

*Influence of Urbanization on the Populations of the European pond Turtle *Emys orbicularis* (L., 1758) in the City of Plovdiv (Bulgaria)*

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Abstract. Landscape change associated with urbanization presents a great challenge for conservation, because of the way it affects biodiversity. Turtles represent a very important component of the urban ecosystems. The European pond turtle, *Emys orbicularis* (L., 1758) is one of the two native aquatic turtle species, occurring in Bulgaria, including the city of Plovdiv, which is the second largest city in the country and its territory covers mainly the urbanized environment and adjacent terrains. According to the data for the last 100 years, the European pond turtle in the studied region is increasing its distribution range within the city, due to the development of dense system of irrigation canals. The presence of the invasive species *Trachemys scripta elegans* was registered in the region of Plovdiv City. The abundances and average density of the populations are relatively low and the age structure of the population of *E. orbicularis* from Maritsa River has the highest percentage of adults and juvenile individuals, indicating that the population of this species in the city is unstable. The main threat to European pond turtle in Plovdiv City is the anthropogenic factor, which is mainly through the loss of suitable habitats on the one hand and the direct destruction of specimens on the other.

Key words: *Emys orbicularis*, urban populations, urbanization, Plovdiv City, Bulgaria.

Introduction

Urbanization is recognized to be one of the main factors for habitat loss leading to local biodiversity extinction in urban areas (MCKINNEY, 2008). Landscape change associated with urbanization, particularly sprawl, has been significant during the last

half century and is expected to continue through the next decades (ALBERTI *et al.*, 2003). Effects of landscape change on stream ecosystems have been extensively documented (PAUL & MEYER, 2001). Modifications of the land surface during urbanization produce changes in both the

type and the magnitude of runoff processes. These changes result from vegetation clearing, soil compaction, ditching and draining, and covering the land surface with impervious roofs and roads.

Turtles face an increasingly serious set of threats to their survival throughout the world (KLEMENS, 2000), making them one of the most severely threatened vertebrate groups. They also represent a very important component of urban ecosystems, occurring in a variety of aquatic habitats (and some terrestrial surroundings) and therefore tolerate the impact of human activity to varying degrees. This leads to a reduction in their diversity compared to natural conditions and changes in the structure of their populations. In addition to urbanization can result in changes in distribution, movement, home range and activity of native species (FORMANN *et al.*, 2002) and thus understanding anthropogenic effects on activity and habitat use is essential for developing sound conservation and management plans in urban areas. However, this problem is still poorly studied in Europe, and especially in Bulgaria.

In Bulgaria, the European pond turtle (*E. orbicularis*) is distributed along rivers, streams, irrigation canals and in marshes, ponds, dams and fisheries throughout the country up to 1100 m a.s.l. (BESHKOV & NANEV, 2002) and it can be registered even in cities and urban areas. The city of Plovdiv is the second largest city in Bulgaria and its territory covers mainly the urbanized environment and adjacent terrains. The favorable geographic location of the city, the presence of the Plovdiv hills and the influence of the Maritsa River determine the existence of unique natural areas with rich biodiversity. As stated by MOLLOV *et al.* (2013) there is still a huge gap of knowledge about the species' ecology, population structure, reproductive biology and ethology in the country, especially in urban areas. The objectives of this study were to estimate the distribution, population size, density, age structure of the populations of *E. orbicularis*

in the city of Plovdiv and to evaluate the main conservation problems and threats for the urban populations.

Material and Methods

The data presented in the current study was obtained in the period from March 2007 to October 2010 in the territory of Plovdiv City and its surroundings.

The general data for each individual observed includes: date, time, place of observation and altitude (marked with the GPS receiver "Garmin eTrex Vista"); age group (adult, subadult and juvenile) established on the basis of the dimensional characteristics and coloration of the individuals (ARNOLD & OVENDEN, 2002); the dominant vegetation in the habitat.

Zoogeographic classification was done after BEŠKOV & BERON (1964). The chorotype classification follow PETROV (2007).

