we recorded the following morphological variables to the nearest 0.1 mm (Powerfix ELECTRONIC DIGITAL CALIPER): snout-vent length (SVL); tail length (TL); head length (HL; distance from the anterior edge of the ear aperture to the tip of the snout) and head width (HW; horizontal line joining the anterior edge of each ear aperture). Weight was measured to the nearest 0,01 g with DW-100 AS digital balance. These measurements were used to calculate two other measures of head morphology relative to body size: HL/SVL and HW/SVL.

REPRODUCTION - Females (N =9) with oviductal eggs present (determined by ventral palpitation) were moved to individual terrariums on June 6th 2010. All females were kept under the same conditions. Natural and artificial light was provided throughout 12 hours per day, with food (fly larvae) and water available *ad libidum*. Following oviposition, the females were measured (snout-vent length, SVL), weighed and autopsied for determination of the presence of enlarged vitellogenic follicules. The previously marked eggs were carefully dug up after oviposition, measured (length, width and weight, and moved to a plastic box used for incubation). The eggs were incubated at a temperature of 28 ºC, and 70%-80% humidity, which were controlled daily. The unfertilized eggs, which were lighter (0,25 ± 0,15 g) and haven't showed signs of the fetus under a light source, were separated from the fertilized ones after oviposition.

EGG MEASUREMENTS – Egg volume (*V)* and surface area (*S)* were calculated through width (*L)* and length (*B)* of the egg. These parameters help estimate possible population size,

morphology, offspring mass and hatching ability, and egg shell characteristics (NARUSHIN, 2005). We used the formulas $V = (0{,}6057 - 0{,}0018B)\ LB^2$, $S = (0{,}9658\ B/L + 2{,}1378)\ LB$ (k_V=0,525 and k_S=2,864) from NARUSHIN (2005) to calculate egg volume and surface area, respectively, assuming that the geometry of lizard egg is more similar to a bird egg, than that of a ellipsoid body. In contrast, in the work of authors like LJUBISAVLJEVIĆ, ET. AL. (2010A), CASTILLA AND BAUWENS (2000A), LJUBISAVLJEVIĆ, ET. AL. (2007) and LJUBISAVLJEVIĆ, ET. AL. (2008), the values of egg volumes were obtained by approximating the volume of the ellipsoid: $V=4/3\pi\ a2b$, with a and b being half of the width and length of the egg, respectively. The clutch mass was calculated as the total egg mass in a clutch. Each clutch was in all cases assigned to an individual female, allowing us to calculate the relative clutch mass (RCM) as the ratio of clutch mass to post-oviposition body mass. The offspring were measured after hatching (mass and SVL). The research was conducted under approval of the Ministry of culture, Board for environmental protection (KLASA: UP/I-612-07/10-33/0662, URBROJ: 532-08-01-01/1-10-02).

STATISTICS – Standard descriptive statistics was used (mean, standard error, range, minimum and maximum) for all values. Throughout this study, values were presented as mean ± SE. In presenting some of the graphic results, we used log-transformed values, to ensure data normality and to generate homogeneous variances. All data were tested with Shapiro-Wilk W test of normality (SHAPIRO AND WILK, 1965), and showed no abnormality ($p \leq 0{,}05$). Linear correlations were used to study the inter relationships among various reproductive traits. For statistical analyses we used the program PAST ver. 2.06 (HAMMER, ET. AL., 2001).

RESULTS

MORPHOLOGY AND SEXUAL DIMORPHISM- The specimens examined comprised 17 adult males and 9 adult females (Table 1). The largest male we recorded was 75,4 mm and female 70,0 mm SVL. Males had greater snout-vent length, head width and head length compared to females (Table 1, Figure 1).

Table 1. Summary of sexual dimorphism in morphological traits in *P. siculus* from Krk Island. Measures are shown in millimeters. HL (head length), HW (head width) and TL (tail length) are presented as a proportion of snout-vent length (SVL)

Tablica 1. Kratak pregled spolnog dimorfizma u morfološkim značajkama *P. siculus* saotokaKrka. Mjere su prikazane u milimetrima. HL (duljina glave), HW (širina glave) i TL (duljina repa) su prikazane kao proporcije duljine tijela (SVL).

