

## *Risks and Opportunities of Urbanization - Structure of Two Populations of the Balkan Wall Lizard *Podarcis tauricus* (Pallas, 1814) in the City of Plovdiv*

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**Abstract.** The current study analyzes the structure and some features of two urban metapopulations of the Balkan Wall Lizard (*Podarcis tauricus* (Pallas, 1814)) from Nature Monument (NM) "Mladezhki halm" and Nature Monument "Halm na osvoboditelite" in the city of Plovdiv (South Bulgaria). In both study sites, the Balkan Wall lizard inhabits exclusively the interior of the hills and prefers mainly open areas with rare grass and shrub vegetation. The recorded dominant plant species are not autochthonous for the hills, but gradually displaced with many decorative species, used widely in the gardening and the city parks.

The population abundance from both hills is relatively low, with higher values in NM "Mladezhki halm" and generally shows a decrease pattern for the two year period. In the hills of Plovdiv, the Balkan Wall lizard shows a bimodal diurnal and seasonal activity. Both metapopulations showed a sex ratio close to 1:1 with a slight superiority of the females (1:1.29), but with no statistically significant deviation. The age structure of both metapopulations is almost identical - the highest percentage takes the adults, followed by the subadults and juveniles, with no significant deviations from the normal ratio.

The possible reasons for the contemporary distribution and population structure of the Balkan Wall lizard are discussed. Historic land use change and its effect on the populations are discussed as well. The main risks for this species in the city of Plovdiv are construction and forestation (destruction of open terrains). Nevertheless, the Balkan Wall lizard seems to have successfully overcome the risks of urbanization and its population seem stable and sustainable.

**Key words:** *Podarcis tauricus*, metapopulations, urban environment, Plovdiv, Bulgaria

## Introduction

Urbanization is one of the most drastic changes that can be imposed on an environment, fragmenting the land into a mosaic of patches of differing size and shape that are surrounded by the urban matrix - cleared areas, roads, buildings and other modified habitats (DICKMAN, 1987). Most of these patches are small in size and quite isolated from other "green areas". Urban areas offer opportunities for interesting case studies to the ecologists, because they are fragmented portions of natural and semi-natural zones inside a very anthropogenic influenced area (RUGIERO, 2004).

Reptile population responses to urban development are perhaps the least understood in comparison to all other vertebrates in urban environments (GERMAINE & WAKELING, 2001). Although ecologists have traditionally paid little attention to 'urban' species, much can be learnt from their populations that inhabit urban habitats (DAVIS, 1976). The common species are suitable objects for studying the effects of urbanization, such as, for example, some lizard species (JELLINEK *et al.*, 2004). The Balkan Wall lizard *Podarcis tauricus* (Pallas, 1814) is one of the most common lizards in Bulgaria, inhabiting mainly open, dry grassy or rocky habitats covered by scarce vegetation below 600 m a.s.l., even anthropogenic terrains (BISERKOV *et al.*, 2007). Almost everywhere in the country the species' populations are dense and numerous (BESHKOV & NANEV, 2002), which makes it suitable indicator species for studying the effect of urbanization on its populations.

Within the city of Plovdiv there are several "green areas", besides the urban parks, of low conservation value, being heavily visited by people. The hills of Plovdiv are green areas which resemble natural sites, surrounded by heavily urbanized land (MOLLOV, 2005). Because of

their unique geomorphologic formations and certain biodiversity conservation role, three of them were protected by the law and were declared as "nature landmarks", according to the Bulgarian legislation.

