Urban Ecology Studies of the Amphibians and Reptiles in the City of Plovdiv, Bulgaria

Ivelin A. Mollov

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PREFACE

Urban ecology is a rapidly developing scientific area, which undergoes constant change as new knowledge on the subject is acquired. Although modem cities are considered areas with low biodiversity the effects of urbanization on species richness can be either positive or negative, depending on several variables. Some of these variables include: taxonomic group, spatial scale of analysis, and intensity of urbanization.

Several studies show that each city is unique with its characteristics and environment, thus presenting new and interesting opportunities for species inhabiting them and new possibilities for scientists to study them. Having in mind that there are quite extensive urban ecology studies (including on amphibians and reptiles) on most western European cities, the cities from Eastern Europe and their biodiversity are somewhat overlooked and not quite well studied yet. The current monograph presents the data on the ecology of amphibians and reptiles from a 10-year study period and is the first of its kind for the city of Plovdiv (South Bulgaria) and one of the few for Eastern Europe.

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CHAPTER ONE

INTRODUCTION

In contemporary environmental research, the study of the impact of urbanization on animal and plant communities, the preservation of biodiversity in cities, and the creation of a sustainable urban environment for the biota and its proper management is taking a very serious place.

The concentration of the human population in cities and the significant urban development and growth rates have led to the emergence of specific, particular environmental conditions, forming populations and communities of animals and plants, that are significantly different from those occurring in nature. The emergence of modern cities is also associated with the emergence of urban ecosystems. The species' composition, structure of populations and communities in these ecosystems is by default not accidental, but is a reflection of objective processes occurring in specific conditions in the urbanized territories (Vershinin 1997, 1-47).

Urbanization is recognized to be one of the main factors for habitat loss leading to local biodiversity extinction in urban areas (McKinney 2008, 161-176). It was also recognized that the negative impact of habitat loss can be ameliorated through adequate management plans. Furthermore, habitat loss and habitat configuration are two of the most important aspects when studying ecosystems in urban areas (Löfvenhaft, Runborg, and Sjögren-Gulve 2004, 403-427).

As urbanization is spreading rapidly across the globe, a basic challenge for conservation is to understand how it affects biodiversity. Although urbanization often causes extinctions of native species, the complex nature of urban land use can have a complicated influence on local biodiversity. Several studies have described the effects of urbanization on species richness, indicating that urbanization can affect species richness either positively or negatively, depending on several variables. Some of these variables include: taxonomic group, spatial scale of analysis, and intensity of urbanization (McKinney 2008, 161-176). Under the conditions of urbanization, some species undergo a process of synanthropization, while other species cannot adapt to the new conditions and are isolated in separate fragmented populations, or pushed outside the city (Vershinin 1997, 1-47).

According to Marzluff (2001, 19-47), recent reviews of birds (the most studied group on this issue) indicate that species richness generally decreases with increasing urbanization in most cases or does not change significantly. A lot less attention is given to the other vertebrate taxa, especially aquatic and semi-aquatic species (fishes, amphibians and reptiles).

Amphibians and reptiles represent a very important component of urban ecosystems. They occur in a variety of terrestrial and aquatic habitats 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 and communities. Scientific publications of recent years have shown opportunities for the use of amphibians and reptiles as model animal groups in complex urban studies (Vershinin 1997, 1-47; Bolshakov, Pyastolova, and Vershinin 2001, 315-325; Ficetola and DeBernardi 2004, 219-230; Jellinek, Driscoll, and Kirkpatrick 2004, 294-304). However, this problem is still poorly studied in Europe, and especially in Bulgaria.

The problem of clarification of the synanthropic processes and changes occurring in the amphibian and reptile populations in urban environments is very topical, and studies in this area will help to effectively plan conservation and restoration activities for the urban herpetofauna.

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. Amphibians and reptiles, as important components of this biodiversity, have not been the subjects of extensive research so far. This raises the need to carry out the fullest possible study of the processes of synanthropy and the adaptation of populations and communities of amphibians and reptiles to the environmental factors in the city of Plovdiv and its surroundings.

CHAPTER TWO

MAIN PRINCIPLES OF URBAN ECOLOGY

According to Klausnitzer (1990, 1-246), urban ecology studies living organisms in relation to their environment in cities and other human settlements. It is an independent, specific area in ecology and, more specifically, in landscape ecology (Dedyu 1989, 1-408). Objects of the study of urban ecology include human settlements, industrial zones, roads, etc. One of its main objectives is the optimization of the urban environment from an ecological point of view. Its main tasks can be summarized in the following two points: (1) organization of environmental monitoring in cities and their surroundings; and (2) study of the state of flora and fauna, pollution due to pesticides and heavy metals, and the impact of urban factors on living organisms, including on human health (Dedyu 1989, 1-408).

Urbanization poses the following problems to humanity: the vulnerability of fragile urban ecosystems; concentration and migration of the human population from villages to cities; poor quality of the habitats of many animal species; loss of biodiversity and fertile land; accumulation of pollutants, changing the local climate, etc. (Steams 1970, 1006-1007; McDonnell and Pickett 1990, 1232-1237; Trepl 1994, 15-19; Sukopp and Zerbe 1996, 107-124; Comelis and Hermy 2004, 385-401).

Historically, the big city is an unsustainable end-stage in the development of human settlements (Klausnitzer 1990, 1-246). In the current monograph, the European concept of “city”, a “socio-spatial unit with a cohesive residential and administrative centre”, is used, unlike the American one, which defines it as “a conglomerate of settlements in whose center are administrative buildings, and the residential buildings are in the surrounding area” (Skibniewska 1994, 11-14).

The urban environment is a heterogeneous mosaic of residential and industrial buildings, road networks, parks and other types of green areas (McIntyre 2000, 825-835). The detailed mapping and classification of the built-up area among the open spaces, or the so-called “urban matrix”, is used to monitor and model the processes taking place in urban ecosystems, in architectural plans and in management plans (Pauleit and Duhme 2000, 1-20). The other main components of land cover in cities are green areas, urban parks, open spaces, etc. Their spatial characteristics are related to the study, maintenance and conservation of biodiversity in cities (Comelis and Hermy 2004, 385-401).

According to McDonnell and Pickett (1990, 1232-1237), in order to properly understand and manage the urbanization processes, it is necessary to classify the individual components of the urban environment (physical and chemical factors, populations, communities, ecosystems and human intervention) and assess the links between them to identify ecologically important impacts of urban factors.

According to Bunce and Jongman (1993, 3-10), the main concepts in landscape ecology, which are the theoretical basis in urban ecology as well, are the following:

1. *Sustainability concept.* Sustainability is the capacity of an ecosystem to maintain life and preserve it as a system. This is one of the main approaches in landscape ecology, in which it is essential to maintain ecosystems that self-reproduce and do not lose nutrients or species/genes. This principle is increasingly included in urban planning programs.

2. *Landscapes hierarchy concept.* Landscapes operate at different levels, and include complexes of different elements. Research design may include territories from hundreds of thousands of square kilometers to individual fragments of several square kilometers (for example, in cities).

3. *Urban-to-rural gradient concept.* This was proposed for the first time in the 1970s by Klausnitzer, on the basis of his research in Leipzig (1990, 1-246). Consequently, the concept was further elaborated by McDonnell and Picket (1990, 1232-1237) and McDonnell et al. (1997, 21-36). According to the main postulate of the concept, urbanization causes changes in the natural environment that can be traced to different levels of organization of the biota, from the city center (urban area) through their suburban zone to the natural (often semi-natural) habitats in the rural area. These environmental variables affect the structure and function of populations, communities or entire ecosystems (McDonnell and Pickett 1990, 1232-1237).

4. *Concept of biodiversity conservation.* The greater the anthropogenic pressure on semi-natural biotopes, the greater the need to take care of the biodiversity. This concept is key to planning and managing landscapes. Human interference can disturb or maintain high biodiversity, depending on the mode of action. Many natural and semi-natural ecosystems, which in the past occupied enormous territories, are now fragmented as part of the urban green areas (Sukopp and Weiler 1988, 39-58).

5. *Concept of the metapopulation.* This concept represents the relationships between subpopulations in more or less isolated fragments in one landscape and helps us understand the impact of progressive isolation (e.g. in cities) on the vegetation of these fragments and associated animal populations. Typical processes in metapopulations are temporary extinction and recolonization. There are three key points:

a) Subpopulation dynamics (rate of disappearance and immigration) – if a fragment is small and isolated, the rate of disappearance may exceed that of recolonization and the subpopulation will disappear.

b) The connectivity between the fragments – important landscape variables include the absence of barriers and the presence of corridors.

c) The spatial and temporal variation (gradient) of the quality of the biotope – this is influenced by the absence or presence of human activity.

Another theoretical basis of urban ecology as part of the landscape ecology comes from *The Theory of Island Biogeography* (MacArthur and Wilson 1967). In the context of habitat fragmentation, this theory addresses individual urban habitats as *"islands"* that belonged in the past to a large natural biotope. These "islands" are small in size, isolated from each other by barriers (roads or buildings), with changed microclimatic conditions (Klausnitzer 1990, 1-246). Preston (1962, 185-215) predicts that the big non-fragmented habitat would support many of the rare species that do not exist in the small, isolated "islands" of the same habitat, and therefore it should have a richer species composition. MacArthur and Wilson (1967) themselves emphasize that the widespread use of the theory is limited because the processes of dissemination, competition, invasion and adaptation are some of the most difficult to study and interpret.

The issue of the impact of habitat isolation and fragmentation on biodiversity has been studied by many authors (Bunce and Jongman 1993, 3-10; Clergeau 1996, 102-104; Fisher 1998, 155-158; Kotze and Samways 1999, 1339-1363; Bolger et al. 2000, 1230-1248; Gibbs 2000, 314-317; Gibb and Hochuli 2002, 91-100; Hunter 2002, 159-166; Wade et al. 2003; Comelis and Hermy 2004, 385-401; Schoereder et al. 2004, 1-8; Zanette, Martins, and Ribeiro 2005, 105-121), using spiders, carabid beetles, ticks, flies, butterflies, bees, birds, squirrels, etc. as model species.

CHAPTER THREE

ECOLOGICAL STUDIES ON MODEL GROUPS OF ANIMALS IN URBAN ENVIRONMENT

More and more studies are beginning to address ecological characteristics of urban areas around the world (Sukopp and Werner 1982; McDonnell and Pickett 1990, 1232-1237; Sukopp and Numata, 1995; Grimm et al. 2000, 571-584). Human activity can directly affect land cover, which in turn determines biodiversity, primary productivity, soil quality and water regime. Urban areas also influence the microclimate and air quality, changing the characteristics of the ground surface, which leads to the production of additional heat – the so-called *"urban heat island effect"* (Oke 1987, 1-24). The increase in impervious surfaces in cities is reflected in both geomorphological and hydrological processes in changes in water runoff and deposition of sediments (Leopold, 1968; Arnold and Gibbons, 1996). Transformation of land cover favors organisms capable of rapid colonization that can quickly adapt to these new conditions and tolerate the presence of people, and in urban environments they usually dominate over many endemic and sensitive organisms with a narrower ecological specialization. As a result, urbanized areas typically have unusual combinations of community-forming organisms in which *"ecotone species"* typically increase and *"interior species"* decrease (Marzluff 2001, 19-47).

According to some authors (Trojan 1981, 3-12; Niemelä et al. 2000, 3-9; Collins et al. 2000), the low anthropogenic press increases the species richness of some animals in the cities. This is due to the newly created urban habitats, their mosaic location and the many ecotones that urbanization creates (Frankie and Ehler 1978, 367-387). However, with a high degree of degradation of the environment, one or two species remain dominant, while others disappear or occur in very few habitats and play no significant role in the flow of energy into the ecosystem (Trojan, Górska, and Wegner 1982, 125-135).

There are relatively few generalized and in-depth studies on animals in urban areas, except for their consideration as pests (McIntyre 2000, 825-835). Little attention is paid to the influence of the developing urban environment on their abundance and diversity. There is still no way to know how most animals respond (positively, negatively or neutrally) to urban conditions.

There are three main types of reactions of animal communities to urban environment changes: degradation, enrichment and transformation (Trojan, Górska, and Wegner 1982, 125-135). Reactions may be direct (deaths due to pollution or habitat loss) or indirect (as a result of habitat change or abundance of food resources) (McIntyre 2000, 825-835).

Birds are perhaps the most obvious and easily recognizable fauna in cities and as such have received considerable attention from ecologists compared to other animal groups. Individual local communities can be characterized either with low species richness and high abundance or with high species richness and low abundance (Wood, Greenwood and Agnew 2003, 206-216). Increasing the abundance of some species of birds in urban environments is due to their ability to absorb extraneous resources that are abundant in cities (for example, food and nesting sites) and habitats that occur only in man-made areas (Jones and Wieneke 2000, 53-60).

Local ecological factors influencing urban habitats also play an important role in determining the presence and distribution of species in urban environments (White et al. 2005, 123-135). Most studies in this regard show that preserving the high diversity of birds in habitats is directly dependent on the creation and maintenance of structurally complex and floristically diverse habitats that are dominated by native species (Recher and Serventy 1991, 90-102; Parsons, French, and Major 2003, 43-56; French, Major, and Hely 2005, 545-559; White et al. 2005, 123-135). Sewell and Catterall (1998, 41-64) add that maintaining indigenous plant species and not exotic ones is key to the successful recovery and maintenance of insectivorous birds in cities.

According to many authors, native mammalian species, especially those of medium size, are most sensitive to habitat changes due to urbanization with accompanying secondary influences, such as introduced predators, inter-species competition and human-induced mortality (How and Dell 1993, 28-47; Tait, Daniels, and Hill 2005, 346-359). Currently, most of the studies on mammalian urban communities focus on different aspects of the food spectrum and species' behavior (Markus and Hall 2004, 345-355), with significantly fewer studies focusing on the study of species-habitat interactions at different levels of the dynamic urban environment. The most commonly studied species of mammals are those that are easily recognized and observed (Smith and Murray 2003, 291-301; Goldingay and Sharpe 2004, 663-677; Matthews et al. 2004, 159-168).