		Female			Male	
Trait	N	Mean ± SE	Range	N	Mean ± SE	Range
SVL	9	61,88 ± 2,07	53,3 - 70,0	17	67,44 ± 1,49	55,3 - 75,4
TL	9	91,74 ± 9,85	40,0 - 124,0	17	127,8 ± 2,98	99,8 - 150,3
HL	9	14,42 ± 0,31	13,2 - 15,7	17	17,87 ± 0,38	15,0 - 20,0
HW	9	8,68 ± 0,21	7,9 - 9,5	17	11,19 ± 0,24	9,3 - 12,4
HL/SVL	9	0,234 ± 0,003	0,218 - 0,248	17	0,265 ± 0,002	0,255 - 0,273
HW/SVL	9	0,142 ± 0,002	0,133 - 0,150	17	0,166 ± 0,002	0,150 - 0,182

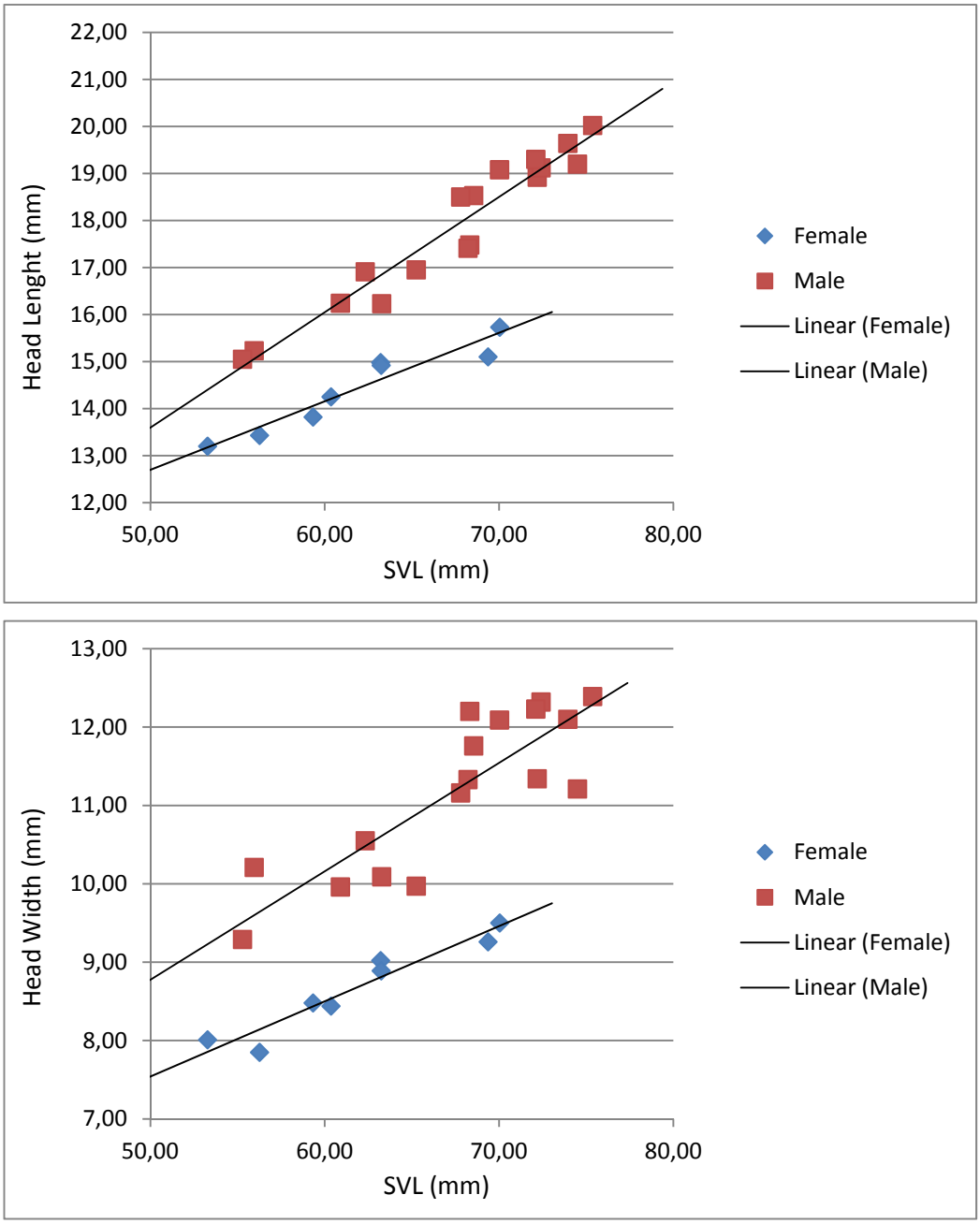

Figure 1. Sexual dimorphism in body proportions of the Italian Wall Lizard, *P. siculus*, based on the measurement of specimens from Krk Island. At the same snout–vent length (SVL), males have both broader (A) and longer heads (B).

Slika 1. Spolnidimorfizamkoddimenzijatjelesnihproporcijaprimorskegušterice, *P. siculus*, dobiven na temelju mjera primjeraka s otokaKrka. Na jednaku duljinu tijela (SVL), mužjaci imaju šire (A) i duže (B) dimenzije glave.

FEMALE AND CLUTCH CHARACTERISTICS – Out of 10 collected females, nine laid eggs. We assume that the last gravid female was not gravid or miscarried due to shock. The

mean value of female SVL was 61,88 ± 0,76 mm. The female, clutch and egg characteristics are shown in Table 2. In Table 3. we present the egg characteristics of hatched eggs only.

Table 2. Female, egg and clutch characteristics of *P. siculus*

Tablica 2. Značajke ženki, jaja i legala *P. siculus*

Measurement	Mean value ± SE	Range	N