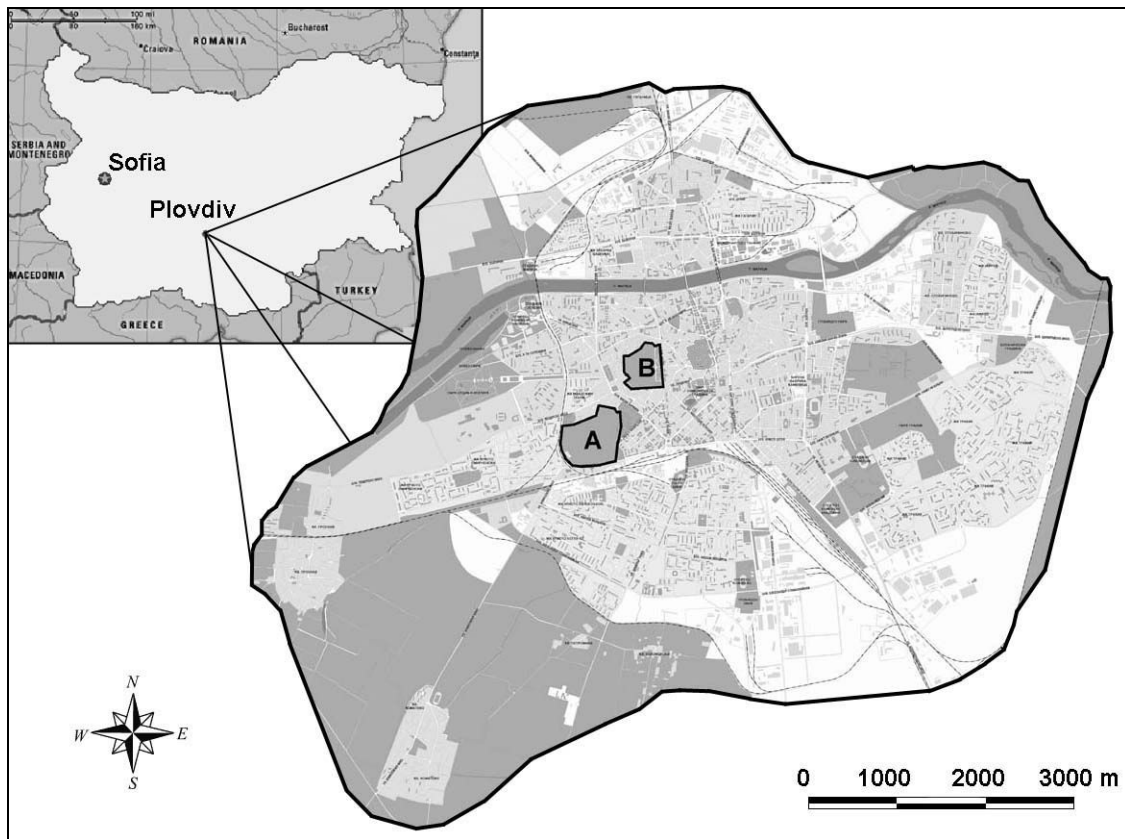
The aim of the current study is to analyze the structure and some characteristics of two local metapopulations of the Balkan Wall lizard (*Podarcis tauricus*) from NM "Mladezhki halm" and NM "Halm na osvoboditelite" in Plovdiv and present data about the species' distribution, habitat selectivity, diurnal and seasonal activity, abundance, age and sex ratio in urban environment.

## Material and methods

The study was conducted between March and October 2007 and 2008 on two hills (NM "Mladezhki halm" and NM "Halm na osvoboditelite") in the city of Plovdiv (South Bulgaria).

*Study area.* NM "Mladezhki halm" ("The hill of youth") is situated on 36.2 ha of land (285.5 m a.s.l.) and NM "Halm na osvoboditelite" ("The hill of Liberators") is situated on 22.0 ha of land (265 m a.s.l.). Both nature monuments are situated in the centre of the city (Fig. 1) and by origin they are syenite hills formed during the Palaeogene. Both hills are declared for protected territories with Regulation № RD466 from 22.12.1995 by Ministry of Environment and Waters (MOEW), with the aim to protect the natural landscape and the unique geomorphologic formations (DIMITROV *et al.*, 2002).

*Abundance estimates.* For calculating the abundances of the populations we used a line transect method (SUTHERLAND, 2000). This method assumes 100% detectability in the center of the line transect, which is achievable in fairly open habitats, which are present in the hills of Plovdiv. Eight randomly chosen transects (random samples), each 1000 m long, were made through each of the studied areas.



**Fig. 1.** Location of the two urban protected areas within the city of Plovdiv  
 A - NM "Mladezki halm", B - NM "Halm na osvoboditelite".

Recording distances were covered by means of GPS receiver. The abundance in this case is considered as total number of individuals on the studied area per line transect (TURPIE, 1995).

For each observed specimen we recorded data on date, time, place of observation and surrounding vegetation. The lizards' sex was determined based on the morphological characteristics given by TZANKOV (2007) and BISERKOV *et al.* (2007). Based on the body size (visually and by measuring), we established three age groups: adult (male and female), subadult and juvenile. Data about the condition of the lizard's tail (absent or regenerated) was also collected (STRIJBOSCH *et al.*, 1989).

*Data analysis.* The statistical processing of the data was performed with the software "Statistica v. 7.0" (STATSOFT INC., 2004), using descriptive statistics. The

deviations from the normal sex and age ratio were compared using the  $\chi^2$ -test and the tail loss frequency data was compared using the Mann-Whitney U-test for independent samples. Both tests are suitable when the data is not normally distributed (FOWLER *et al.*, 1998). For the comparison of the abundances we used t-test with normalized data, using natural logarithm -  $\ln(x+1)$  (FOWLER & COHEN, 1995). For statistically significant results we considered those with  $p < 0.05$  [ $\alpha = 5\%$ ].

*Distribution and spatial data.* The distribution maps were generated from the collected GPS data for the two-year period, using the "MapSource v. 6.12" software (GARMIN LTD., 2007) with electronic topographic map "BG Topo Maps v. 2.12" (KOTZEV, 2005) and "DIVA-GIS Annapurna v. 6.0" (ROJAS & HIJMANS, 2008).

## Results

*Distribution.* The overall distribution of both metapopulations of *Podarcis tauricus* for the whole period of study in both study sites is presented in Fig. 2 and Fig. 3.