Similar to bird studies, achieving a more comprehensive understanding of the interactions between mammalian communities and urban habitats is a significant challenge. The reason for this is the large diversity of habitats and factors that act at different ecological levels in cities, affect the distribution and species abundance, and cause species-specific reactions. How and Dell (2000, 198-217), for example, suggest that mammals are generally more influenced by habitat fragmentation, whereas McAlpine et al. (2005, 7-11) conclude that the loss of habitats plays a more important role than their fragmentation and the density of the road network.

In the scientific literature, amphibians and reptiles are united by many authors under the common name *"herpetofauna"*, although the two classes of animals exhibit different reactions to urbanization and related environmental changes. There is currently a huge gap in our knowledge of the understanding of habitats' requirements for both reptiles and amphibians in urban environments. For example, it is known that some species of reptiles are well adapted to urban environments, while others are limited to fragmented parts of habitats and often disappear locally. However, this pattern varies greatly between cities (How and Dell 1994, 132-140; 2000, 198-217; Cooper 1995, 21-28). Similar to birds and mammals, there is no information on the importance of the various environmental factors that affect different levels of the amphibian and reptile communities. It seems that the significance of the different factors varies between reptiles and amphibians, both as groups and between species (How and Dell 2000, 198-217; Anderson and Burgin 2002, 630-637; Jellinek, Driscoll, and Kirkpatrick 2004, 294-304). For example, according to Jellinek, Driscoll, and Kirkpatrick (2004, 294-304), lizards are more influenced by the composition and structure of vegetation, not by the size of habitats (with some exceptions). Drinnan (2005, 339-349) shows that the size of the habitats has a significant impact on amphibians. White and Burgin (2004, 109-123), on the other hand, argue that frogs are mainly affected by changes in water runoff and water quality. Drinnan (2005, 339-349) further reports that there is a threshold for amphibians and reptiles, and species more sensitive to urbanization require a significantly large fragmentation of habitats to ensure their survival (> 50 ha), while more adaptive species can inhabit much smaller fragments (approximately 4 ha).

Since invertebrates play a significant role in the ecosystems' functionality, such as reductants, parasites, pollinators and prey for many other species (Bhullar and Majer 2000, 171-173), it is crucial to understand the impact of urbanization on their populations and communities as well. A summary of current research on the problem shows that the large fragments of habitats with natural vegetation (Gibb and Hochuli 2002, 91-100; Clark 2004, 78-81; Hochuli et al. 2004, 63-69), the diversity of vegetation (Emery and Emery 2004, 124-130; Burwell and Grimbacher 2005, 62-76) and the quality of the habitats (Gibb and Hochuli 2002, 91-100; New and Sands 2002, 207-215; Dover and Rowlingson 2005, 599-609) are critical factors for the protection of invertebrates in cities. Other factors important for particular species include: the regime of fires (Gibb and Hochuli 2002, 91-100; New and Sands 2002, 207-215; Dover and Rowlingson 2005, 599-609) and inter-species relationships (Hochuli et al. 2004, 63-69; Burwell and Grimbacher 2005, 62-76; Dover and Rowlingson 2005, 599-609). Unlike other animal groups, the impact of urbanization on invertebrates is extremely specific and depends on the study group.

So far, studies have been carried out in Bulgaria on certain groups of the fauna of Sofia (Nankinov 1982, 387; Milchev 1985, 195-203; Markova 1998, 44-50; Markova, Georgieva, and Karadjova 2000, 19-24; Markova and Alexiev 2001, 151-157; Kamburova 2004, 451-455; Stoyanov, Kyutchukov, and Domuschiev 2004, 437-450; Antonova and Penev 2008, 103-110; Penev et al. 2008, 483-509). There are some in-depth systematic studies on terrestrial snails (Dedov and Penev 2000, 121-131; 2004, 307-318), carabid fauna (Niemelä et al. 2002, 387-401; Stoyanov 2004, 401-415), spiders (Antov et al. 2004, 355-362) and nematode fauna (Mladenov, Lazarova, and Peneva 2004, 281-297), conducted on the basis of the urban gradient concept. Episodic studies have been made on the species diversity of other invertebrate groups: ants (Antonova 2004, 423-428; Lapeva-Gjonova and Atanasova 2004, 417-422); centipedes (Stoev 2004, 299-306); opiliones (Mitov and Stoyanov 2004, 319-354); aphids (Tasheva-Terzieva 2004, 365-370), flies of the Phoridae family (Langourov 2004, 429-436) and others.

The majority of the above-mentioned articles on the vegetation and fauna of Sofia, as well as those about the climate and the soils of the city, are included in the book *Ecology of the City of Sofia. Species and Communities in an Urban Environment,* edited by Penev et al. (2004).

The landscape and architectural aspects of Sofia's ecology are discussed in the monograph of Kovachev (2005, 1-368), which also analyzes the historical development of the green areas of Sofia City from the end of the 19th century until the end of the 20th century.

A study on the terrestrial snails of Stara Zagora City and some rural areas was carried out by Irikov and Georgiev (2002, 5-16) and Georgiev (2008, 147-151). The authors examined the habitat distribution of snails in urban environments with some ecological and zoogeographic notes.

Studies on vertebrate animals in the urban environment have been conducted mainly in the city of Sofia on birds (Nankinov 1981, 25-35; 1982, 387; Kiuchukov and Todorov 1995, 7-9; Kodzhabashev, Dyankov and Simova 2000, 303-320; Kiuchukov 1995, 169-174; 2000a, 84-96; 2000b, 81-89; Kamburova 2004, 452-455) and mammals (Markov et al. 1994, 100-105). The bats of Plovdiv City and Stara Zagora City have also been studied (Stoycheva, Georgiev, and Velcheva 2008, 538-542; 2009, 83-93; Tilova et al. 2008, 129-136).

CHAPTER FOUR

A SYNOPSIS OF THE ECOLOGICAL STUDIES ON AMPHIBIANS AND REPTILES IN THE URBAN ENVIRONMENT

Studies on amphibians and reptiles in the urban environment

The majority of studies on amphibians and reptiles conducted in urban environments are mainly confined to the inventory of species composition and the distribution of species in the studied territory (Vershinin 1990, 67-71; Ruchin et al. 2003, 225; Chibilev 2003, 70-73; Kral, Pellantova, and Kokes 1983, 51-66; West and Skelly 1997, 197-203; Anton 1999, 211-232; Leontyeva and Semenov 1999, 69-275; Padhye and Mahabaleshwarkar 2000; Thakur and Gour-Broome 2000; Toth 2002, 163-167; Foster 2004; Rugiero 2004, 151-155; Strugariu et al. 2007, 31-43). Another major part of the research is focused on the habitat distribution of amphibians and reptiles in urban environments (Ruchin et al. 2003, 225; Beebee 1979, 241-257; Banks and Laverick 1986, 44-50; Chovanec 1994, 43-54; Webb and Shine 2000, 93-99; Fearn et al. 2001, 573-579; Shine and Koenig 2001, 271-283; Ensabella et al. 2003, 396-400; Gomez-Zlatar 2003, 1-105; Kühnel and Krone 2003, 299-315; Ficetola and DeBernardi 2004, 219-230; Bosman and Munckhof 2006, 23-25; Gagne and Fahrig 2007, 205-215; Garden et al. 2007, 669-685; Nicoară and Nicoară 2007, 22-29; Ottburg, Pouwels, and Slim 2007).

Studies on the influence of habitat loss, fragmentation and isolation on amphibians and reptiles

The importance of habitat loss and fragmentation, resulting in the reduction of amphibian and reptile populations, has been outlined in recent years by Cushman (2006, 231-240) and Gardner, Barlow, and Peres (2007, 166-179). These authors identify a gradient of increasing anthropogenic pressure on amphibian species, with a reduction in the structural complexity of the habitats. Many amphibian populations are naturally fragmented in the urban landscape at the local level, which can be included in larger networks of metapopulations at a regional level (Marsh and Trenham 2001, 40-49; Smith and Green 2005, 110-128). In addition, amphibians require additional habitats in different spatial scales to successfully complete their complex life cycle, and for this reason, their populations are fragmented or structured as metapopulations (Pope, Fahrig, and Merriam 2000, 2498-2508; Marsh and Trenham 2001, 40-49). Urbanization reduces the ability of these subpopulation networks to function due to the construction of roads and urban infrastructures, such as buildings, fences and open areas that suppress and hamper the distribution of amphibians (Vos and Chardon 1998, 44-56).

Almost all studies report a negative correlation between the level of urbanization and amphibian species' composition, presence/absence, abundance or community structure (Burnell and Zampella 1999, 614-627; Atauri and de Lucio 2001, 147-159; Houlahan and Findlay 2003, 1078-1094; Willson and Dorcas 2003, 763-771; Woodford and Meyer 2003, 277-284; Pearl et al. 2005, 76-88; Rubbo and Kiesecker 2005, 504-511; Bowles, Sanders, and Hansen 2006, 111-120; Parris 2006, 757-764; Gagné and Fahrig 2007, 205-215; Skidds et al. 2007, 439-450). In general, the decline of amphibian and reptile populations in urban areas is directly related to changes in the landscape structure due to urbanization, which leads to a reduction in wetlands and greater isolation (Lehtinen, Galatowitsch, and Tester 1999, 1-12; Rubbo and Kiesecker 2005, 504-511; Parris 2006, 757-764; Gagné and Fahrig 2007, 205-215).

Surveys on changes in amphibian and reptile habitats over a longer period of time show feedback between urbanization and existing habitats. Gibbs (2000, 314-317) conducted an urban-rural gradient mosaic analysis in the city of New York, USA, and reported a decrease in the number of wetlands and an increase in distances to the nearest adjacent habitat, correlating with the change in settlement patterns and rural development to urban. According to Wood et al. (2003, 206-216), the reduction of the populations of the northern crested newt (*Triturus cristatus*) in the UK is due to the loss of temporary standing water bodies caused by urban development. According to the same authors, these critical habitats are more endangered in the UK, as they are usually shallow, vulnerable to soil drainage and highly sensitive to pollution. In the same way, spring basins, which are the habitat of many amphibian species in the northeast of the United States, are also at risk of destruction from urbanization due to their small size and short-wave periods (Grant 2005, 480-487) and due to the fact that they are rarely placed under any protection (Dodd and Smith 2003, 94-112; Semlitsch 2003, 8-23). Small, temporary wetlands (<4.0 ha) are of great importance for the reproduction of amphibians and play a critical role in reducing distances between isolated habitats (Gibbs 2000, 314-317).

Urban habitats' creation and restoration

Amphibians and reptiles with common habitat requirements may exist within urban landscapes as they are able to use artificial habitats such as garden lakes, decorative fountains, micro dams, and irrigation canals. Indeed, there is evidence that some species have benefited from the construction of water reservoirs and wetlands, especially during the initial urbanization phase when amphibian colonization is less obstructed, as they can replace the functions of rural or natural ponds destroyed during this process with artificial ones (Hammer and McDonnel 2008, 2432-2449). For example, the common frog (*Rana temporaria*) in the UK occurs in cities and suburban areas more than in rural areas, most likely due to the abundance of artificial water basins (Carrier and Beebee 2003, 395-399). However, water basins and wetlands in urban and suburban areas are often limited in their suitability for amphibian species with more specific habitat requirements. In many of the ponds, there are artificially maintained exotic species of fish or inadequate hydrological regimes; they are often contaminated (fertilizers, sediments, pesticides, grease and oil, heavy metals), or are often visited by humans and have artificial lighting that makes reproduction difficult (Knutson et al. 1999, 1437-1446; Rubbo and Kiesecker 2005, 504-511; Baker and Richardson 2006, 1528-1532).

In addition, the characteristics of urban basins may exclude the occurrence of certain species in them. For example, a vertical wall of the pool may mean that it is only suitable for tree frogs (*Hyla arborea*), as they are able to climb out when leaving the pool (Parris 2006, 757-764). Urban wetlands are also often surrounded by roads and infrastructure that can form barriers to the distribution of amphibians, potentially making them inaccessible for moderate to widespread species (Rubbo and Kieseker 2005, 504-511). Therefore, some species with more specific habitat requirements can be attracted to artificially created habitats, but they cannot support a population, and so artificial urban habitats can function as *"ecological traps"* or *"source-sink" systems* (Battin 2004, 1482-1491). Some recreational activities could turn some, otherwise inappropriate, urban ponds and wetlands into amphibian breeding grounds. For example, wetlands in the Minnesota City area, USA, have been successfully restored by removing parts of the dikes, allowing the pools to be replenished and then colonized by amphibians (Lehtinen, Galatowitsch, and Tester 1999, 1-12). The restoration of wetlands on an island on the Danube River in Austria has been successful in attracting several amphibians by creating places where no carnivorous species are present (Chovanec 1994, 43-54).

In order to restore wetlands in urban landscapes to provide suitable habitats for amphibians, it is necessary to create and maintain appropriate fluctuations in the water regime, the presence of adjacent land habitats, good water quality, a connection with surrounding populations and a lack of local and exotic species of predatory fish (Beebee 1979, 241-257; Petranka et al. 2007, 371-380).

Quality of the amphibian and reptile habitats in the cities

The quality of the amphibian habitats is influenced by the size and type of vegetation in the ponds, wetlands and surrounding terrestrial habitats; the water regime, the quality of water, the presence of predators and competitors, and the nature and frequency of human-induced disturbances. Suitable habitats for amphibians should provide opportunities for breeding, foraging and dispersal, as well as places for refuge and hibernation (Wells 2007). Poor habitats cannot support viable populations, and such scarce habitats could potentially turn into "source-sink" systems and thus reduce the size of a larger metapopulation (McKinney 2002, 883-890).

Vegetation. Urbanization can lead to the loss of aquatic vegetation in lakes, swamps and streams, or the loss of forest and other terrestrial plant communities from the landscape. Aquatic vegetation provides shelter for larvae and adult amphibians and some reptiles, as well as places for laying eggs (Skidds et al. 2007, 439-450). Furthermore, vegetation in wetlands as well as terrestrial plant communities provide opportunities for dispersion, food, shelters and places for hibernation (deMaynadier and Hunter 1999, 441-450).