Female SVL (mm)	61,88 ± 2,07	53,3 - 70,00	8
Clutch size	5,37 ± 0,26	3 -7	9
Female mass after oviposition (g)	5,22 ± 0,16	3,95 - 7,03	9
Clutch mass (g)	1,91 ± 0,11	0,46 - 2,79	9
Relative clutch mass (RCM) (g)	0,35 ± 0,03	0,10 - 0,71	9
Egg mass (g) – after ovipos.	0,36 ± 0,02	0,13 - 0,54	43
Egg length (mm) – after ovipos.	12,52 ± 0,14	10,52 - 14,95	43
Egg width (mm) – after ovipos.	7,68 ± 0,17	3,91 - 9,08	43
Egg volume (mm^3) – after ovipos.	448,91 ± 19,91 637,82 ±150,95	108,82 - 653,97 289,28 – 910,01	43

Table 3. Mass and volume values of *P. siculus.* Here only characteristics of hatched eggs were used.

Tablica 3. Vrijednosti težine i volumena*P. siculus.* Korištene su značajke samo izleglih jaja.

Measurement	Mean value ± SE	Range	N
Egg mass (g) – after ovipos.	0,44 ± 0,06	0,34 - 0,54	26
Egg length (mm) – after ovipos.	12,85 ± 0,77	11,75 - 14,25	26
Egg width (mm) – after ovipos.	8,15 ± 0,67	5,34 – 8,91	26
Egg volume (mm^3) – after ovipos.	499,8 ± 83,87 696.41 ± 100,60	235,08 - 653,97 500,17 ± 910,01	26

The number of eggs in a clutch varied from 3 – 7 (mean value = 5.37). Three clutches with three eggs, three clutches with seven eggs, two clutches with four eggs and one clutch with five eggs were recorded. The average relative clutch mass value was 0,35 ± 0,19 RCM.

In Table 4.we present compared volume values calculated by the two different formulas of all eggs that produced offspring (26).