The index of occurrence (*A*) was calculated, using the following Eq. (1) (after PETROV & MICHEV (1985)):

$$A = \frac{N}{S} \cdot 100 \quad (1),$$

where *A* - index of occurrence; *N* - the number of UTM (1x1 km) squares in which the species is found; and *S* - the total number of squares in the surveyed area.

The abundance (*Ab*) for each studied population was calculated. According to SUTHERLAND (2000), abundance is defined as the total number of individuals of a given species found in a given territory. In the present work, due to differences in transect length, we used a number of individuals per 1000 linear meters (Eq. 2). Data obtained in this way gives a better opportunity for comparison and analysis.

$$Ab = \frac{n}{L} \cdot 1000 \quad (2),$$

where *Ab* - abundance (number of individuals per 1000 linear meters); *n* - number of observed individuals; and *L* - area studied in linear meters.

For the calculation of the average density of amphibians and reptiles populations (D_s) in the standing water bodies, we divided the number of all reported specimens by the total area of the water basin. In the present work the population density is presented as the number of individuals per m^2 , calculated according to Eq. (3) (after SUTHERLAND, 2000):

$$D_s = \frac{n}{A} \quad (3),$$

where D_s - density (number of individuals per m^2); n - total number of all observed specimens; and A - the area of the water basins in m^2 .

Description of line transects used

Maritsa River passes through the whole territory of the city of Plovdiv in a west-east direction. Within the boundary of the studied region falls a 13 km section of the river, which was divided into 13 one-kilometer transects. From the irrigation canals passing through the study area, transect was marked along one of them (where the presence of *E. orbicularis* was recorded) - from the road to the village of Tsaratsovo to Plovdiv State Fishery (4400 m). These flowing basins, as well as two large (over 1 km^2) standing water basins - Rowing Base, Plovdiv and Plovdiv State Fishery, were also surveyed.

Environmental factors

In this study, some basic abiotic and biotic factors (air and water temperature, water pH and predominating vegetation) affecting the distribution, and some population properties of the European pond turtle populations, were measured by standard methods. Air and water temperature were measured with digital thermometer "TCM", minimal capacity 0.1°C and water pH was measured using digital pH-meter "WTW", minimal capacity 0.01.

Natural environment of the city of Plovdiv

Plovdiv Municipality is located within the Plovdiv Field in the middle of the Thracian Lowland (south Bulgaria) at 160 m a.s.l. The city of Plovdiv takes up about 53 km^2 of the Plovdiv municipality and represents an urbanized area with a population of 375,580

inhabitants. The study area covered 127 km^2 , calculated from the UTM map of Bulgaria (10x10 km). The borders of the research area were identified based on a 1-kilometer UTM grid (10x10 km standard quadrats were divided into 100 smaller quadrats of 1x1 km). Thus, the study area includes the administrative boundaries of the city (Fig. 1) and the surrounding areas, excluding other urban areas (MOLLOV & VELCHEVA, 2010).

Statistical analyses and software used

The processing and mapping of GPS data was accomplished with the "MapSource" v.6.12 software by Garmin Ltd. on an electronic topographic map, and the visual presentation utilized ArcGIS v.10.0 (ESRI, 2011).

The statistical processing of the data was done with the software package "Statistica" v.7.0 (StatSoft Inc., 2004). Data was analyzed for distribution normality by the Shapiro-Wilk test. When comparing or looking for correlations between individual variables, non-parametric tests (χ^2 -test, Mann-Whitney U-test for independent variables, Spearman correlation index) were used when the data did not have a normal distribution. These differences were statistically valid with $p \leq 0.05$ [$\alpha = 5\%$]. Principal Component Analysis (PCA) was applied, and values greater than 0.7 were accepted as statistically valid for this test (FOWLER *et al.*, 1998).

Results and Discussion

Distribution in the city of Plovdiv

Based on literary data (1910-2001), *Emys orbicularis* is registered in total of 3 localities in 3 UTM quadrats (Distribution index - 2.36), the contemporary number of localities (after MOLLOV & VELCHEVA, 2010) is 11 in 9 UTM quadrats (Distribution index - 7.09).