*Habitat characteristics.* At the two study sites, the Balkan Wall lizard inhabits mainly open rocky areas with short grass-shrub vegetation. The habitats on both hills

are almost identical, so we are discussing them together. We identified the following dominant plant taxa: *Gleditschia triacantos*, *Robinia pseudoacacia*, *Magnolia denudate*, *Picea pungens*, *Criptomeria japonica*, *Abies cephalonica* and *Abies alba* from the trees and *Crataegus monogyna*, *Paliurus spina-christi*, *Cornus mas*, *Prunus spinosa*, *Rosa canina* and *Forsythia suspense* from the shrubs.

**Table 1.** Abundance (individuals/1000 linear meters) of both metapopulations of *Podarcis tauricus* in Plovdiv for the two-year period.

**Legend:** Mean – mean abundance, CI – confidence interval (95%), SD – standard deviation.

Site	2007			2008		
	Mean	CI	SD	Mean	CI	SD
NM “Mladezhki halm”	3.12	-0.70÷6.95	4.58	3.00	0.20÷5.79	3.33
NM “Halm na osvoboditelite”	1.87	1.05÷2.70	0.99	0.62	-0.14÷1.39	0.92

*Abundance.* The abundance of the population at NM “Mladezhki halm” is higher, compared with the abundance of the population at NM “Halm na osvoboditelite”, but there are no statistically significant differences (t-test,  $p>0.05$ ). There is also a visible pattern of decrease in the population abundances on both hills for the two year period (Table 1), but only the population from NM “Halm na osvoboditelite” has statistically significant differences (t-test,  $t=2.57$ ,  $p=0.02$ ).

*Diurnal and seasonal activity.* The Balkan Wall lizard shows a bimodal daily activity pattern, with one peak in the morning and second in the afternoon (Table 2). The seasonal activity also shows a bimodal activity pattern (Fig. 4) with one peak in the spring (March-May) and second peak in the autumn (August-September).

*Escape behaviour and tail loss frequency.* Like other lacertids *Podarcis tauricus* exhibits tail autotomy to escape potential predation. A certain number of the observed animals were with broken or regenerated tails – at NM “Mladezhki halm”, 4.08% of the lizards were with

broken tails and 2.04% with regenerated tails and at NM “Halm na osvoboditelite”, 15% were with broken tails and 10% with regenerated tails.

**Table 2.** Diurnal activity of both metapopulations of *Podarcis tauricus* in Plovdiv for the whole period of study

Time zones	NM “Mladezhki Halm”	NM “Halm na osvoboditelite”
Before 8:00	-	-
8:00-9:00	1	1
9:00-10:00	4	1
10:00-11:00	6	2
11:00-12:00	6	4
12:00-13:00	4	1
13:00-14:00	3	-
14:00-15:00	3	-
15:00-16:00	4	1
16:00-17:00	6	2
17:00-18:00	6	3
18:00-19:00	5	2
19:00-20:00	2	2
After 20:00	-	1

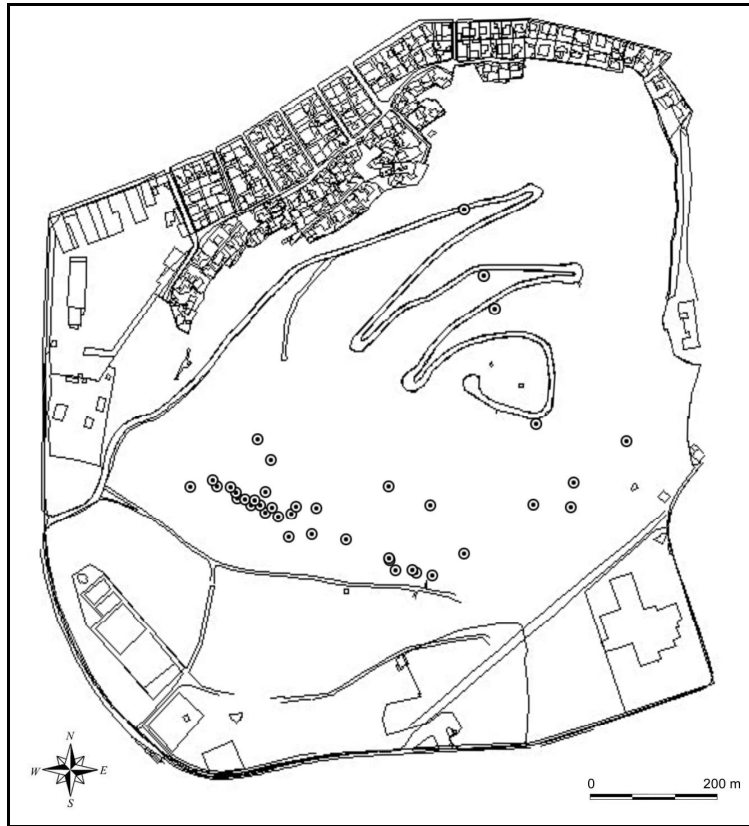


Fig. 2. Distribution of *Podarcis tauricus* at NM "Mladezhki halm".