Water regime. The water regime and length of the ponds have a strong influence on the structure and composition of amphibian communities and aquatic reptiles (Werner et al. 2007, 1697-1712). For example, some species require short-lived ponds that retain water for a short period of time (e.g. one or two months), while others need permanent water habitats that never dry up. Rubbo and Kiesecker (2005, 504-511) suggest that the water regime can play a significant role in the distribution of amphibians in the urban-to-rural gradient due to the complexity of the life cycle of the species and the inter-specific relationships (predatory fish and other predators). The water regime can be changed as a result of urbanization, including changes in the degree, duration, frequency and peak of the water level, and the amount of water flowing. For example, urban development in the Portland area of Oregon, USA, has led to the transformation of large, shallow, well-overgrown, short-lived wetlands into smaller, deeper wetlands with less vegetation and more stable, permanent wetlands that are often inhabited by fish (Kentula, Gwin, and Pierson 2004, 734-743). The loss of temporary wetlands in this area has reduced the habitats of several amphibian species whose larvae have a rapid growth rate (e.g. *Ambystoma macrodactylum*), but on the other hand increasing the life of the water basins has allowed the existence of species with larvae with a longer period of metamorphosis (e.g. *Rana catesbeiana*) and some reptiles (Pearl et al. 2005, 76-88).

Urban water management can change the water regime of urban wetlands by increasing the probability of the drainage of water basins, especially during dry seasons or by re-directing the water elsewhere (Hogan and Walbridge 2007, 1142-1155). This practice may lead to a lower reproductive success of amphibians in urban and suburban areas. Larvae or metamorphosed specimens can perish under these conditions if they are unable to move to another wetland or wet micro-habitat. Changes in the hydrological regime can lead to the loss of refugia and breeding sites, reduced abundance of food, etc. (Willson and Dorcas 2003, 763-771). Increasing urbanization in riparian areas has the potential to reduce the quality of habitats of amphibians and aquatic reptiles and lead to a reduction of their populations. For example, Price et al. (2006, 436-441) suggest that the increased urbanization level from 1972 to 2000 near Davidson in North Carolina, USA, may be the cause of a significant and rapid reduction in the salamander population reported in this region.

Studies on the terrestrial habitats of amphibians and reptiles

Terrestrial habitats are particularly important for reptiles. Many amphibians also require terrestrial habitats that are not used for breeding but for access to essential resources such as shelter and food as well as hibernation sites. For this reason, the availability of suitable terrestrial habitats can be an important element of the mosaic of habitats suitable for amphibians and reptiles in the cities (Semlitsch 2003, 8-23). For example, Baldwin, Calhoun, and deMaynadier (2006, 442-453) report that the *Rana sylvatica* chooses wooded wetlands because it uses forests as a shelter in the summer after breeding. The migration of this species ranges from 120 to 340 m. For this reason, the conservation of amphibian populations in urban and suburban landscapes requires the conservation of not only aquatic habitats but also the terrestrial habitats near them.

The quality of terrestrial habitats also determines whether amphibians and reptiles can successfully disperse and move between green areas through the urban matrix. The movement and survival of amphibians and reptiles in terrestrial habitats is a critical moment that ensures successful distribution and recolonization within regional metapopulations (Semlitsch 2003, 8-23), but maintaining the connectivity between terrestrial habitats is a major challenge in urban and suburban landscapes (Gibbs 2000, 314-317). The dense network of roads, buildings, fences and other physical barriers does not allow many of the amphibians and reptiles to successfully spread among the numerous habitats (Knutson et al. 1999, 1437-1446; Dodd and Smith 2003, 94-112). Amphibians and reptiles are often killed while crossing roads, and such road traffic mortality may have significant impacts on their populations in cities, especially near breeding sites (Carr and Fahrig 2001, 1071-1078; Eigenbrod, Hecnar, and Fahrig 2008, 35-46). For example, using survival tables for *Ambystoma maculatum*, Gibbs and Shriver (2005, 281-289) show that per year the risk of adult mortality is about 10% and may lead to the destruction of the local population. The same authors have calculated that 22-73% of the population in central and western Massachusetts, USA, will be exposed to this threshold level of risk.

Predators and competitors

The presence of predatory fish, especially non-native species, in ponds and wetlands often leads to a reduction in the abundance and species diversity of amphibians. The larvae of many amphibian species are vulnerable to predation by some species of fish (Kats and Ferrer 2003, 99-110). Predatory fish are often absent from water basins and wetlands with a short water regime, and they are prone to remain in more durable ponds that often dominate urban and suburban areas (Kentula, Gwin, and Pierson 2004, 734-743). For example, Rubbo and Kiesecker (2005, 504-511) reported that fish are more common in permanent wetlands in cities and suburban areas than in less permanent ponds in rural areas in central Pennsylvania, USA. Therefore, they find that urban water basins have a lower abundance of amphibian larvae than those in rural areas.

In addition to the negative effects of predatory fish and some birds, amphibians are also subjected to negative pressures from pet animals, especially cats and dogs. For example, Wood et al. (2003, 206-216) estimated that the domestic cat population in the UK amounted to approximately 9 million specimens, killing 4 to 6 million reptiles and amphibians over a five-month study period.

Introduced non-native species of amphibians and reptiles, on the other hand, may compete with native species due to limited resources in urban areas (Kiesecker 2003, 113-126).

Studies on direct anthropogenic pressure

It is well known that amphibians react to direct human disturbances, artificial light (Baker and Richardson 2006, 1528-1532) and noise pollution (Bee and Swanson 2007, 1765-1776), as a result of which their reproductive behavior may change, potentially reducing the success of reproduction and thus disturbing the dynamics of the population. For example, Baker and Richardson (2006, 1528-1532) show that males of *Rana clamitans melanota* make less reproductive calls and move more often when exposed to artificial light than in normal light conditions.

In addition, many urban wetlands are intensively visited by people as they are used for active recreation. Rodriguez-Prieto and Fernandez-Juricic (2005, 1-9) assess the impact of the flow of people on *Rana iberica* in central Spain. By simulating different levels of human presence near the water basins used by frogs, they found about an 80% and 100% reduction in the basins used by frogs in correlation with a 5-fold and 12-fold increase in direct human disturbances, respectively.

In urban and suburban areas, amphibians are also collected by humans for food, as bait for fishing or as pets, which can also lead to a reduction in population size or to the introduction of invasive species in urban areas (Jensen and Camp 2003, 199-213).

Ecological studies on amphibians and reptiles in Bulgaria

Studies on the ecology of amphibians and reptiles in Bulgaria began in the 1960s. The first ecological publication in the Bulgarian herpetological literature belongs to Tuleshkov (1959, 169-180) and it is dedicated to the habitat selection of the sand viper (*Vipera ammodytes*). Subsequently, a number of studies have been carried out on the ecology of various representatives of amphibians and reptiles in Bulgaria. Peters (1963, 203-222) published some data on the ecology of *Lacerta trilineata* – mostly habitat preferences, 24-hour activity and the diet of the species in the country.

In 1963, Beshkov and Tsonchev conducted the first large study on the population, habitat preferences, daily and annual activity, feeding and breeding of the fire salamander (*Salamandra salamandra*) of the Vitosha Mts. (Beshkov and Tsonchev 1963, 79-91).

In the 1970s, Vladimir Beshkov conducted the first large-scale ecological and biological study of the Greek stream frog (*Rana graeca*), giving, for the first time, data on its diet, breeding, daily and seasonal activity, as well as the home range, habitat preferences and some population characteristics of this species (Beshkov 1970a, 79-91; 1970b, 159-180; 1972, 25-136).

The same author has explored different aspects of the ecology and biology of amphibians and reptiles in Bulgaria, giving, for the first time, data on: the breeding of *Zamenis longissimus* and *Vipera ammodytes* (Beshkov 1975, 75-83; 1977, 3-11); the population density and home range of *Bombina variegata* (Beshkov and Jameson 1980, 365-370); the reproduction and migration of *Rana temporaria* (Beshkov and Angelova 1981, 34-42; Beshkov 1988, 34-39); the population size, reproduction and migrations of *Bufo bufo* (Beshkov, Delcheva and Dobrev 1986, 62-70); the population size of *Mauremys rivulata* (Beshkov 1987, 58-64); the seasonal and daily activity of *Vipera ammodytes* (Beshkov 1993a, 3-12); and the reproduction of *Zootoca vivipara* (Beshkov, Guillaume and Heulin 1994).

In 1984, the largest and one-of-a-kind study on the distribution, population size and conservation measures of both tortoise species in Bulgaria – *Testudo hermanni* and *Testudo graeca* – was published (Beshkov 1984, 14-34).

The only study on the impact of industrial pollution on the distribution of amphibians and reptiles in Bulgaria from that period also belongs to the same author (Beshkov 1978, 3-11).

Several more targeted studies have been carried out over the past few years on the ecology of certain species of reptiles in terms of specific environmental problems – the effect of fires on the population dynamics and structure of the green lizard (*Lacerta viridis*) (Popgeorgiev and Mollov 2005, 95-108), *Testudo hermanni* and *Testudo graeca* (Popgeorgiev 2008a, 115-127) and other amphibian and reptile species (Popgeorgiev 2008b; 2009) in the Eastern Rhodopes Mts. and Sakar Mts.; on the population size and habitat preferences of six species of sympathetically occurring lizards (Tzankov 2005, 235-242) and one study on the population size and density, sex and age structure of *Testudo hermanni* and *Testudo graeca* (Ivanchev 2007, 153-163; Zhivkov et al., 2007, 1015-1022; Zhivkov, Raikova-Petrova and Trichkova 2009, 11-26).

In the last few years, a series of studies have been carried out on the possibility of using some morpho-physiological parameters of *Pelophylax ridibundus* for the purposes of ecological bio-monitoring in Bulgaria (Boyadzhieva et al. 2001, 165-171; Zhelev et al. 2001, 99-104; Zhelev, Adzhaliyski and Koycheva 2002a, 121-128; 2002b, 113-120; Zhelev and Mollov 2004, 137-151; Zhelev, Petkov and Adzalijski 2005, 229-236; Zhelev, Angelov and Mollov 2006, 235-244; Velcheva et al. 2006, 155-160; Zhelev 2007, 181-190 and others).

Literary overview on the species composition of amphibians and reptiles in the city of Plovdiv and its surroundings

An extensive review of the literature on the herpetofauna in the territory of the city of Plovdiv and its surroundings showed that there is data on 10 species of amphibians and 16 species of reptiles (not in alphabetical order):

Triturus ivanbureshi (Arntzen and Wielstra, 2013) – Kovachev (1912, 1-90); Buresh and Tsonkov (1941, 71-237); Angelov and Kalchev (1961, 18-21);

Lissotriton vulgaris (Linnaeus, 1758) – Kovachev (1905a, 1-50; 1905b, 1-13; 1912, 1-90); Buresh and Tsonkov (1941, 71-237); Angelov (1960a, 7-40); Angelov and Kalchev (1961, 18-21);

Bombina bombina (Linnaeus, 1761) – Kovachev (1912, 1-90); Buresh and Tsonkov (1942, 8-165); Angelov and Kalchev (1961, 18-21); Beshkov (1961, 16-18); Beškov and Beron (1964, 1-39); Beshkov et al. (1967, 5-10);

Bombina variegata (Linnaeus, 1758) – Angelov (1960b, 333-337); Angelov and Kalchev (1961, 18-21); Donev (1984b, 115-120);

Bufo bufo (Linnaeus, 1758) – Kovachev (1912, 1-90); Buresh and Tsonkov (1942, 8-165); Angelov (1960b, 333-337); Angelov and Kalchev (1961, 18-21);

Bufotes viridis complex – Buresh and Tsonkov (1942, 8-165); Angelov (1960a, 7-40; 1960b, 333-337); Angelov and Kalchev (1961, 18-21); Cyren (1941, 36-146); Euzet, Combes, and Batchvarov (1974, 129-140);

Pelobates syriacus balcanicus (Karaman, 1928) – Buresh and Tsonkov (1942, 8-165); Angelov and Kalchev (1961, 18-21); Beškov and Beron (1964, 1-39);

Rana dalmatina (Bonaparte, 1840) – Angelov (1960b, 333-337); Angelov and Kalchev (1961, 18-21); Popov (1973, 121-125); Bachvarov (1980, 183-190);

Pelophylax ridibundus (Pallas, 1771) – Angelov (1960a, 7-40; 1960b, 333-337); Popov (1973, 397-404; 1975, 13-17); Donev (1984a, 35-44; 1986, 81-102); Cyren (1941, 36-146); Bachvarov (1968, 143-152);

Hyla arborea complex – Angelov (1960a, 7-40; 1960b, 333-337); Angelov and Kalchev (1961, 18-21); Cyren (1941, 36-146);

Mediodactylus kotschyi (Steindachner, 1870) – Shkorpil (1897, 1-23); Kovachev (1905b, 1-13; 1910, 1-16; 1912, 1-90); Buresh and Tsonkov (1933, 150-207); Müller (1939, 1-17);

Ablepharus kitaibellii (Bibron et Bory, 1833) – Mollov (2005b, 79-94);

Emys orbicularis (Linnaeus, 1758) – Kovachev (1910, 1-16); Buresh and Tsonkov (1933, 150-207); Angelov (1960a, 7-40); Kirin (2001, 95-98);

Testudo graeca (Linnaeus, 1758) – Buresh and Tsonkov (1933, 150-207); Drenski (1955, 109-166); Angelov (1960a, 7-40); Beshkov et al. (1967, 5-10);

Testudo hermanni (Gmelin, 1789) – Shkorpil (1897, 1-23); Drenski (1955, 109-166);

Lacerta trilineata (Bedriaga, 1886) – Kovachev (1907, 217-218; 1912, 1-90); Buresh and Tsonkov (1933, 150-207); Angelov, Tomov and Gruev (1966, 99-105);

Lacerta viridis (Laurenti, 1768) – Buresh and Tsonkov (1933, 150-207); Angelov (1960a, 7-40); Angelov, Tomov and Gruev (1966, 99-105); Donev (1984c, 45-50);

Podarcis muralis (Laurenti, 1768) – Kovachev (1905b, 1-13); Buresh and Tsonkov (1933, 150-207);

Podarcis tauricus (Pallas, 1814) – Kovachev (1912, 1-90); Buresh and Tsonkov (1933, 150-207); Angelov, Tomov and Gruev (1966, 99-105); Donev (1984c, 45-50); Cyren (1933, 219-246);

Dolichophis caspius (Gmelin, 1789) – Buresh and Tsonkov (1934, 106-188);

Coronella austriaca (Laurenti, 1768) – Kovachev (1905b, 1-13; 1912, 1-90); Buresh and Tsonkov (1934, 106-188);

Zamenis longissimus (Laurenti, 1768) – Kovachev (1912, 1-90); Buresh and Tsonkov (1934, 106-188); Beshkov and Dushkov (1981, 43-50);

Elaphe sauromates (Pallas, 1814) – Kovachev (1912, 1-90); Buresh and Tsonkov (1934, 106-188);

Natrix natrix (Linnaeus, 1758) – Kovachev (1912, 1-90); Buresh and Tsonkov (1934, 106-188); Angelov (1960a, 7-40); Bachvarov (1969, 191-196) Kirin (1994a, 35-39; Kirin; 1994b, 41-46; 1995, 77-80);

Natrix tessellata (Laurenti, 1768) – Kovachev (1912, 1-90); Buresh and Tsonkov (1934, 106-188); Angelov (1960a, 7-40); Kirin (1994a, 35-39);

Vipera ammodytes (Linnaeus, 1758) – Kovachev (1905b, 1-13; 1912, 1-90); Buresh and Tsonkov (1934, 106-188); Beshkov and Dushkov (1981, 43-50).