The European pond turtle has been reported for the "Maritsa River in Plovdiv City" by KOVACHEV (1910), "near the "Ostrova" Area in Plovdiv City" by ANGELOV (1960) and State Fisheries - Plovdiv by KIRIN (2001). In the current study it was recorded with a total of 11 localities in 9 UTM quadrats (LG1710, LG1720, LG1762, LG1783, LG1607, LG1608, LG1619, LG1629, LG1649). All recorded localities are presented in Fig. 2.

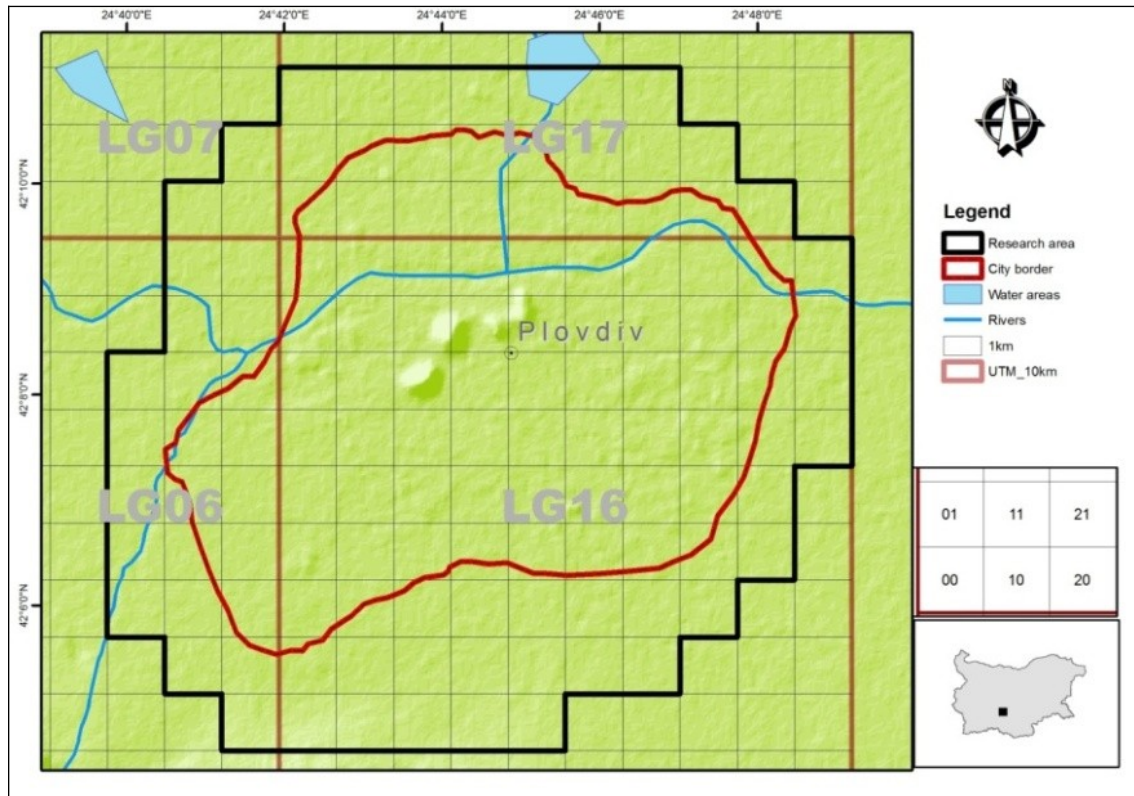


Fig. 1. UTM map (1x1 km) of the study area - Plovdiv City and its surroundings.