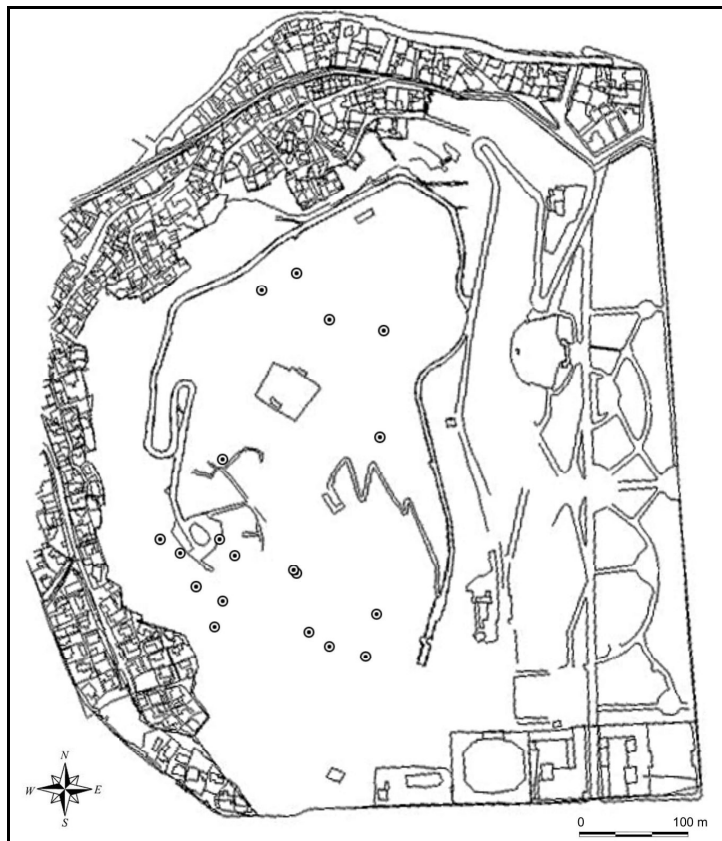


Fig. 3. Distribution of *Podarcis tauricus* at NM "Halm na osvoboditelite".

Both interpopulational (U-test,  $U=32.5$ ,  $p=0.81$ ) and intersexual (U-test,  $U=36.0$ ,  $p=0.65$ ) tail-brake frequency differences were not significant (U-test gives in all cases  $p>0.05$ ), but the population from "Mladezhki halm" shows the lowest values. The comparison of the tail loss frequency between the age groups also showed not significant differences ( $\chi^2=1.75$ ,  $df=2$ ,  $p=0.41$ ).

*Sex and age structure.* In both metapopulations, our study shows a sex ratio close to 1:1 with a slightly deviation towards the females (Fig. 5). However, all these deviations from the 1:1 ratio are not significant ( $\chi^2$ -test,  $df=1$ ,  $p>0.05$ ). The sex ratio in the population from NM "Mladezhki halm" is 1:1.29 ( $\chi^2=0.64$ ,  $df=1$ ,  $p=0.42$ ) and the sex ration in the population from NM "Halm na osvoboditelite" is 1:1.28 ( $\chi^2=0.25$ ,  $df=1$ ,  $p=0.61$ ) towards the females.

The age structure in both metapopulations is almost identical. The highest percentage is taken by the adults, followed by the subadults and the juveniles (NM "Mladezhki halm": adult - 42.86%, subadult - 36.73%, juvenile - 20.41%; NM "Halm na osvoboditelite": adult - 45%, subadult - 35%, juvenile - 20%). The deviation of the equal distribution of the age groups (1:1:1) is not significant on both hills - NM "Mladezhki halm" ( $\chi^2=3.96$ ,  $df=2$ ,  $p=0.13$ ) and NM "Halm na osvoboditelite" ( $\chi^2=1.90$ ,  $df=2$ ,  $p=0.38$ ).

## Discussion

Our study indicated that in both study sites the lizards inhabit only the interior of the hills. At NM "Mladezhki halm" the majority of records came from the southern side of the hill in contrast to NM "Halm na osvoboditelite" where the distribution was more homogenic. Apparently the spatial structure of both metapopulations appears to be aggregated (grouped).

Most of the described dominant vegetation on the hills is not autochthonous. The indigenous vegetation on both hills consisted of only grass and shrub species (including some endemic species like *Genista rumelica*, *Hypericum rumelicum*, *Centaurea affinis*) and almost no trees. In the beginning of the XX century and afterwards the indigenous vegetation was gradually displaced with many decorative shrub and tree species, used widely in the gardening and the city parks (DIMITROV *et al.*, 2002).