Ecological studies on amphibians and reptiles

Apart from the fragmentary data on the distribution of individual amphibians and reptiles, which are also found in Plovdiv City, two preliminary studies on amphibians and reptiles have been conducted in Plovdiv and its surroundings. One studies the problem of the impact of road traffic on the populations of two species of amphibians (*Bufotes viridis* complex and *Bufo bufo*) in Plovdiv (Mollov 2005a, 82-88). The other study is an overview article on the species composition and distribution of amphibians and reptiles in three protected areas in Plovdiv with ecological, conservation and zoogeographic notes (Mollov 2005b, 79-94).

Currently, there is a huge gap in the data on the abundance, density, sex and age structure of the populations, habitat distribution, seasonal and daily activity, and other ecological characteristics of amphibian and reptile populations and communities in the city.

CHAPTER FIVE

METHODOLOGY FOR URBAN ECOLOGICAL STUDIES ON AMPHIBIANS AND REPTILES

The data presented in this monograph was obtained in the period from March 2007 to October 2010 in the territory of Plovdiv City and its surroundings (see Chapter Six). For some of the species, data from older observations (2002-2006) from the same region was also used.

Field methods. The amphibians and reptiles were determined visually, using available field guides (Bannikov et al. 1977, 1-414; Arnold and Ovenden 2002, 1-288; Biserkov et al. 2007, 1-196). For every recorded species, a valid Bulgarian and Latin name is given following Biserkov et al. (2007, 1-196) and Speybroeck, Beukema and Crochet (2010, 1-27). A new specific name for the eastern taxon of the *Triturus karelinii* group was proposed by Wielstra et al. (2013, 441-453) – *Triturus ivanbureshi* (Wielstra and Arntzen, 2013). The species *Hyla orientalis* (Bedriaga, 1890), mentioned for Bulgaria by Frost (2013), seems to have a contact zone with *Hyla arborea* in Bulgaria, as they co-occur in close proximity in eastern Serbia and northeastern Greece (Stock et al. 2012, 1-9). According to Tzankov and Popgeorgiev (2015, 131-139), both taxa were recorded via bioacoustics in the country, so it is listed as "*Hyla arborea* complex" in the current work. Finally, the generic name *Bufotes* (Rafinesque, 1815) has been assigned to green toads, and even though the species *Bufotes viridis* (Laurenti, 1768) was listed for Bulgaria, it appears that *Bufotes variables* are also present in the country. Since the taxonomic state of the green toad in Plovdiv City is still unclear, it is also listed as "complex".

In some cases, amphibians and reptiles were captured manually or with the help of snares, loops, etc. for more accurate determination before being released at the same place. Some individuals were identified by their sounds, eggs, larvae or skin sheds.

For each recorded species, the following general and specific information was collected:

- The general data for each individual observed includes:
    - species affiliation;
    - date, time, place of observation and altitude (marked with the GPS receiver "Garmin eTrex Vista");
    - perpendicular distance (in meters) from the medial axis of the line transect to the individual;
    - sex (where it was possible to determine it); for the anurans, sex was determined based on the characteristics indicated by Biserkov et al. (2007, 1-196); for the lizards it was based on the characteristics given by Tsankov (2007, 1-40) and Biserkov et al. (2007, 1-196); and for the turtles it was based on the characteristics given by Biserkov et al. (2007, 1-196);
    - age group (adult, subadult and juvenile) established on the basis of the dimensional characteristics and coloration of the individuals (Bannikov et al. 1977, 1-414; Biserkov et al. 2007, 1-196; Arnold and Ovenden 2002, 1-288);
    - the dominant vegetation in the habitat.
- Specific data:
    - For the anurans, information was collected on the number of clumps, cords and single-lay eggs found.
    - For the marsh frog (*Pelophylax ridibundus*), the morph was also recorded in some cases (see Vershinin 2006, 197-200).
    - The green toad (*Bufotes viridis* complex) was marked with mark-recapture using photographic images on the dorsal side of individuals and software for auto-mathematical recognition of images (Sutherland 2000, 1-278; Speed, Meekan, and Bradshaw 2007).
    - For all lizard species (Reptilia, Sauria), the tail state was noted – whole, missing or regenerated (Strijbosch, Helmer, and Scholte 1989, 151-174).
    - Additional morphometric data on the eggs (length and width), measured by using a digital caliper with an accuracy of 0.01 mm, were gathered for the Kotschy's gecko (*Mediodactylus kotschyi*). The egg volume was calculated as an ellipsoid: $V=4/3\pi a^2 b$, with *a* and *b* indicating half the width and length of the egg (Arribas and Galan 2005, 163-190).

For each species, a zoogeographic classification was done on the basis of the works of Beškov and Beron (1964, 1-39), Gruev and Kuzmanov (1999, 1-344), Gruev (2000, 73-94; 2002, 31-40) and Undzhian (2000, 1-

88). The zoogeographic categories (complexes, elements, subelements) are given following Gruev and Bechev (2000, 5-34).

For each species, its current conservation status is given according to contemporary Bulgarian and international nature conservation legislation, as well as the specific conservation problems and threats in the studied area.

For each registered species, the index of occurrence (A) was calculated, using the following Formula 1 (Dyakov 1971, 301-308; Petrov and Mitchev 1985, 43-48):

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

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.

We identified Important Herpetological Areas (IHA) in the study area, based on the number of localities and number of species detected in a given territory. Polygons were generated by using the Kernel Index from Hawth's analysis tools extension for ArcGIS 10 (ESRI 2011; Beyer 2004).

For the comparison of the number of amphibians and reptiles along flowing water basins, the abundance (Ab) was calculated. According to Turpie (1995, 175-185) and Sutherland (2000, 1-278), 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 (Formula 2). Data obtained in this way gives a better opportunity for comparison and analysis.

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

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

The line transect method was used to calculate the population density (Heyer et al. 1994, 1-364; Sutherland 2000, 1-278). Transects were selected at random and the distance traveled was recorded using a GPS receiver. The transect width is fixed at 5 m (2.5 m on each side of the median line of observation). The density is calculated using Formula 3:

$$D_e = \frac{n}{2\text{rl}} \times 10000 \quad (3),$$

where De – ecological density, expressed in the number of individuals per hectare (ha); n – the number of observed individuals; r – the distance to the observed individual from the median line; and l – transect length.

For the calculation of the average density of amphibians and reptiles populations (Ds) 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 Formula 4 (Sutherland 2000, 1-278):

$$D_S = \frac{n}{A} \text{ (4)},$$

where Ds – 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.

Individual marking was done only on the green toad (*Bufotes viridis* complex) to trace those parameters that cannot be detected by the line transect method (density, migration, sex and age structure of the populations), using the Lincoln-Petersen index (Begon, Harper, and Townsend 1986, 1-876; Sutherland 2000, 1-278). Only the green toad was subjected to individual tagging, as it is the only species in the research area whose coloring and morphology allow us to use the method with automatic recognition of photographic images of the dorsal side of individuals, where toads are not captured, injured or stressed.

The mortality of the green toad was calculated as a percentage (%) for each age and sex group separately. The ratio was formed as the number of dead individuals in a given group to the total (dead + live individuals) of the same group. The likelihood that toads would be killed on the roadway by road traffic is calculated using Formula 5, given by Gibbs and Shriver (2002, 1647-1652):

$$P_{\text{killed}} = e^{-Na/v} \text{ (5)},$$

where P_{killed} – the probability with which the animal would die when trying to cross the road; N – the number of passing cars in 1 minute; a – the width of the danger zone (the area through which the tires are passing) from the width of the road (in m); v – the speed at which the animal moves (in m/min); and e – the basis of the natural logarithm.

The species diversity of amphibian and reptile communities is reported with the Simpson (S) and Shanon-Wheiner (H') indices (Begon, Harper, and Townsend 1986, 1-876).

The reciprocal value of the Simpson Diversity index is calculated by the following Formula 6 (Begon, Harper, and Townsend 1986, 1-876):

$$S = \frac{1}{\sum p_i^2} \quad (6),$$

where S – Simpson's Diversity index; and p_i – proportion of species i.

The Shannon-Wheiner Diversity index is calculated with the following Formula 7 (Begon, Harper, and Townsend 1986, 1-876):

$$H' = -\sum_{i=1}^{S}(p_i \ln p_i) \quad (7),$$

where S – the number of species; and p_i – the relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community.

Differences in amphibian and reptile communities were analyzed by cluster analysis (Bray-Curtis index, group-average link).

Berger-Parker (d) was used for the dominance index. As a criterion for species richness, Hill's numbers were used (Hill 1973, 427-432). The calculations of the mentioned indices and cluster analysis were performed with the program "BioDiversity Pro" (McAleece et al. 1997).

To calculate the degree of synanthropy, two major indices were used. Firstly, the Jędryczkowski (*Ws*) Synanthropic Index (Jędryczkowski 1979, 95-106), which shows the level of synanthropic species in the community (Formula 8):

$$W_s = \frac{L_s}{L_o} \quad (8),$$

where *Ls* – the number of synanthropic species; and *Lo* – the total number of species in the community.

The Index of Synanthropy (*SI*) proposed by Nuorteva (1963, 1-49), allowing a more precise classification on a species level, was also used (Formula 9, adapted by Mollov 2014, 109-112):

$$SI = \frac{2a + b - 2c}{2} \quad (9),$$

where *a* – percentage (%) of the individuals in the urbanized area (human settlements); *b* – percentage (%) of individuals in suburban areas; and *c* –

percentage (%) of individuals in the biotope, little affected by anthropogenic influence (rural areas).

The Index of Synanthropy has values from +100 to -100, where:

+100 – Full preference for densely populated urban areas and human settlements;
+75 – Clear preference for urban areas and human settlements;
+50 – Slight preference for urban areas;
0 – Indifferent to urban areas and human settlements;
-25 – Preference for non-populated areas;
-50 – Avoidance of urban areas and human settlements;
-75 – Clear avoidance of urban areas and human settlements;
-100 – Complete absence in urban areas.

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 (Fig. 5-1). In addition, within the studied area are also the last few kilometers (to the estuary) of the Parvenetzka River (5800 m), as well as several irrigation canals. Of the irrigation canals passing through the study area, transects are marked along five of them: Irrigation Canal No. 1 – from the road to the village of Tsaratsovo to Plovdiv State Fishery (4400 m); Irrigation Canal No. 2 – from Plovdiv State Fishery to Rogosh Cemetery (3600 m); Irrigation Canal No. 3 – from Trakia Railway Station to the road to the village of Parvenets (8200 m); Irrigation Canal No. 4 – passes north of the village of Markovo to the village of Branipole (2800 m); and Irrigation Canal No. 5 – from the road to the village of Parvenets to Parvenetska River (2300 m). These flowing basins (Fig. 5-1), as well as two large (over 1 km^2) standing water basins – Rowing Base, Plovdiv and Plovdiv State Fishery – were surveyed for the presence of amphibians and reptiles.

The following transects were used in the territories of the Plovdiv hills (Fig. 5-2) and the big city parks (Fig. 5-3): "Mladezhki hulm" Hill (3 transects): Transect No. 1 – starts from the southwest part of the hill and covers the entire western part to the peak (3600 m); Transect No. 2 – starts from the southeast part of the hill and covers the whole eastern part to the very top (2000 m); and Transect No. 3 – covers the park part of the hill in its southern part (1600 m); "Hulm Bunardzhik" Hill (2 transects): Transect No. 4 – starts at the northeastern side of the hill and covers the entire north and west sides and the peak (1200 m); Transect No. 5 – starts at the eastern part of the hill and covers part of the park, the whole southern and eastern side and the peak (3200 m); and "Danov hulm" Hill (1 transect): Transect No. 6 – starting from the northwestern part of the hill, covering the entire western, southern and eastern parts, including the peak (1200 m).