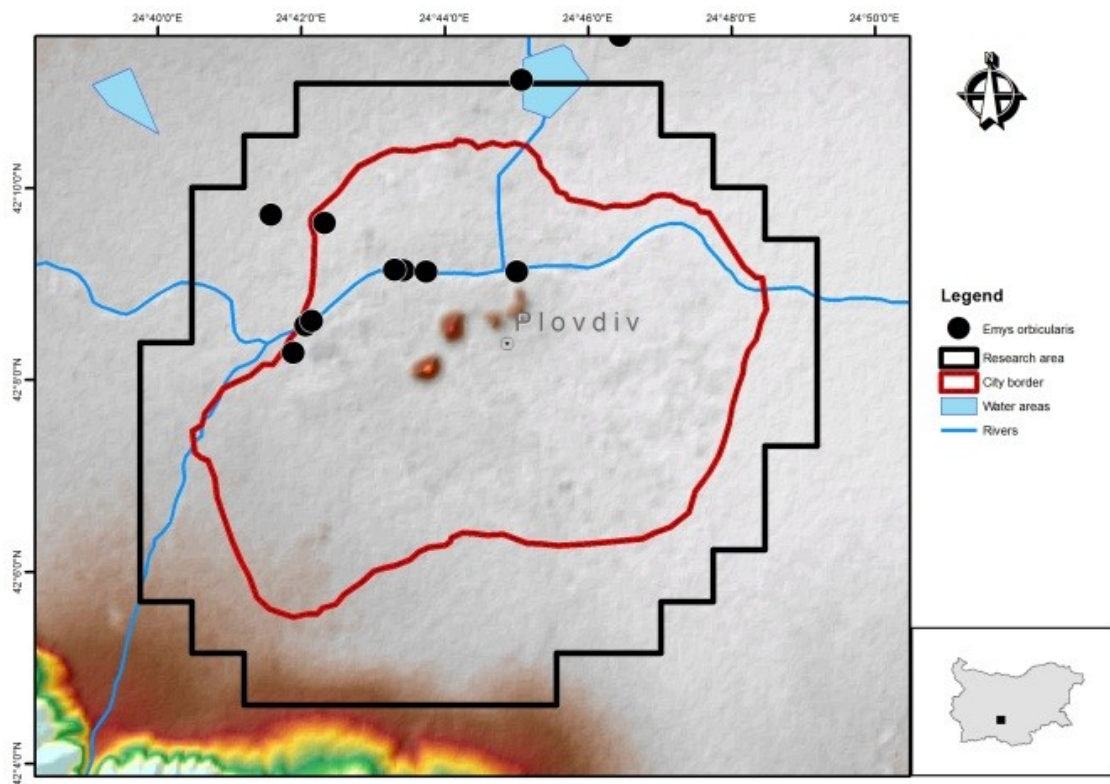


Fig. 2. Distribution of the European Pond Turtle (*Emys orbicularis*) in the city of Plovdiv.

Within the city limits we also recorded the invasive Red-eared Slider - *Trachemys scripta elegans* (Wied-Neuwied, 1839). The red-eared slider is a decorative freshwater turtle species, sold in pet shops as a pet. Unfortunately, when the turtles become too large to be kept in captivity, their owners release them in different places in the country. Because of the high ecological plasticity of the species, it successfully survives in natural conditions and that is why it has become a potentially dangerous invasive species in Europe (CADI & JOLY, 2004). So far there are two records of red-eared sliders in Plovdiv City. The first one is from 2004, when a specimen was spotted on the banks of the Maritsa River near the bridge of the international fair - LG1649 (Dulev, Plovdiv, pers. comm., 2004) and the second was registered in this study on 14.VII.2008 - a couple (male and female), released in a fountain in the garden behind the Regional Natural History Museum - Plovdiv (LG1648).

Habitat distribution

The urban landscape of Plovdiv City is a complex matrix of residential and business buildings, roads, open, wooded, and other terrestrial habitats, as well as dense network of rivers and irrigation canals. According to MOLLOV (2011) the European pond turtle occurs in 6 urban habitat types in the city of Plovdiv - constant standing, freshwater ponds; rivers and streams; irrigation canals; riparian willow formations; riparian reed formations and floodplain crops (rice fields). It is a typically aquatic species, that can be rarely observed far away from the water basins.