In nature, the Balkan Wall lizard inhabits lowlands with scarce vegetation: lawns with *Amorpha frueticosa* and *Marsdenia erecta* shrubs (KABISCH & ENGELMANN, 1970); sand dunes with partly quite meagre vegetation, consisting of grasses and *Artemisia sp.* as dominant plant (NÖLLERT, 1983) in Bulgaria and open lowlands with grass-shrub vegetation consisting of *Inula sp.*, *Calendula sp.*, *Chrysanthemum sp.*, *Euphorbia sp.* and *Trifolium sp.* as well as olive groves, cultivated areas, gardens, road sides, brambles and fences in Greece (CHONDROPOULOS & LYKAKIS, 1983). Similar habitats are described by UNDJIAN (2000), BESHKOV & NANEV (2002) and SCHLÜCHTER (2006) from other natural sites in Bulgaria.

The population abundance of *Podarcis tauricus* on both urban hills is considerably lower, in contrast with natural populations. POPGEORGIEV (2009) reported values from 0.52 to 12.04 ind./1000 m from several populations from the Eastern Rhodopes Mts. and a value of 12.01 ind./1000 m from another population from Sakar Mt.

We recorded a decrease in the average population abundance for the two-year period. However it is hard to draw any conclusions about the populations' fate, due to the short period of study. The lower population density at NM "Halm na osvoboditelite" could be explained with the

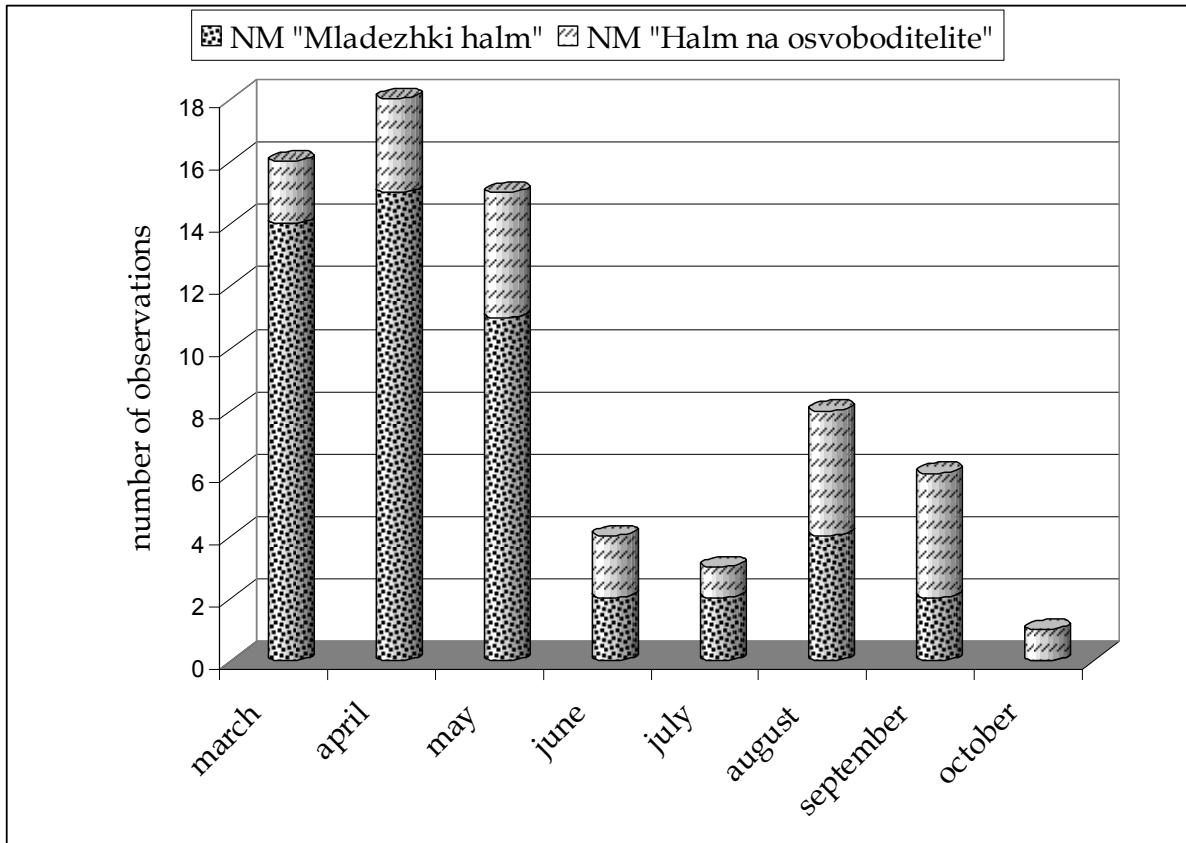


Fig. 4. Seasonal activity of both metapopulations of *Podarcis tauricus* in Plovdiv for the whole period of study