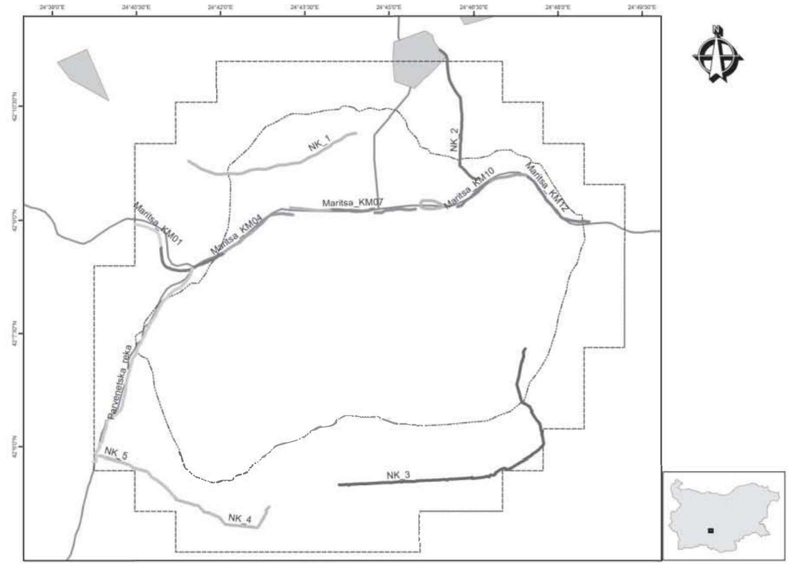

Fig. 5-1. Map of the selected transects alongside Maritsa River, Parvenetska River and the irrigation canals in the studied area (the explanations are in the text). *See colour centerfold for this image in colour.*

The following transects were used in the territory of the large urban parks (Fig. 5-3): "Tsar Simeonova Gradina" Park (1 transect): Transect No. 7 – starts from the western part of the park and covers all water basins and lawns through the entire park (800 m); "Otdih i Kultura" Park (3 transects): Transect No. 8 – starts from the mouth of the Parvanetska River, passes through the forest, goes into the western part of the Rowing Canal and covers the entire remaining part of the park on the south side of the canal and the road (2100 m); Transect No. 9 – starts at the "Bratskata Mogila" Monument and covers the northern part of the park to the road, up to the Rowing Canal Bridge (2000 h); Transect No. 10 – starts at "St. Georgi" Hospital and covers the entire southern part of the park to the "Plovdiv" Mall (2100 m); "Lauta" Park (1 transect): Transect No. 11 – starts at the "Locomotiv" Stadium and passes along the entire park in an eastward direction, in a zigzag manner (5100 m); and "Rogozh" Cemetery (1 transect): Transect No. 12 – starts at the main entrance of the park and goes through the entire cemetery (2500 m).

Fig. 5-2. Map of the selected transects in the Plovdiv hills (the explanations are in the text). *See colour centerfold for this image in colour.*

Classification of the urban habitats. The classification of urban habitats in Plovdiv City followed the "Palearctic Habitat Classification" for habitat types occurring in Bulgaria (Meshinev and Apostolova 2005, 351-371). For the purposes of the current study, habitats not populated by amphibians or reptiles were excluded from the analyses. The identified urban habitat types within the study area are presented with their full names, codes according to the Palearctic Habitat Classification and abbreviations used in the current monograph in Table 5-1.

The polytopic/stenotopic dichotomy was defined in the following sense: polytopic species were defined as ecologically tolerant species that occur in more than five habitat types, while stenotopic species were ones occurring in less than five habitat types.

Fig. 5-3. Map of the selected transects in the city parks in Plovdiv City (the explanations are in the text). *See colour centerfold for this image in colour.*

Table 5-1. Types of urban habitats identified in the city of Plovdiv.

Abbre-viation	Habitat name	Code
Aquatic and semi-aquatic habitats		
Vpsv	Constant standing, freshwater ponds	22.1
Vvsv	Temporary standing, freshwater ponds	22.2
Vrp	Rivers and streams	24.1
Vnk	Irrigation canals	89.2
PVkvf	Riparian willow formations	44.1
PVktf	Riparian reed formations	53.6
PVzk	Floodplain crops (rice fields)	82.4
Terrestrial habitats		
Ssts	Dry artificial grasslands	81.1
Svts	Wet artificial grasslands	81.2
Sesnh	European communities of low dry bushes	31.2
Sbh	Barbed bushes	31.7
Snik	Continuous intensive crops	82.1

Szks	Cereals with field margins (strips) of natural vegetation	82.2
Shog	Bush orchards (vines)	83.2
Svog	High orchards	83.1
Sgp	Large urban parks	85.1
Smpg	Small urban parks and gardens	85.2
Sg	Gardens and courtyards	85.3
Svpmb	Inner spaces between buildings	85.4
Siz	Abandoned lands	87.1
Srs	Ruderal communities	87.2
Svgss	Internal bare rock slopes	62.4
Sjsg	Residential buildings (urban type)	86.1
Sjss	Residential buildings (rural type)	86.2
Ssiz	Old industrial areas	86.4

Environmental factors. In this study, some basic abiotic, biotic and anthropogenic factors affecting the formation, distribution, composition, structure and functioning of the amphibian and reptile communities were measured by standard methods (Table 5-2).

Table 5-2. Measured abiotic, biotic and anthropogenic environmental factors in the research area.

Factor	Means of measuring	Categories	Unit(s)
	Abiotic factors		
1. Air temperature	Digital thermometer “TCM”, minimal capacity 0.1°C	-	°C
2. Temperature of the substrate	Digital thermometer “TCM”, minimal capacity 0.1°C	-	°C
3. Temperature of the shelter	Digital thermometer “TCM”, minimal capacity 0.1°C	-	°C
4. Water temperature	Digital thermometer “WTW”, minimal capacity 0.1°C	-	°C
5. Dissolved oxygen	Digital oxymeter “WTW”, minimal capacity 0.1°C	-	g/ml

6. Water pH	Digital pH-meter "WTW", minimal capacity 0.01	-	-
7. Area and depth of the water basin	Metric with measuring tape or using GIS	-	m
8. Bottom type of the water basin	Visually	1. soil (mud) 2. sand 3. gravel 4. concrete	-
Biotic factors			
1. Vegetation cover (percentage)	Visually	1. < 25% 2. 25-50% 3. 50-75% 4. >75%	-
2. Presence of predatory fish	Visually	1. Yes 2. No	-
Anthropogenic factors			
1. Degree of human disturbance	Visually, based on the number of people met during a 30 min walk on a sunny day	1. < 5 people 2. 5-20 people 3. >20 people	-
2. Width of the road	Metric with measuring tape	-	m
3. Number of cars passing by for 1 hour	Visually	-	Number of cars

Statistical analyses and software used. Line transect data and mark-recapture data were calculated and processed with the Microsoft Excel computer program. The "I3S" v.2.0 software was used for optical image recognition (Speed, Meekan, and Bradshaw 2007).

The processing and mapping of GPS data was accomplished with the "MapSource" v.6.12 software (Garmin Ltd. 2007) on an electronic topographic map, using "BG Topo Maps" v.2.12 (Kotzev 2005), and the visual presentation utilized ArcGIS v.10.0 (ESRI 2011). "Herpetologically Important Areas" in the surveyed area were identified based on the number of registered species and the number of their localities. Polylines were generated using the Kernel Index from Hawth's advanced analysis tools for ArcGIS v.10.0 (Beyer 2004).

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 (Shapiro, Wilk and Chen 1968, 1343-1372). When comparing or looking for correlations between individual variables, parametric tests (Pearson correlation index, ANOVA) or non-parametric tests (x^2-test, Mann-Whitney U-test for independent variables, Spearman correlation index) were used when the data did not have a normal distribution (Fowler, Cohen, and Jarvis 1998, 1-259). These differences were statistically valid with $p \leq 0.05$ [$\alpha = 5\%$]. In some cases, a Principal Component Analysis (PCA) was applied, and values greater than 0.7 were accepted as statistically valid for this test.

CHAPTER SIX

THE CITY OF PLOVDIV: LOCATION AND GEOGRAPHICAL CHARACTERISTICS

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 altitude. 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 (Mollov and Velcheva 2010, 25-38). 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. 6-1) and the surrounding areas, excluding other urban areas (see Mollov and Velcheva 2010, 25-38).

Geology. The city of Plovdiv is located in the western part of the Upper Thracian Plain on the two banks of the Maritsa River. It is situated 15 km north of the Rhodopes Mountains, 50 km south of the Balkan Mountains. Its slopes are marked by the course of the Maritsa River running from west-northwest to east-southeast. The river collects its waters from a number of tributaries coming from the Central Balkan Mountains, the Sredna Gora Mts., and the Rhodopes Mts. The waters of the Maritza River increase, and it gets deep, and in Plovdiv City its width reaches 180-185 m. The riverbanks are at a low level, so at high tide there can be floods (Rusev 1966, 231-291).

Plovdiv City is situated about 160 meters above sea level and it is part of the Thracian-Strandzha geographical area on the Upper Thracian Plain (Gruev and Kuzmanov 1999, 1-344).

The typical rocky formations in the valley are the seven (now six) syenite hills – "Mladezhki hulm" Hill with a height of 286 m, "Hulm Bunardzhik" Hill at 265 m a.s.l., "Danov hulm" Hill at 222 m above sea level and Trihulmie Hill (which is actually three hills, situated very close to each other) at 212 m a.s.l. (see Mollov 2005b, 79-94).

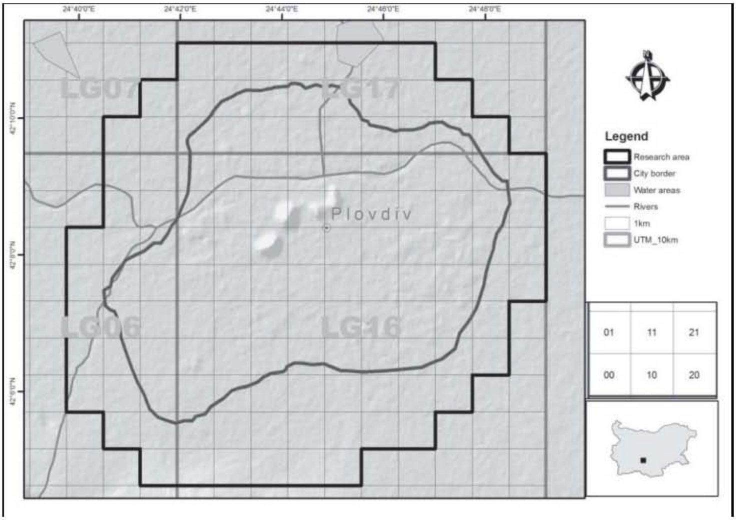

Fig. 6-1. UTM map (1x1 km) of the study area – Plovdiv City and its surroundings. *See colour centerfold for this image in colour.*

Urban areas have a specific surface litter-urban liaison with different heights, which increases the so-called "roughness of the terrain." Artificial coatings, asphalt, paving, ceramics, and plaster walls have significant albedo variations for soil and vegetation. It reaches a mode other than the natural course of radiation and heat flow and the formation of the so-called "urban environment."

Climate. Plovdiv and its territory are situated in the climatic region of southeastern Bulgaria in the transitional continental European sub-continental climatic zone. The prevailing wind is westerly. The average wind speed is 4.5 m/s. The average annual temperature is 12.6°C. The annual average amplitude is approximately 23°C. The average annual relative humidity is 73%, with the highest in December (86%), and the lowest in August (62%). The average annual rainfall is 540 mm, with the maximum in May/June and the minimum in September (31 mm). The average annual number of days with snow cover in Plovdiv is 33 days. The western part of Thracian Plain, where the city is located, has a moderate warm climate with warm summers and evenly wet spring and winter (Dimitrov 1979, 1-234).

What marks the Plovdiv Region out in terms of climate is the well-understood trend of the leveling of seasonal rainfall (which is absent in other areas). Secondly, there is the specific thermal regime – mostly transient air temperatures over 0°C in winter, an intermediate position in the average air temperatures, the small number of days of "chilly weather" and, in the summer, a significant proportion of "drought time" (34-35% in July and August).

Another characteristic of Plovdiv's climate is the high frequency of temperature inversions in the atmosphere (up to 81% of the days in the year).

Soils. The character of the landscape strongly influences the soil in the area. The characteristics of bioclimatic conditions play an important role for the nature of the soil. Along the Maritsa River there are accumulative deposits, accompanied by alluvial soils. In their distribution there are localities with shallow groundwater, and conditions are present for the formation of alluvial marsh soils in areas with combined *"solonez"* and *"solonchaks"* (Penkov 1973, 1-276).

Floristic characteristics. The majority of the area around the city has been converted to cropland and highly built-up urban areas, so naturally abundant flora and fauna are very limited (Gruev and Kuzmanov 1999, 1-344). The natural landscape has been replaced by the anthropogenic one.

The natural vegetation in this part of the Upper Thracian Plain can be seen only in the preserved individual trees, groves, bushes and partly grassed areas, and these show that there are stretches of vast forests with broadleaf trees. There are predominantly mixed oak forests mainly of the Sub-Mediterranean type, consisting of oak and other deciduous tree species. As for the low and foothill areas, these forests are replaced by Sub-Mediterranean deciduous shrubs, composed of the same species (the first stage of the replacement of old forests destroyed by man), interspersed with species such as juniper that are widespread in the foothills and middle mountain belt. The composition of these shrubs is a mixture of numerous Sub-Mediterranean representatives and other aliens in place of felled forests (Paspalev 1964, 5-18).

Protected Areas. In the territory of the Municipality of Plovdiv there are four protected areas declared under the Protected Territories Act (1998), with a total area of 845,560 daa: the "Mladezhki hulm" Hill Nature Monument (NM); the "Hulm Bunardzhik" Hill NM; the "Danov hulm" Hill NM; and the "Pochivka na malak kormoran - Plovdiv" protected area.

The *"Mladezhki hulm" Hill NM* is located in the southwestern part of Plovdiv City. The NM has an area of 36.2 ha and it is located at 285.5 m above sea level. The hill was declared as a nature monument by Order No. RD466 dated 22 December 1995 by the Ministry of Environment and Waters (MOEW) in order to preserve the natural landscape and the unique geomorphological formations (Dimitrov et al. 2002, 1-80).

"Mladezhki hulm" Hill NM distinguishes itself from the other two hills with its wealth of rare and protected plant species and communities that can be attributed to the primary flora of the Plovdiv hills. The reasons for this are its relative isolation, geographical location, and its steep and hardly accessible slopes. Here the steep and rocky parts are occupied by *Pistacia terebinthus, Celtis australis,* and *Jasminum friticans*. Due to the intensified human intervention, which began with the destruction of the centuries-old oak and elm forests, which covered the entire Plovdiv field and have been the focus of the subsequent forestry activities from the beginning of the 20th century until today, the species composition and the nature of the vegetation on the hills have changed. Natural herbaceous plants have been almost entirely destroyed and replaced by ruderal species. However, there are a number of rare, endemic and protected plant species typical of the former flora of the hills, which distinguishes it from the other two hills.