Ecological classification and level of synanthropy

Following the classification given by MOLLOV & VELCHEVA (2015) according to the humidity and temperature regime, the European pond turtle can be classified as hydrophylic and mesothermic species. The species usually inhabit aquatic, humid and mid-humid habitats with moderate temperatures.

The species was recorded in all three zones along the urban-rural gradient in the city and occurs in a wide range of urban habitats and can be classified as "hemerodiaphoric", according to Klausnitzer's classification (KLAUSNITZER, 1990).

Zoogeographic classification

According to the Chorotype classification after PETROV (2007), *Emys orbicularis* is classified as Turanian-Euro-Mediterranean chorotype. Another classification used in the current study is by faunistic complexes and elements (after BEŠKOV & BERON, 1964). According to that classification, the European Pond Turtle belongs to the Mediterranean faunistic complex, Holo-Mediterranean faunistic element.

According to PETROV (2007), the presence (and even predominance in some areas, including the city of Plovdiv) of Mediterranean chorotypes in the reptiles in Bulgaria is not a surprise, given the geographic location of the country and its relatively warm climate. The predominance of the Mediterranean chorotypes in Plovdiv City could also be explained by the theory of the "heat island effect" (OKE, 1982).

Ecological properties of the populations

The species's populations were studied along urban-rural gradient along Maritsa River in 2007 (a 13 kilometer stretch within the city limits), an irrigation canal in the north part of the city, the Rowing Canal - Plovdiv and Plovdiv State Fishery.

Along Maritsa River of the 13 one-kilometer transects surveyed, all turtles were found between the fourth and the eighth kilometer (center of the city). The abundance (individuals per 1000 linear meters) of the species's population in Maritsa River, calculated by us, using line transect method was 0.692, and the abundance in the studied irrigation canal - 0.454. This species adheres to such coastal areas where there is preserved tree vegetation on the very waterfront. Such plots are almost absent in most of the studied water basins and this is

the reason for the limited distribution of the species in the studied area.

The Principal Component Analysis (PCA) and Spearman correlation rank were performed to trace the impact of the four factors studied on the abundance of species's populations. Both tests were done, following the effect of air (Factor 1) and water temperature (Factor 2), water pH (Factor 3) and the type of coastal vegetation (Factor 4) on the size of their populations (Table 1 and 2).

For *E. orbicularis*, a statistically significant value was found for the second factor (Table 1), which explains about 26% of the results. An average positive, statistically significant correlation with the water pH and a weak one with no statistical significance with the coastal vegetation type were also recorded for this species (Table 2).

Turtles from the Emydidae family are characterized as long-lived organisms with delayed sexual maturity and a long reproductive lifespan. These traits, together with high adult survivorship and low egg and hatchling survivorship, result in a stable population age structure that should be dominated by juveniles and subadults (CONGDON *et al.*, 1994). As a result, the ratio of non-reproductives to reproductives should greatly exceed one, and adults should represent only a small fraction of the population (GIBBS & AMATO, 2000). The age

structure of the population of *E. orbicularis* was recorded only at the Maritsa River. The ratio between the three age groups is as follows: 1:0.75:0.5, with the largest percentage being the adults (44.44%), followed by the subadults (33.33%) and the juveniles (22.22%). There was no statistically significant difference found for this species from the 1:1:1 ratio ($\chi^2=0.67$; $df=2$; $p=0.72$). This age structure shows that this urban population of the species is unstable and is likely to decrease.

The only large standing water reservoirs (over 1 km²) in the studied area are the Rowing Canal and Plovdiv State Fishery. The area of the Rowing Canal is 1.25 km² and the total area of the fishponds is 1.46 km². The average density of the *E. orbicularis* populations in the two basins are presented in Table 3.

In Plovdiv State Fishery, there are more species of amphibians and reptiles compared to the Rowing Canal due to the great variety of coastal and aquatic vegetation and micro-habitats in the fishponds compared to the total absence of such conditions in the canal. In addition, the Rowing Canal is used much more intensively and is visited by thousands of people every day, which is the main reason for the low species richness and lower population density (Fig. 3).