Table 4. Comparison of volume values of hatched eggs (N = 26) obtained by two different formulas

Tablica 4. Usporedba vrijednosti volumena izleglih jaja (N = 26) dobivenih s dvije različite formule

Date of measurement	Volume V, cm^3 (Narushin, 2005)	Volume V, cm^3 (ellipsoid body)	N eggs
01.07.2010.	0,499±0,083	0,696±0,1	26
09.07.2010.	1,003±0,225	1,267±0,307	23
18.07.2010.	1,299±0,312	1,662±0,441	23
20.07.2010.	1,284±0,284	1,668±0,452	23

The values of volumes obtained through the formula for ellipsoid body have showed to be 20% – 30% higher than the volume values obtained through the formulas from the work of NARUSHIN (2005).

EGG CHARACTERISTICS – In all eggs laid, the volume increased due to egg shell permeability up to 750,68 ± 2,49 mm^3during the average incubation period (31 days, 28 - 35 days). The increase in egg surface area was 238,45 ± 1,96 mm^2. The volume increase per day was estimated at23,12 ± 0,96 mm^3, while the egg mass increase was 0,0224 ± 0,0087 g per day. Increase in egg length from the first to the last measurement was 3,81 mm, egg width 3,63 mm and mass 0,79 g (Table 5). 23 juveniles managed to hatch, two of which were still-born (probably suffocated).

Average egg mass after oviposition was 0,36 ± 0,14 g ranging from minimum of 0,13 g to maximum of 0,54 g and interestingly none of the eggs lighter than 0,30 g managed to hatch (Figure 2.). Most of these eggs were discarded as unfertilized because they were yellowish in color and compact inside, opposite to white and liquid in healthy eggs.

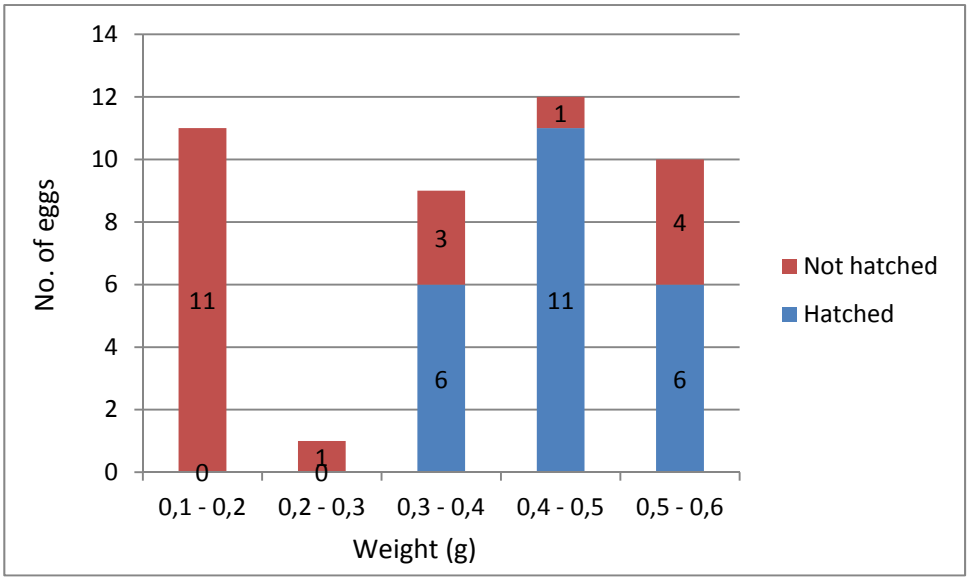

Figure 2. Number of hatched eggs according to their weight

Graf 2. Broj izleglih jaja spram težine jaja

The average time from oviposition to hatching was 41 days (35-44 days). Table 5. and Figure 3. shows how values of egg characteristics increased during the incubation period.