Despite the strong anthropogenic impact, the animal world of the hill is quite diverse. Birds of great interest are present, such as the protected species *Asio otus,* whose wintering population can be located on the trees between the residential buildings at the foot of the hill. Among the other species of birds on the hill are the predominantly occurring representatives of synanthropic species – *Streptopelia decaocto, Sturnus vulgaris, Passer domestica, Parus major,* etc. *Talpa europaea* can be found especially in the "forest park" together with *Sciurus vulgaris,* as well as some species of mycelial rodents and bats.

"Hulm Bunardzhik" Hill NM is located in the central part of Plovdiv and occupies an area of 22.0 ha (265 m above sea level). The hill was declared a natural landmark by Order No. RD466 dated 22 December 1995 by the MOEW in order to preserve the natural landscape and the unique geomorphological formations (Dimitrov et al. 2002, 1-80).

The main factor determining the current vegetation, both on "Hulm Bunardzhik" Hill and the other hills, is the anthropogenic influence. Over the years, the hill has been directly or indirectly subjected to human exposure, resulting in the primary vegetation being destroyed, and many species have disappeared due to the massive introduction of ruderal and weed elements. Today they make up more than 50% of the vegetation of the hill.

The remaining indigenous species that can be attributed to the former primary flora of the hill can still be found on the high rocky slopes: *Juniperus oxicedrus, Pistacia terebinthus, Celtis australis, Frangula alnus* and others.

The fauna is comparatively richly represented. Birds are almost exclusively synanthropic species, and are predominantly the same species as occurring in the "Mladezhki hulm" Hill NM. The bats *Nyctalus nyctalus* and *Pipistrellus pipistrellus* can also be seen.

"Danov hulm" Hill NM is situated in the center of Plovdiv, west of the "Main Street", and occupies an area of 5.3 ha. "Danov hulm" Hill was declared a natural landmark in 1995 by Order No. RD466 on 22 December 1995 of the MOEW in order to preserve the natural landscape and the unique geomorphological formations (Dimitrov et al. 2002, 1-80).

"Danov hulm" Hill has a relatively poor floristic composition due to its smaller area and stronger anthropogenic influence, as it is located in the center of the city. The woodland is mainly acacia, summer oak, lime tree, linden, wild carob, horse chestnut, etc., which severely disturbed and changed the nature of the natural vegetation of the hill. For this reason, natural herbaceous plants have been replaced by ruderal ones.

On "Danov hulm" Hill, the fauna is represented almost exclusively by synanthropic species. Among the birds commonly met are *Streptopelia decaocto, Sturnus vulgaris, Passer domestica* and others. The mammals in the protected area are represented by *Sciurus vulgaris,* and the bats by *Nyctalus nyctalus.*

The *"Pochivka na malak kormoran - Plovdiv" protected area* is situated along the Maritsa River in the area of "the 6th km Bridge" near Plovdiv, Pazardjik road close to Plovdiv and borders with the studied area. On 5 September 2006, Order No. RD644 of the MOEW, for the purpose of preserving the habitat, resting place and accumulation of the globally threatened and protected species of cormorant *Phalacrocorax pygmeus* during its migration, declared an area of 408,560 daa to be a protected area.

CHAPTER SEVEN

SPECIES COMPOSITION, TAXONOMY AND SPATIAL DISTRIBUTION

In the current study, we identified a total of 6 species of amphibians in the study area, which represents 31.58% of Bulgarian amphibian species, and 9 species of reptiles, which is 24.32% of Bulgarian herpetofauna. In the literary data for the research area for the period 1905-2005, a total of 10 amphibian and 17 reptile species were reported (Table 7-1). For comparison, in the city of Sofia, eight species of amphibians are recorded (Milchev 1985, 195-203), in Varna, – 8 species of amphibians and 14 reptiles are recorded (Delov, Peshev, and Vasilev 2005, 191-196), and for Ruse, 7 species of amphibians and 13 reptile species were reported (Undzhiyan 2000, 1-88).

Class Amphibia (Amphibians)

Triturus ivanbureshi (Arntzen and Wielstra 2013) – Southern Crested Newt

This species was reported for the first time by Kovachev (1912, 1-90) for the Maritsa River in Plovdiv, and later by Buresh and Tsonkov (1941, 171-237) for "Swamps along Maritsa River in Plovdiv (22.II.1930)". In December 1957 the species was discovered near Komatevo Village near Plovdiv by Angelov and Kalchev (1961). Since then, the southern crested newt has not been detected in the city again (it was not registered in this study either), and in our view, it has disappeared from the study area.

Lissotriton vulgaris (Linnaeus, 1758) – Common (Small) Newt

The common newt was reported for the first time for Plovdiv by Kovachev (1905a, 1-50; 1905b, 1-13; 1912, 1-90) in swamps along the Maritsa River in the city. This species was only mentioned again in the fifties of the last century by Angelov (1960a, 7-40) and Angelov and Kalchev (1961, 18-21) in the "Ostrova" area (now "Otdih i kultura" Park) on the outskirts of the city. Since these reports, the common newt has not been found again in the city (it was not registered in this study either), and in our view, it has disappeared from the research area.

Bombina bombina (Linnaeus, 1761) – Fire-bellied Toad

The species was reported for the city by Kovachev (1912, 1-90) and later by Buresh and Tsonkov (1942, 68-165) for Komatevo Village near Plovdiv (18.IV.1932). In May and October 1960 the species was found "near the village of Komatevo" (now a quarter in the city) and "near the "Ostrova" Area in Plovdiv" by Angelov and Kalchev (1961, 18-21). Since then, the fire-bellied toad has not been registered in the city again (and it was not found in this study). Its nearest presence to the study area is Radinovo Village – LG0754, 02.VIII.2005 (Georgiev, Plovdiv, pers. comm., 2005).

Bombina variegata (Linnaeus, 1758) – Yellow-bellied Toad

The species was reported from the "Ostrova" Area in Plovdiv by Angelov (1960a, 7-40) and Donev (1984c) and from the southern suburbs of the city by Angelov (1960b, 333-337) and Angelov and Kalchev (1961, 18-21). In this study, the yellow-bellied toad was not registered in the study area, but it has been found north of Parvenets Village – LG0661 and LG0662, 02.VIII.2005 (Georgiev, Plovdiv, pers. comm., 2005).

Table 6-1. Species composition of the amphibians and reptiles in the study area recorded from literary data and during the current study. *Legend:* N – number of localities, U – number of UTM quadrats (1x1 km), A – distribution index.

No.	Species	Species, reported by literary data (1905-2005)			Species, recorded in the current study (2007-2009)		
		N	U	A	N	U	A
	Amphibia						
1.	*Triturus ivanbureshi*	3	3	2.36	0	0	0
2.	*Lissotriton vulgaris*	5	4	3.15	0	0	0
3.	*Bombina bombina*	4	3	2.36	0	0	0
4.	*Bombina variegata*	4	3	2.36	0	0	0
5.	*Bufo bufo*	4	3	2.36	3	3	2.36
6.	*Bufotes viridis* complex	12	9	7.09	150	11	8.66
7.	*Pelobates syriacus balkanicus*	2	2	1.57	1	1	0.79
8.	*Rana dalmatina*	4	3	2.36	5	4	3.15
9.	*Pelophylax ridibundus*	6	4	3.15	426	54	42.52

10.	*Hyla arborea* complex	5	4	3.15	21	11	8.66
	Reptilia						
1.	*Mediodactylus kotschyi rumelicus*	10	10	7.87	132	16	12.60
2.	*Ablepharus kitaibellii*	1	1	0.79	0	0	0
3.	*Lacerta trilineata*	7	5	3.94	7	7	5.51
4.	*Lacerta viridis*	6	4	3.15	61	31	24.41
5.	*Podarcis muralis*	1	1	0.79	0	0	0
6.	*Podarcis tauricus*	7	7	5.51	38	10	7.87
7.	*Emys orbicularis*	3	3	2.36	11	9	7.09
8.	*Trachemys scripta elegans*	0	0	0	2	2	1.57
9.	*Testudo graeca*	2	2	1.57	0	0	0
10.	*Testudo hermanni*	2	2	1.57	0	0	0
11.	*Dolichophis caspius*	1	1	0.79	12	11	8.66
12.	*Coronella austriaca*	1	1	0.79	0	0	0
13.	*Zamenis longissimus*	2	2	1.57	0	0	0
14.	*Elaphe sauromates*	2	2	1.57	0	0	0
15.	*Natrix natrix*	5	5	3.94	5	5	3.94
16.	*Natrix tessellata*	3	3	2.36	9	9	7.09
17.	*Vipera ammodytes*	1	1	0.79	0	0	0

Bufo bufo (Linnaeus, 1758) – Common Toad

The species is rare for Plovdiv. In the literature it is reported by Kovachev (1912, 1-90), Angelov (1960a, 7-40), Angelov and Kalchev (1961, 18-21) and Mollov (2005a, 82-88). In the present study, it was found in 3 localities in 3 UTM quadrats (Appendix 1).

Bufotes viridis complex – Green Toad

The green toad is one of the most common amphibian species in the city. In the literature it is reported by Cyren (1941, 36-146), Buresh and Tsonkov (1942, 68-165) Angelov (1960a, 7-40; 1960b, 333-337), Angelov and Kalchev (1961, 18-21), Euzet, Combes, and Batchvarov (1974, 129-140), Mollov (2005a, 82-88; 2005b, 79-94). In this study the species was recorded in 150 localities in 11 UTM quadrats (Appendix 1).

Pelobates syriacus (Boettger, 1889) – Syrian Spadefoot Toad

Of all the identified amphibian species, the Syrian spadefoot toad is the rarest. From the city it has been reported so far only by Angelov and Kalchev (1961, 18-21) for the "Ostrova" Area, and by Džukić et al. (2008, 61-78) for Plovdiv State Fishery. A detailed examination of the distribution of the species in the city and the country was conducted in our previous study (Mollov et al. 2007, 132-136), which includes the only locality in which it was found in this study period – LG1629.

Pelophylax ridibundus (Pallas, 1771) – Marsh Frog

This is the most common amphibian in the city. So far, in the literary data, it was reported only on the outskirts of Plovdiv by Angelov (1960a, 7-40; 1960b, 333-337), Bachvarov (1968, 143-152), Popov (1973, 397-404; 1975, 13-17), and Donev (1984a, 35-44; 1986, 81-102). In the present study, it was recorded throughout the studied area with a total of 426 localities in 54 UTM quadrats (Appendix 1).

Rana dalmatina (Bonaparte, 1839) – Agile Frog

The agile frog is a relatively rare species in the study area and currently, in the literature, it is reported only from around the city (near the "Ostrova" area and the Komatevo Quarter) by Angelov (1960a, 7-40), Angelov and Kalchev (1961, 18-21) and Bachvarov (1980, 183-190). In this study the species was also found only on the outskirts of the city, with a total of 5 localities in 4 UTM quadrats (Appendix 1). In the Bulgarian herpetological literature there is a report for the common frog (*Rana temporaria*) for the city of Plovdiv from Kovachev (1905b, 1-13). In our opinion, this report either concerns the agile frog or it is a mistake. Due to the low altitude of the city, finding a common frog in it is quite improbable.

Hyla arborea complex – Tree Frog

The tree frog has been reported as "common" species on the outskirts of Plovdiv by Angelov (1960a, 7-40; 1960b, 333-337) and Angelov and Kalchev (1961, 18-21) and in the hills of Plovdiv by Mollov (2005b, 79-94). In this study the species was found only on the outskirts of the city and on "Mladezhki hulm" Hill in the city center, with a total of 21 localities in 11 UTM quadrats (Appendix 1).

Class Reptilia (Reptiles)

Testudo graeca (Linnaeus, 1758) – Spur-thighed Tortoise

The spur-thighed tortoise has been reported for the "outskirts of Plovdiv" by Buresh and Tsonkov (1933, 150-207) and the "Ostrova" area in Plovdiv by Angelov (1960a, 7-40). The species was recorded in the city on the "Halm Bunardzhik" Hill (LG1628) on 13.IV.1999 (Nikolov, Plovdiv, pers. comm., 1999) and in an open meadow near arable land and farm buildings east of Trakia Quarter (LG1687) on 21.VI.2000 (Irikov, Plovdiv, pers. comm., 2000), but it was not recorded in this study. According to Beshkov and Nanev (2002, 1-120) in many places in the Thracian Valley, tortoises are being destroyed by human activity. Finding tortoises in the research area, in our opinion, should be considered accidental because these are most likely cases of specimens collected from other places in Bulgaria, kept alive as souvenirs and then released in various places in the city.

Testudo hermanni (Gmelin, 1789) – Hermann's Tortoise

Hermann's tortoise has been reported by Shkorpil (1897, 1-23) for Plovdiv, and one indeterminate species (*Testudo sp.*) was reported by Drenski (1955, 109-166). The species was registered in the city of Plovdiv on 12.V.2000 in the area of the Rowing Channel – LG0697 (Kirov, Ruse, pers. comm., 2000), but not in this study. According to Beshkov and Nanev (2002, 1-120) this species is absent in many places in the lowlands of northern Bulgaria and Thrace, which were destroyed by modern agriculture and the general modification of the landscape. We assume that the recorded specimens in Plovdiv are probably released tortoises, which had previously been kept alive as souvenirs collected from other parts of Bulgaria.

Emys orbicularis (Linnaeus, 1758) – European Pond Turtle

The European pond turtle has been reported for the "Maritsa River in Plovdiv" by Kovachev (1910, 1-16), "near the "Ostrova" area in Plovdiv" by Angelov (1960a, 7-40) and State Fisheries – Plovdiv by Kirin (2001, 95-98). In the current study it was recorded with a total of 11 localities in 9 UTM quadrats (Appendix 2).

Trachemys scripta elegans (Wied-Neuwied, 1839) – Red-eared Slider

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 and Joly 2004, 2511-2518). 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 Natural History Museum (LG1648).