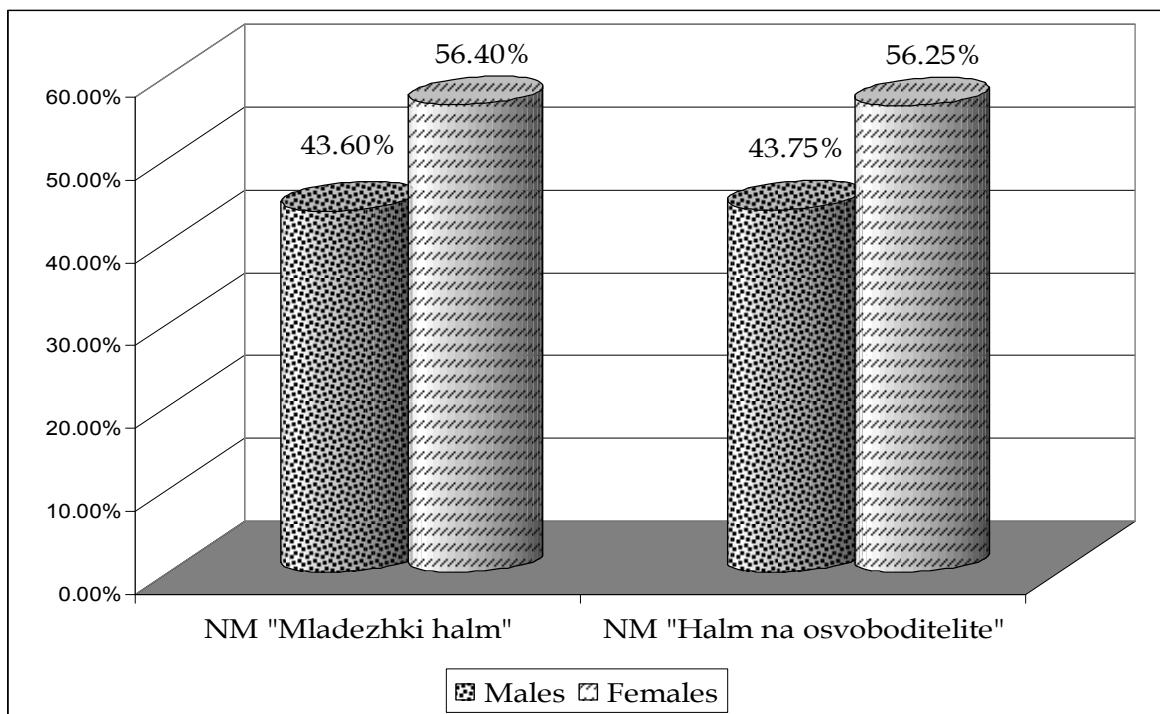


Fig. 5. Sex ratio of both metapopulations of *Podarcis tauricus* in Plovdiv

smaller size of the hill and the higher anthropogenic pressure (MOLLOV, 2005). Perhaps the anthropogenic factor is one of the main drivers affecting the low population abundances on both hills due to the absence of any strong predation pressure (except for some birds of prey and domestic cats) or competition with other lizard species (MOLLOV, 2005).

According to our observations, the diurnal and seasonal bimodal pattern of lizard's activity is more vividly expressed in the population of NM "Halm na osvoboditelite", which is probably due to the different microclimatic conditions. Similar daily activity cycles strongly influenced by weather conditions were reported by CHONDROPOULOS & LYKAKIS (1983) for *Podarcis tauricus* in Greece, by CRUCE (1970) for a natural population in Romania and AVERY (1978) for *P. muralis* and *P. siculus* in Central Italy. In general, many diurnal heliothermic lizards show similar activity patterns, which are usually determined by climate and weather conditions (PIANKA, 1970; BUSACK, 1976) but not by the degree of urbanization in particular.

According to PIANKA (1970), tail loss frequency of lizards (autotomy) is correlated directly to predator abundance and indirectly to the primary productivity of the community. Our results could be partly explained by Pianka's hypothesis due to the fact that the only natural predators of *Podarcis tauricus* on both hills are some birds of prey and the domestic cats, which are more abundant on NM "Halm na osvoboditelite". The absence of any significant sexual difference in the tail-break frequencies of the Balkan Wall lizard may suggest that tail autotomy is used equally often by both females and males. We suppose that both sexes are using tail-breaking for escaping predator attacks and it is not attributed to intraspecific fights

(usually between males). Unlike other lizards, where the tail loss frequency increases with age, *Podarcis tauricus* doesn't follow the same pattern. It seems all age groups use tail autotomy equally frequent to escape predation. Similar results are reported by CHONDROPOULOS & LYKAKIS (1983) and STRIJBOSCH *et al.*, (1989) in Greece.

The normal sex ratio of the natural populations of *Podarcis tauricus* is close to 1:1 as reported by CHONDROPOULOS & LYKAKIS (1983) for the majority of the studied natural populations in Greece regardless of the sampling season. Even though the deviation from the normal sex ratio is not statistically significant, the slight deviation towards the females, recorded in our study, may be partly explained with the urban heat island theory (OKE, 1982; CAMILLONI & BARROS, 1997). The sex determination in reptiles (including lizards) is strongly influenced by the temperature of the surrounding environment (HARLOW & SHINE, 2006; WARNER & SHINE, 2008). At higher environmental temperatures in the centre of the city, where the studied sites are situated, perhaps more females are hatched.