Table 5. Results of egg characteristics of *P. siculus* from first to last measurement (mean value ± SE)

Tablica 5. Vrijednosti značajki jaja *P. siculus* od prvog do zadnjeg mjerenja (srednjavrijednost± SD)

	After oviposition	Last measurement
Surface area (mm^2)	264,40 ± 8,05	521,98 ± 17,44
Volume (mm^3)	448,91 ± 19,91	1246,54 ± 60,03
Length (mm)	12,52 ± 0,14	16,33 ± 0,34
Width (mm)	7,68 ± 0,17	11,31 ± 0,18
Weight (g)	0,36 ± 0,02	1,15 ± 0,06

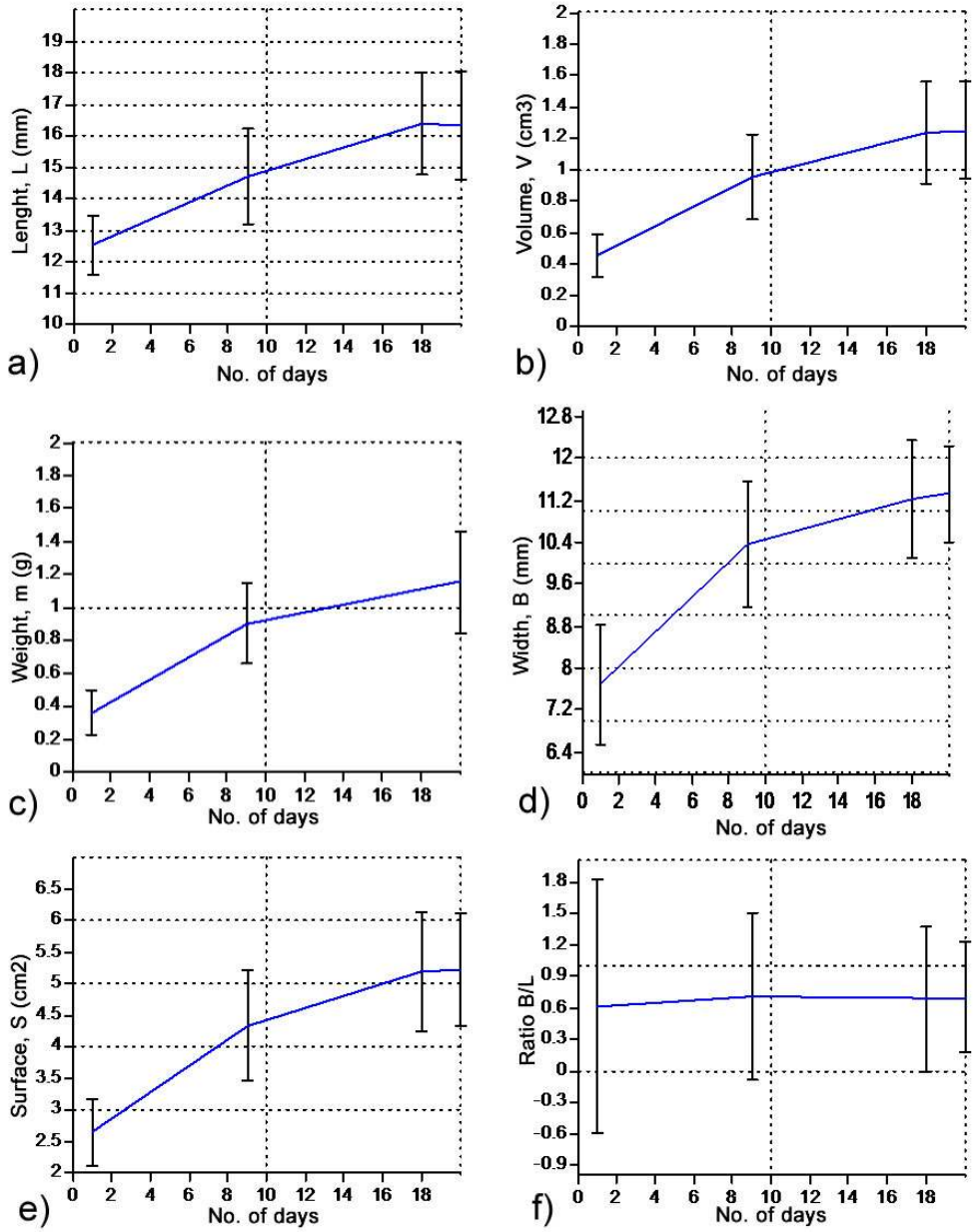

Figure 3. Average egg characteristic values during the incubation period: a) egg length L (mm), b) egg volume V (cm^3), c)egg weight m (g), d) egg width B (mm), e)egg surface S (cm^2), f) ratio between egg width (B) and length (L).