Mediodactylus kotschyi (Steindachner, 1870) – Kotschy's Gecko

This is an extremely common and widespread species in Plovdiv (Shkorpil 1897, 1-23; Kovachev 1905b, 1-13; 1910, 1-16; 1912, 1-90; Buresh and Tsonkov 1933, 150-207; Müller 1939, 1-17; Mollov 2005b, 79-94). In Plovdiv, an endemic of the Bulgarian subspecies *"rumelicus"* has spread (Beshkov and Nanev 2002, 1-120). In the current study, the species was registered with 132 localities in 16 UTM quadrats (Appendix 2).

Ablepharus kitaibellii (Bibron and Bory, 1833) – European Copper Skink

The European copper skink was found for the first time on "Mladezhki Halm" Hill in Plovdiv in a previous study (Mollov 2005b, 79-94), with two localities of the southern part of the hill on 31.III.2003 and on the eastern part on 02.V.2003. Unfortunately, the species was not re-recorded in this study.

Lacerta trilineata (Bedriaga, 1886) – Balkan Green Lizard

This lizard was reported in and around the city center by Kovachev (1907, 217-218; 1912, 1-90), Buresh and Tsonkov (1933, 150-207), Angelov, Tomov and Gruev (1966, 99-105) and Mollov (2005b, 79-94). In the current study it was found only in the outskirts of the city with a total of 7 localities in 7 UTM quadrats (Appendix 2).

Lacerta viridis (Laurenti, 1768) – Green Lizard

This is the most common lizard species in the research area. It was reported by Buresh and Tsonkov (1933, 150-207), Angelov (1960a, 7-40), Angelov, Tomov and Gruev (1966, 99-105), Donev (1984c, 45-50) and Mollov (2005b, 79-94). In this study it was recorded with a total of 61 localities in 31 UTM quadrats (Appendix 2).

Podarcis muralis (Laurenti, 1768) – Common Wall Lizard

This species is a typical petrophile – it inhabits only rocky and stony terrains. Therefore, in the research area, it has only previously been recorded on two of the Plovdiv hills (Kovachev 1905b, 1-13; Mollov 2005b, 79-94). It seems that this species is isolated from the other populations in Plovdiv, but it exists due to the presence of near-natural conditions on the hills. The species was not recorded in the current study.

Podarcis tauricus (Pallas, 1811) – Balkan Wall Lizard

The Balkan wall lizard is a relatively common species both in the urban and rural parts of Plovdiv City (Kovachev 1912, 1-90; Cyrén 1933, 219-246; Buresh and Tsonkov 1933, 150-207; Donev 1984c, 45-50; Mollov 2005b, 79-94). In the present study it was established in a total of 38 localities in 10 UTM quadrats (Appendix 2).

Dolichophis caspius (Linnaeus, 1758) – The Caspian Whipsnake

This is the most common snake species in the research area. In this study it was recorded with 12 localities in 11 UTM quadrats (Appendix 2).

Coronella austriaca (Laurenti, 1768) – Smooth Snake

So far, this species has been reported for Plovdiv City only by Kovachev (1905b, 1-13; 1912, 1-90). Mollov (2005b, 79-94) reported finding a skin-shed of a young smooth snake at “Mladezhki hulm” Hill, but later, when re-defining the material, it was found that this skin-shed belonged to a Caspian whipsnake (*D. caspius*). In our opinion, the smooth snake has disappeared from the city limits.

Zamenis longissimus (Laurenti, 1768) – Aesculapian Snake

So far, the Aesculapian snake has been reported for Plovdiv City only by Kovachev (1912, 1-90) and Buresh and Tsonkov (1934, 106-188). Since then, the species has not been found again. It was not recorded in the current study.

Elaphe sauromates (Pallas, 1814) – Blotched Snake

So far, this species has been reported in the outskirts of Plovdiv City only by Kovachev (1912, 1-90) and Buresh and Tsonkov (1934, 106-188). Since then, it has not been found again and was not recorded in this study.

Natrix natrix (Linnaeus, 1758) – Grass Snake

The grass snake has limited distribution in the city. So far, the species has been reported for the outskirts of Plovdiv City by Kovachev (1912, 1-90), Buresh and Tsonkov (1934, 106-188), Angelov (1960a, 7-40), Bachvarov (1969, 191-196) and Kirin (1994b, 41-46; 1995, 77-80). In the present study it was found in a total of 5 localities in 5 UTM quadrats (Appendix 2).

Natrix tessellata (Laurenti, 1768) – Dice Snake

This species occurs more frequently than the grass snake. So far, for Plovdiv, it has been reported by Kovachev (1912, 1-90), Angelov (1960a, 7-40) and Kirin (1994a, 35-39). In the present study it was found in a total of 9 localities in 9 UTM quadrats (Appendix 2).

Vipera ammodytes (Linnaeus, 1758) – Sand Viper

The sand viper has been reported for Plovdiv only by Kovachev (1905b, 1-13; 1912, 1-90). It was not recorded in this study.

CHAPTER EIGHT

RETROSPECTIVE ANALYSIS OF THE HERPETOFAUNA: HERPETOLOGICALLY IMPORTANT AREAS

Retrospective analysis of the herpetofauna in the study area. The species composition and distribution of amphibians and reptiles in Plovdiv City show a significant change in the last 100 years when comparing them with existing literary data.

From a total of 10 species of amphibians reported for the city of Plovdiv, in this study only six were found. For the 17 species of reptiles reported for the city, in this study only nine were found. In both groups around a 50% reduction in the number of species occurred.

To trace the changes in the frequency of occurrence of amphibians and reptiles in the study area in time, we conducted an analysis of available data from the available literary sources (Table 8-1), using the calculated index of distribution. This enables us to gain even a vague idea about the state of the species of amphibians and reptiles in the past and compare it with their present condition. From the analysis of this data, we could make some predictions for the future existence of the amphibians and reptiles in an urban environment.

Of all recorded amphibian species, four have an increased frequency of occurrence (Table 8-1), but only two were distributed almost throughout the whole study region and are relatively numerous – *Pelophylax ridibundus* and *Bufotes viridis* complex. One of the positive circumstances, which encourage the widespread presence of the marsh frog, is the species' preference for slow flowing waters. The presence of the Maritsa River and Parvenetska River and a dense network of irrigation canals in the outskirts of the city have played a peculiar role of corridors for the distribution of species in the urban area. Moreover, the high ecological plasticity of the species is well known and, unlike most species of amphibians, *Pelophylax ridibundus* can be found even in highly polluted water (Leonteva and Semenov 1999, 269-275). The green toad, on the other hand, is a relatively drought-loving species and it uses small temporary ponds for breeding, which are also abundant in the city. These circumstances and the fact that it is an "explosive" breeding species and, unlike the common toad (*Bufo bufo*), does not have strict fidelity to the place of egg-laying (Kühnel and Krone 2003, 299-315), further contribute to the prevalence of this species in the city.

Aside from both newt species, both yellow-bellied and fire-bellied toads are considered missing from the study area; the state of the remaining amphibian species remained relatively unchanged.

Seven species of reptiles (*Mediodactylus kotschyi, Lacerta viridis, Lacerta trilineata, Podarcis tauricus, Emys orbicularis, Dolichophis caspius* and *Natrix tessellata*) are widely distributed in the city and they are in a stable condition (Table 8-1). It should be noted that the distribution of the Kotschy's gecko in the city of Plovdiv is probably much wider than that recorded in this study because the species occupies buildings which are not accessible, and its presence is difficult to record.

The situation with the grass snake (*Natrix natrix*) and the dice snake (*Natrix tessellata*) in the city is interesting. In the current study, we recorded no change to the localities and frequency of occurrence of the grass snake and an increase for the dice snake. This may be due to the fact that *Natrix natrix* requires relatively large portions of unfragmented habitats and a stable food base – mainly fish and frogs (Leonteva and Semenov 1999, 269-275), which are available mainly along the Maritsa River and some parts of the outskirts of the city. This limits the species' distribution within the city, while the dice snake occurs in irrigation canals and other more unsuited water bodies, and it seems it has a higher ecological plasticity than the grass snake.

The larger and easier to spot, and thus more frequent victims of humans, representatives of the snakes like *Coronella austriaca, Zamenis longissimus, Elaphe sauromates* and *Vipera ammodytes,* which have more specific habitat requirements, are missing from the territory of the city.

The occurrence of the two tortoise species and the red-eared slider in the city should be considered as accidental.

Important herpetological areas in the study region

Based on the number of localities and the number of species detected, using the Kernel Index we identified the Important Herpetological Areas in the study region (Fig. 8-1).

Contrary to most urban studies on amphibian and reptile fauna, where the species richness declines from the rural parts of the city to its center (Hammer and McDonnell 2008, 2432-2449; McKinney 2008, 161-176), we identified the largest number of species with the largest number of localities in the center of the city of Plovdiv.

Table 8-1. Retrospective analysis of the amphibians and reptiles in the area.

Species	Distribution index (A) - past state (1905-2005)	Dynamics	Distribution index (A) - current state (2007-2009)
Amphibia			
Triturus ivanbureshi	2.36	disappearing	0
Lissotriton vulgaris	3.15	disappearing	0
Bombina bombina	2.36	disappearing?	0
Bombina variegata	2.36	disappearing?	0
Bufo bufo	2.36	no change	2.36
Bufotes viridis complex	7.09	increasing	8.66
Pelobates syriacus	1.57	decreasing	0.79
Rana dalmatina	2.36	increasing	3.15
Pelophylax ridibundus	3.15	increasing	42.52
Hyla arborea complex	3.15	increasing	8.66
Reptilia			
Mediodactylus kotschyi	7.87	increasing	12.60
Ablepharus kitaibelii	0.79	decreasing?	0
Lacerta trilineata	3.94	increasing	5.51
Lacerta viridis	3.15	increasing	24.41
Podarcis muralis	0.79	decreasing?	0
Podarcis tauricus	5.51	increasing	7.87
Emys orbicularis	2.36	increasing	7.09
Trachemys scripta	0	accidental	1.57
Testudo graeca	1.57	accidental	0
Testudo hermanni	1.57	accidental	0
Dolichophis caspius	0.79	increasing?	8.66
Coronella austriaca	0.79	disappearing	0
Zamenis longissimus	1.57	disappearing	0
Elaphe sauromates	1.57	disappearing	0
Natrix natrix	3.94	no change	3.94
Natrix tessellata	2.36	increasing	7.09
Vipera ammodytes	0.79	disappearing	0

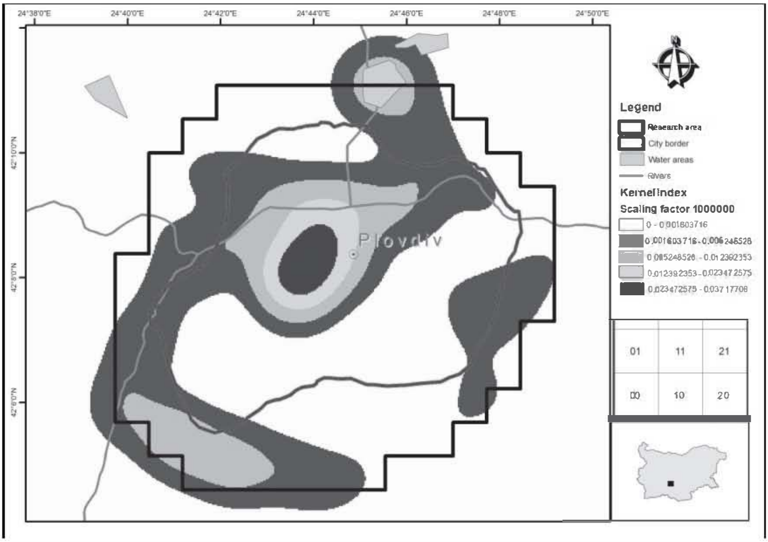

Fig. 8-1. Important Herpetological Areas in the study region. *See colour centerfold for this image in colour.*

This finding is due to the position of the hills of Plovdiv – these are areas which resemble natural conditions more closely but which are, in fact, in the center of the city (Mollov 2005b, 79-94). In addition, the center section of the Maritsa River and the lower section of the Parvenetska River offer good conditions for the spread of amphibians and some reptiles. The irrigation canals in the southern and eastern parts of the city, along with the State Fishery Ponds in the north, also play a significant role in the distribution of the amphibians and reptiles in the urbanized territory.

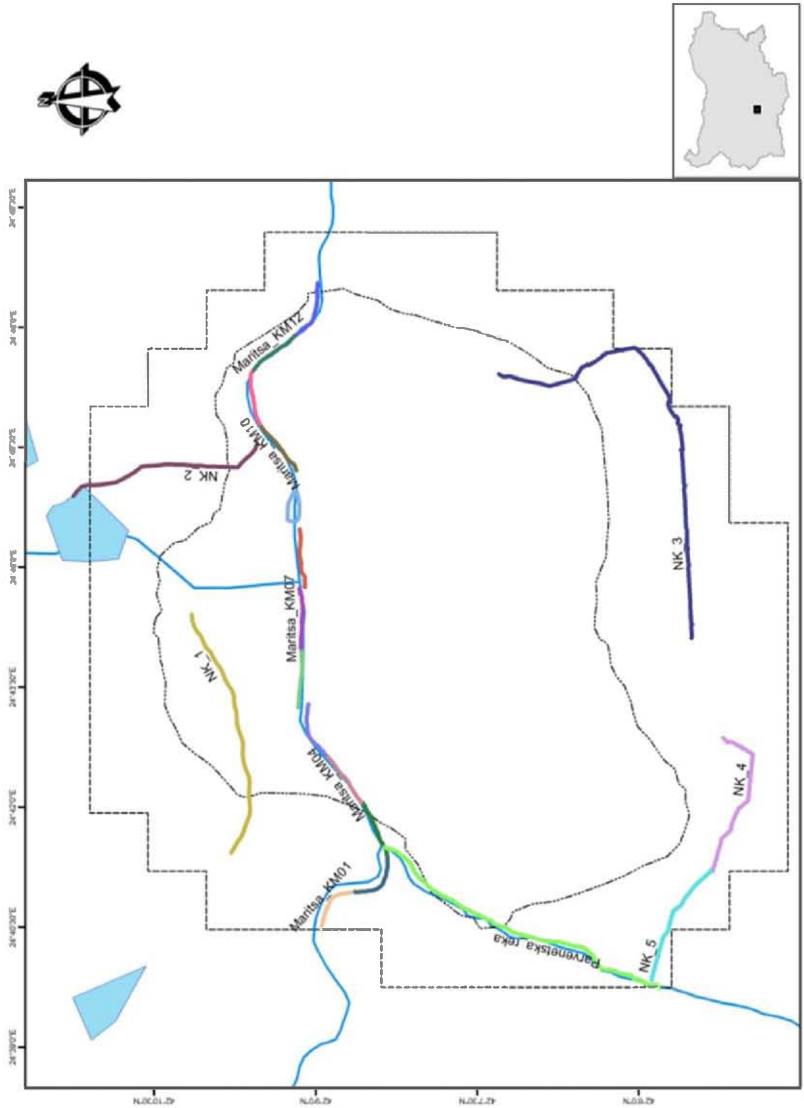

Fig. 5-1. Map of the selected transects alongside Maritsa River, Parvenetska River and the irrigation canals in the studied area (the explanations are in the text).