The age structure showed slight predominance of the adults, with no statistically significant differences between the age groups. The slightly lower percentage in the juvenile lizards could be explained with the fact that the juvenile Balkan Wall lizards are very small in size and their coloration matches the environment, which makes them very hard to spot. So it is possible that the observed juvenile lizards were not all present in the field during the study. On the other hand it is possible that some of the juveniles would probably die before they get to the subadult class thus; there should be fewer subadults than juveniles in the population



unless individuals stay in the subadult size class for more than one year. A stable population can have equal numbers of each age group, more adults, or more juveniles, depending on mortality and fecundity schemes. Unfortunately our results are insufficient to determine any certain population trends.

In our opinion, in the past the Balkan Wall lizard was distributed more widely on and around the hills of Plovdiv with more numerous and dense populations. Before the intensive construction that took place around the hills as the city started to grow, there was an abundance of open terrains, which this species normally inhabits in nature (Fig. 6A.). The rapid construction around the hills had regularly pushed the lizards towards the interior of the hills, fragmenting the species' populations (Fig. 6B). The gradual transformation of the habitats on the hills during the XX century by introducing of several decorative tree and shrubs additionally influenced the distribution and the population's abundance of *Podarcis tauricus* on the hills of Plovdiv nowadays (Fig. 6C).

According to our results and observations the main risks for this species in the city of Plovdiv are construction and forestation (destruction of open terrains). Nevertheless, it seems that the Balkan Wall lizard had adapted successfully to the remaining suitable habitats in the interior of the hills. The fact that three of the hills of Plovdiv were declared as protected territories had also influenced positively the survival of this species in the "hostile" urban environment. In our opinion *Podarcis tauricus* have overcome the risks of urbanization and it should be considered a very adaptable species.

### Conclusions

1. At both study sites the Balkan Wall Lizard inhabits only the interior of the hills.

At NM "Mladezhki halm" the majority of the records came from the southern side of the hill in contrast of NM "Halm na osvoboditelite", where the distribution is more homogenic.

2. At the two study sites the Balkan Wall lizard inhabits mainly open rocky areas with short grass-shrub vegetation. The predominated vegetation on the hills is not autochthonous was gradually displaced with several decorative trees and shrubs, used widely in the gardening and the city parks.

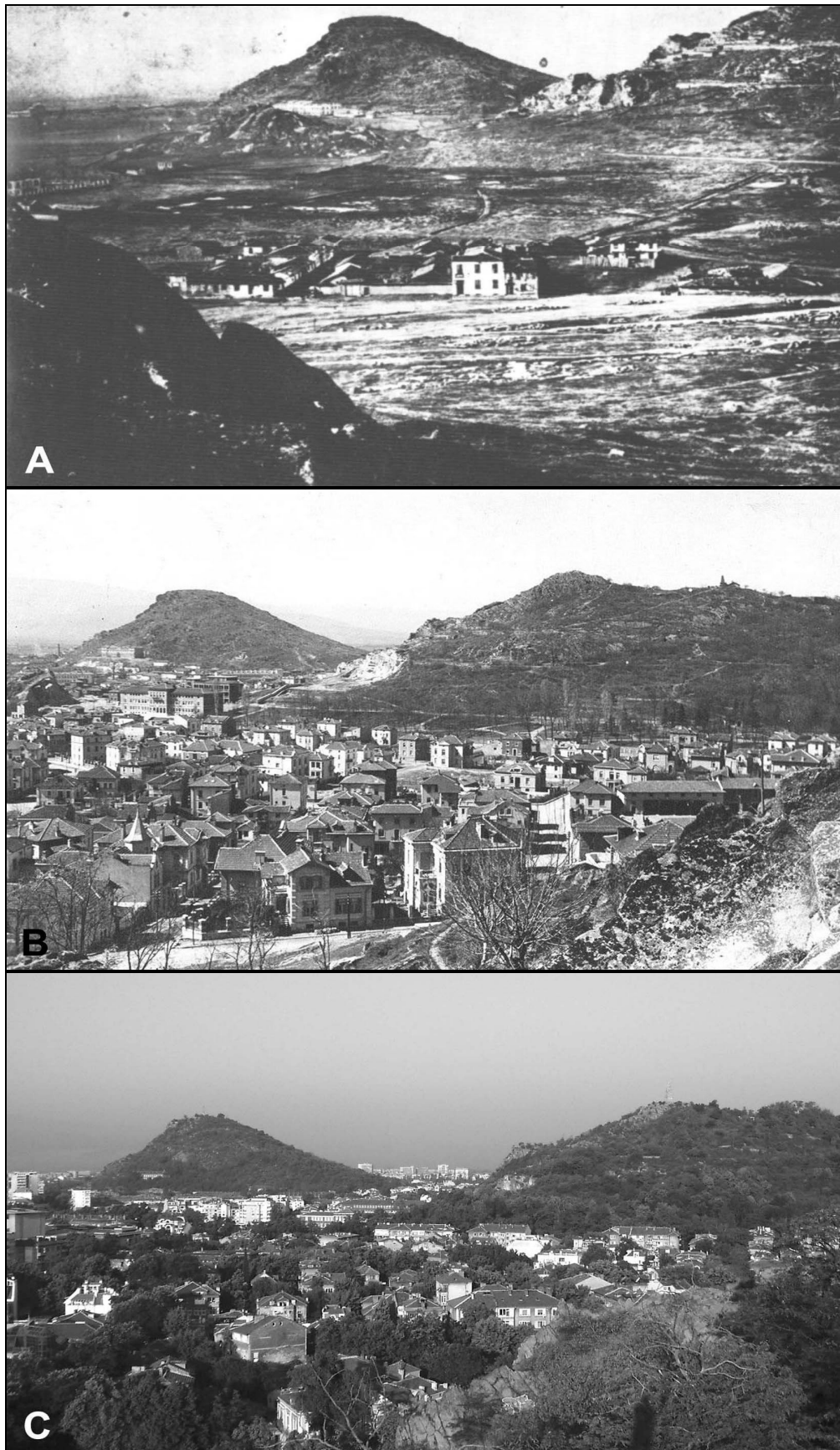
3. The abundance of the populations of *Podarcis tauricus* on both hills is relatively low in comparison to natural sites and varies between the hills and decreased during the two-year period of study.