Table 1. Factorial coordinates of the variables based on the PCA correlations based on the abundance of *Emys orbicularis* in Maritsa River in the studied region. Legend: Values marked with * - statistically significant values ($p>0.70$).

	Factor 1	Factor 2	Factor 3	Factor 4
<i>Emys orbicularis</i>	0.35	0.84*	0.31	-0.30

Table 2. Spearman correlation rank of the four major abiotic factors and the abundance of the population of *Emys orbicularis* in the Maritsa River in the studied region. Legend: Values marked with * - the correlation is statistically significant ($p<0.05$).

Abiotic factor	Population abundance (Ab)
Air temperature, °C	0.074
Water temperature, °C	0.063
Water pH	0.606*
Type of vegetation	0.353

Table 3. Average density (ind./m²) of the European pond turtle's populations in the two large standing water basins in the study area.

	Rowing Canal	Plovdiv State Fishery
Average density (ind./m ²)	0.008	0.014

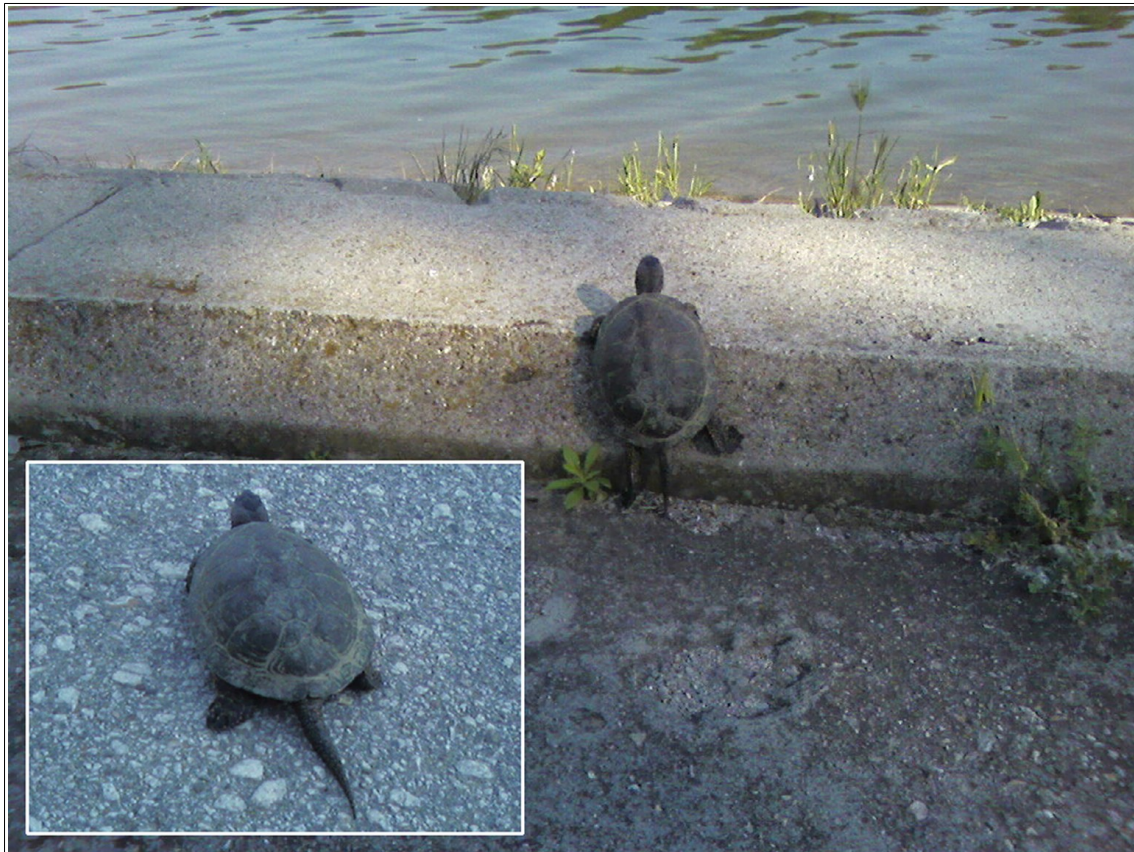


Fig. 3. European Pond Turtle (*Emys orbicularis*) – subadult specimen from the Rowing Canal in the city of Plovdiv (15.05.2008, photo: I. Mollov).