Slika 3. Srednje vrijednosti značajki jaja za vrijeme perioda inkubacije: a) duljina jaja L (mm), b) volume jaja V (cm^3), c) težina jaja m (g), d) širina jaja B (mm), e) površina jaja S (cm^2), f) omjer širine (B) i duljine (L) jaja.

REPRODUCTIVE RELATIONSHIPS – Egg mass and female mass had no statistically significant correlation($r = 0,11168$, $p = 0,61192$), probably due to small specimen count.

The relationship between offspring mass and female mass did not show significant correlation (r = -0,053, p = 0,807), same as the relationship between female SVL and clutch size(r = -0,046, p = 0,777). Clutch size and female mass also showed the same result (r = -0,088, p = 0,573). Data scattering from the regression line was quite strong in all three analyses and showed a lot of deviations. The females mostly laid larger eggs, but a few deviated from that rule. Furthermore, we compared the clutch, egg and female size of *P. siculus* from this study to some other Lacertid species (Table 6) described in the literature.

Table 6. Comparison of egg, clutch and female size of other Lacertid species and *P. siculus* (mean value ± SE)

Tablica 6. Usporedba veličine ženki, jaja i legla *P. siculus* s ostalim vrstama porodice Lacertidae (srednja vrijednost± SD)

Species	Female SVL (mm)	Female mass after oviposition(g)	Egg mass (g)	Egg length (mm)	Egg width (mm)	Egg volume (mm^3)	References
Genus *Podarcis*							
P. siculus	63,24 ± 0,78	5,36 ± 1,03	0,36 ± 0,14	12,52 ± 0,94	7,68 ± 0,06	448,91 ± 2,21	This study
P. siculus	/	/	0,40 ± 0,05	11,3 ± 0,7	7,8 ± 0,3	/	IN DEN BOSCH &BOUT, 1998
P. atrata	63,0 ± 0,3	/	0,37 ± 0,01	12,4 ± 0,1	7,3 ± 0,1	/	CASTILLA AND BAUWENS, 2000A
P. lilfordi	61,9	/	0,63 ± 0,01	14,4 ± 0,01	8,8 ± 0,1	/	CASTILLA AND BAUWENS, 2000B
P. bocagei	55,40 ± 0,66	/	0,26 ± 0,01	/	/	236,3 ± 4,87	GALAN, 1997
P. melisellensis	62,91 ± 2,52	/	/	/	/	257,02 ± 23,78	BEJAKOVIC , ET AL.. 1996
P. muralis	/	/	0.204 ± 0.004	10.77 ± 0.16	6.20 ± 0.06	218.53 ± 6.20	ALEKSIĆ&LJUBISAVLJEVIĆ, 2001
P. taurica	52,71 ± 0,71	2,85 ± 0,109	0,424 ± 0,02	14,01 ± 0,31	7,41 ± 0,08	406,08 ± 15,70	LJUBISAVLJEVIĆ, ET AL., 2010A
Genus *Iberolacerta*							
I. monticola	67,28 ± 0,53	4,92 ± 0,09	0,417 ± 0,01	12,62 ± 0,09	7,83 ± 0,06	407,62 ± 7,36	RUA&GALAN, 2003
Genus *Lacerta*							
L. agilis	85,05 ± 1,074	/	0,59 ± 0,03	/	/	453,4 ± 16,6	AMAT, et al., 2000
Genus *Dalmatolacerta*							
D. oxycephala	62,90 ± 0,25	4,132 ± 0,08	0,25 ± 0,007	12,26 ± 0,11	6,25 ± 0,06	256,80 ± 5,95	BEJAKOVIC , ET AL.. 1995
Genus *Dinarolacerta*							
D. mosorensis	63,76 ± 0,82	/	0,53 ± 0,03	16,28 ± 0,23	7,98 ± 0,11	/	LJUBISAVLJEVIĆ, ET AL., 2007
Genus *Darevskia*							
D. praticola	54,74 ± 0,60	/	0,26 ± 0,008	10,67 ± 0,17	6,61 ± 0,07	/	LJUBISAVLJEVIĆ, ET AL., 2008