4. The Balkan Wall lizard showed a bimodal daily activity pattern, with one peak in the morning (between 9:00 and 12:00 am) and second peak in the afternoon (between 16:00 and 19:00 pm). The seasonal activity also showed a bimodal activity pattern with one peak in the spring (March-May) and second peak in the autumn (August-September).

5. Like other lacertids *Podarcis tauricus* exhibits tail autotomy to escape potential predation. In certain number of the observed animals broken or regenerated tails were observed, but both interpopulational and intersexual differences were not significant. The population from "Mladezhki halm" showed the lowest values of tail breaking frequencies.

6. In both metapopulations, our study showed a sex ratio close to 1:1 with a slightly deviation towards the females (1:1.29). However, all deviations from the 1:1 ratio were statistically not significant.

7. The age structure in both metapopulations was almost identical. The highest percentage was shown by the adults, followed by the subadults and the



**Fig. 6.** NM “Mladezhki halm” and NM “Halm na osvoboditelite”: A - a photograph of the two hills made in 1862; B - a photograph of the two hills made somewhere before 1957; C - a photograph of the two hills made in 2008 (explanations are in the text).

juveniles. The deviation among the age groups was not significant on both hills.

8. The main risks for this species in the city of Plovdiv are construction and forestation (destruction of open terrains). However, *Podarcis tauricus* seems to be well adapted to the urban environment and at this point not particularly threatened.

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**Риск и възможности на урбанизацията - Структура на две популации на кримския гущер *Podarcis tauricus* (Pallas, 1814) в град Пловдив**

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**Резюме.** Настоящото проучване анализира структурата и някои характеристики на две локални метапопулации на кримския гущер (*Podarcis tauricus*) от ПЗ „Младежки хълм“ и ПЗ „Хълм на освободителите“ в гр. Пловдив.

И при двата хълма кримският гущер обитава изцяло само вътрешността на хълмовете и не се среща в периферията им или извън нея. В ПЗ „Младежки хълм“ се наблюдава леко предпочитание на вида към южните склонове на хълма, за разлика от ПЗ „Хълм на освободителите“, където разпространението е по-хомогенно.

И в двете проучвани защитени територии кримският гущер обитава основно открити пространства с ниска тревисто-храстова растителност. Установените доминантни растителни таксони не са автохтонни за хълмовете, а са постепенно интродуцирани декоративни дървесни и храстови видове.

Обилието на метапопулациите на *Podarcis tauricus* и на двата хълма е сравнително ниска, като по-високи стойности има в ПЗ „Младежки хълм“ и като цяло проявява тенденция на намаляване за двугодишния период.

Кримският гущер показва бимодална дневна активност с един пик от 9:00 до 12:00 и втори пик от 16:00 до 19:00. Сезонната активност на този вид на Пловдивските хълмове има подобен

характер с два пика – през пролетта и есента.

Подобно на повечето същински гущери *Podarcis tauricus* проявява автотомия (самооткъсване) на опашката за да избяга от потенциален хищник. Известна част от наблюдаваните от нас гущери бяха с откъснати или регенерирани опашки, но сравняването между двете популации и между двата пола не показва статистически значими различия.

И при двете метапопулации съотношението между двата пола е близко до 1:1, с лек превес на женските (1:1.29), като отклоненията от нормалното съотношение не е статистически достоверно. Възрастовата структура и при двете показва много близки стойности между двете популации, като най-голям процент имат възрастните, следвани от субадултните и с най-малък процент ювенилните.

Основните рискове за този вид са строителството и залесяването на открити пространства с не-автохтонна растителност. Въпреки това изглежда вида е добре адаптиран към градска среда и не е застрашен от изчезване.

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