Population densities of *E. orbicularis* may vary considerably, depending on the region. In general the population density of European pond turtle in Plovdiv City is extremely low. Extensive review on the population densities of this species in various regions throughout its range is given by [AYAZ et al. \(2008\)](#) and other authors, unfortunately data comparisons are impossible, due to the different methods used.

Conservation significance, problems and threats

According to the contemporary Bulgarian and international legislation the

European pond turtle is included in Appendices II and III of the Bulgarian Biodiversity Act ([BDA, 2002](#)); Appendix II of the Convention for the Conservation of Wild European Flora and Fauna and Natural Habitats, ([Bern Convention, 1979](#)); Appendices II and IV of Council Directive 92/43 of the Council of the European Economic Community of 21.05.1992 on the Conservation of Natural Habitats and Wild Fauna and Flora ([EC, 2006](#)); listed as “near threatened” (NT) category in the Europe's Red List ([COX & TEMPLE, 2009](#)) and the Red List of Endangered Species to [IUCN \(2019\)](#).

Emys orbicularis is characterized by high conservation significance at national and international levels. Although it is common species in the country, its conservation is necessary in order to preserve the native herpetofauna (as part of European and world fauna) and to preserve biodiversity in cities.

The main threat for the species in the city of Plovdiv is the direct destruction by man and partly the loss of habitats. A negative influence on the populations comes from the collecting of live specimens by private collectors. According to BESHKOV (1993), and corroborated by our observations, occasionally *E. orbicularis* are caught by accident on the hooks of fishermen, and most of them are often killed afterward. The two species of aquatic snakes are also killed by fishermen because they rarely "attack" the caught fish.

Keeping the red-eyed slider (*Trachemys scripta elegans*) as a pet and releasing it into various water basins in the city can lead to the potential distribution of this highly invasive species, which is a competitor to *E. orbicularis*.

On the basis of the results of the present study, we can make the following recommendations for the conservation of the *Emys orbicularis* populations in Plovdiv City.

A particularly negative influence on the species' populations is the so-called "cleaning" of the Maritsa River bed, which is carried out periodically by the municipality. This cleaning does not only remove the trees, branches and debris that fall in the river bed, but also all the tree and shrub vegetation along the shore. This activity not only directly destroys the habitats, but also increases water erosion. Our recommendation is that river clearing is limited only to the cleaning of the branches and debris that have entered the water and the bed of the river.

Another very negative impact is caused by the collection of sand and inert materials from the banks of the Maritsa River. This activity in some places has led to unrecognizable river banks, as some species are directly affected, including *E. orbicularis*.

A positive role for the distribution of the European pond turtle in the city has been the construction of a dense network of irrigation canals on the outskirts of Plovdiv City. In order for this network to continue to function, it is necessary to maintain and repair it in many places.

With regard to the pollution of water basins, where *E. orbicularis* occur in the city, we recommend detailed future research on and monitoring of the impact of the most common pollutants in these ponds, as well as on the reproduction and survival rates of the species in these areas.

Conclusions

According to the data for the last 100 years, the European pond turtle in the studied region is increasing its distribution range within the city, due to the development of dense system of irrigation canals. The presence of the invasive species *Trachemys scripta elegans* was registered in the region of Plovdiv. The abundances and average density of the populations are relatively low and the age structure of the population of *E. orbicularis* from Maritsa River has the highest percentage of adults and juvenile individuals, indicating that the population of this species in the city is unstable. The main threat to European pond turtle in Plovdiv City is the anthropogenic factor, which is mainly through the loss of suitable habitats on the one hand and the direct destruction of specimens on the other.

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