DISCUSSION

COMPARISON WITH OTHER SPECIES – Table 6. presents the results of research conducted on other species of the family Lacertidae, and the comparison with results obtained in this study. Inside the *Podarcis* genus, egg mass of *P. siculus* from this study proved to be somewhat less than the egg mass of other species in the genus, and a significant difference is observed in *P. muralis* (egg mass is almost half the egg mass of *P. siculus*) and *P. lilfordi* (egg mass twice the mass of *P. siculus*). The length and width values of the eggs were approximately equal for almost all listed species of *Podarcis* genus, except in *P. muralis*, where the values were slightly lower. The egg volume of *P. siculus* from this study was significantly greater than egg volume of *P. bocagei, P. melisellensis and P. muralis*. The egg mass, width and length of *P. siculus* from this study did not differ from those of *P. siculus* published in the paper by IN DEN BOSCH AND BOUT (1998).

In comparison with other genera, *P. siculus* egg mass from this study proved to be somewhat less than the egg mass of other species, and a significant difference is observed in species *D. praticola* and *D. oxycephala* (almost half the egg mass of *P. siculus*). The length and width values of the eggs were approximately equal for all listed species, with the exception of a slightly higher egg length in *D. mosorensis*. The egg volume of *P. siculus* was almost equal to the egg volume of *L. agilis*, and significantly greater than egg volume of *D. oxycephala*.

MORPHOLOGY AND SEXUAL DIMORPHISM – Sexual dimorphism in head size has been reported in many lizard species (HERREL ET AL., 2007, LJUBISAVLJEVIĆ ET AL., 2010B, LJUBISAVLJEVIĆ, ET AL., 2011), presumably because of an advantage of large head size in male-male competition and fights. *Podarcis siculus* is an aggressive and territorial species and male combats are usual (EDSMAN, 1989). Thus, male head size may be important in male-male competition and could be subject to sexual selection. As expected, our results show the same trend.

REPRODUCTIVE RELATIONSHIPS AND STRATEGIES – The amount of reproductive energy can be distributed in such a way that either a few clutches with a small amount of larger eggs are deposited seasonally (island species), or one clutch containing a larger amount of smaller eggs, and consequently smaller hatchlings (continental species) (BAUWENS, 1999, CARRETERO, 2006). There was no significant correlation between clutch size, female mass and SVL. The females of the observed population in this study have not showed the tendency in increasing egg size like the smaller species of the genus do, nor an increase in clutch size,

like the larger species of the genus do (CASTILLA AND BAUWENS, 2000B). It is possible that females of the studied population with both smaller and larger body size produce the same amount of eggs. The reasons for such a result could be the following: the female population specimen was too low for a more accurate result, or due to long alcohol conservation of the lizards, the measurements could have been inaccurate. On the other hand, this strategy varies from populations and species, so it could be possible that this is the reproductive strategy the population of *P. siculus* from Krk Island uses. However, this is a preliminary study and conclusion, and to get a more accurate result, another year of research is necessary with a larger specimen count.

INVASIVNESS – It is reported by DOWNES AND BAUWENS (2000A) that in competition with *P. melisellensis*, *P. siculus* dominates over the species, taking up basking spaces longer than the other species. That access to basking sites may have important consequences for the ability to capture food, and for growth rates, which could have significant ramifications for fitness and life history of lizards. Slower growth during a lizard's early life can lead to smaller sizes at maturity, the production of fewer offspring per clutch, and lighter clutch masses and hatchlings, which in the end could lead to the problem of domination over other lizard species that cohabitate with *P. siculus.* DOWNES AND BAUWENS (2000A) and VAN DAMME, ET AL. (1990) propose to test this hypothesis in a way to remove *P. siculus* from an area and look at colonization from the other species in the same area.

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