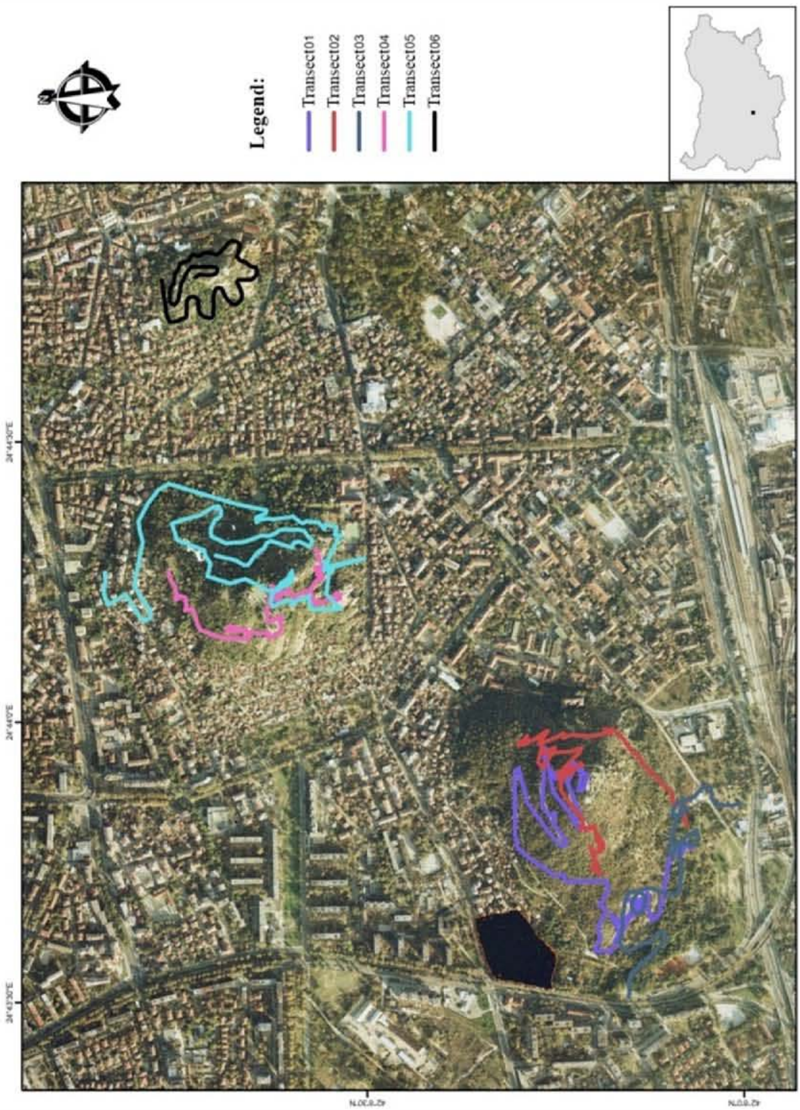

Fig. 5-2. Map of the selected transects in the Plovdiv hills (the explanations are in the text).

Fig. 5-3. Map of the selected transects in the city parks in Plovdiv City (the explanations are in the text).

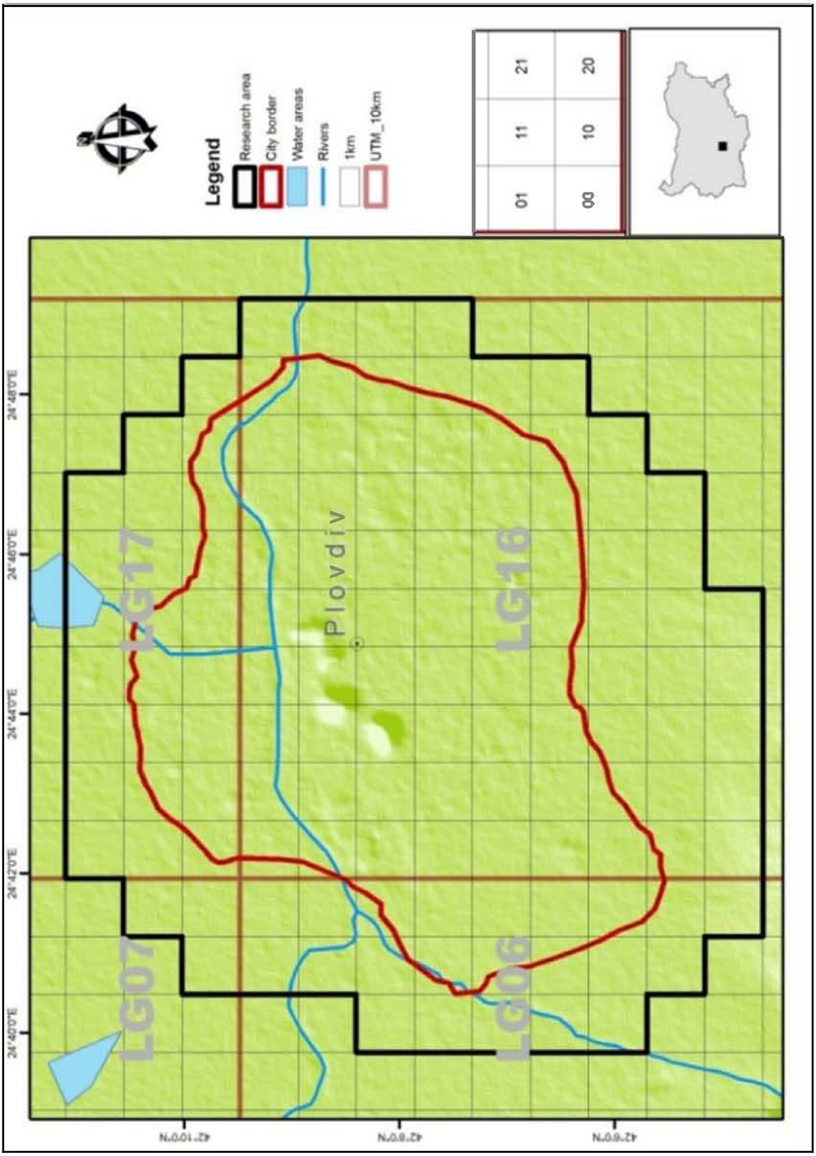

Fig. 6-1. UTM map (1x1 km) of the study area – Plovdiv City and its surroundings.

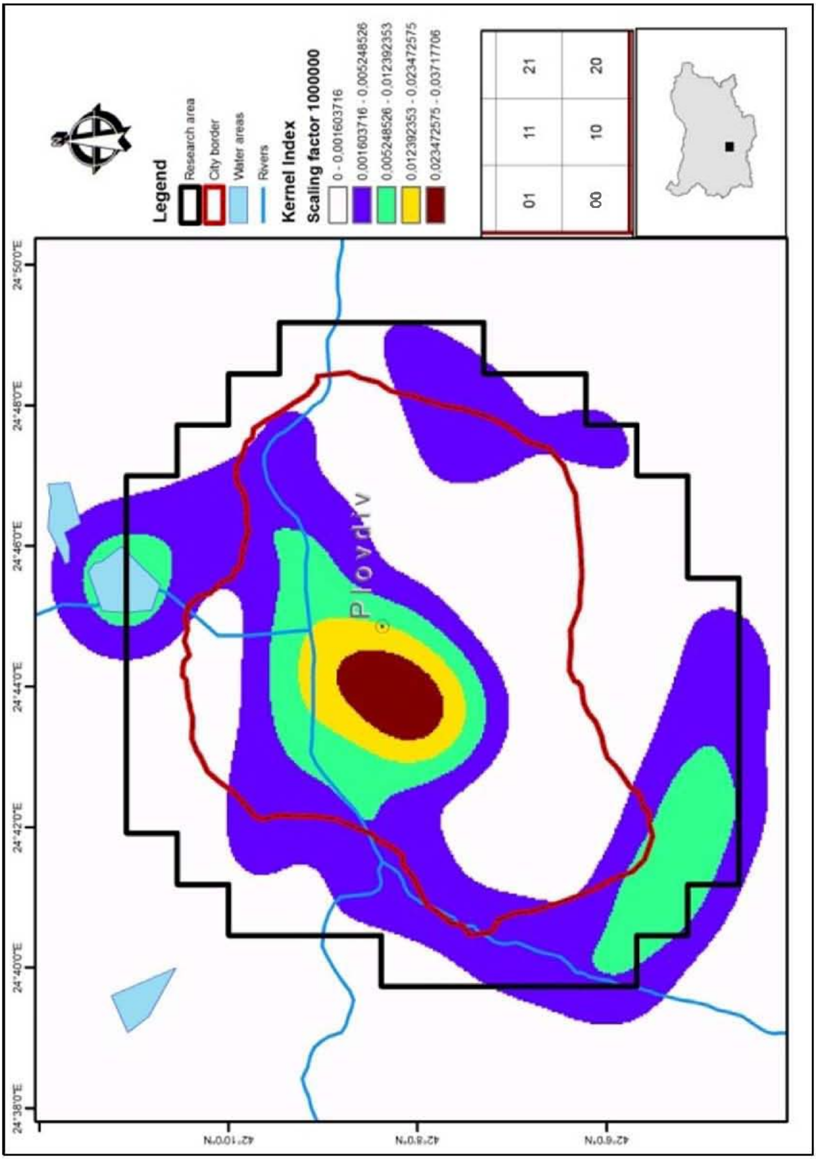

Fig. 8-1. Important Herpetological Areas in the study region.

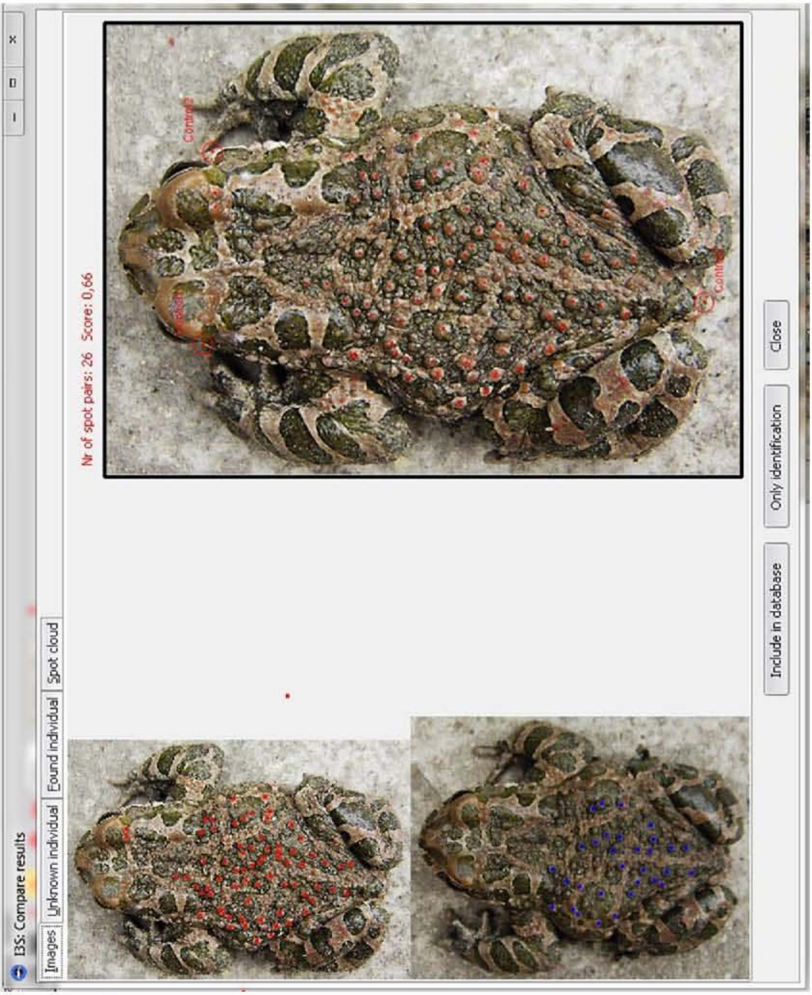

Fig. 13-3. An example of a visual comparison of two *Bufotes viridis* complex individuals with the "I3S" software v.2.0 (explanations are in the text).

CHAPTER NINE

HABITAT DISTRIBUTION

The most serious cause of amphibian and reptile decline in Europe is the loss of habitats (Jellinek, Driscoll, and Kirkpatrick 2004, 294-304). Urbanization is recognized to have a negative impact on habitat loss, though this can be ameliorated through adequate management plans (Löfvenhaft, Runborg, and Sjögren-Gulve 2004, 403-427). In order to propose efficient management plans in urban areas, local studies should be conducted towards surveying the ecological needs of amphibians and reptiles. Moreover, species' specific information is needed to emphasize the inter-specific differences in the preference for different habitat/landscape elements (Hartel, Öllerer, and Nemes 2007, 109-132). Furthermore, habitat loss and habitat configuration are two of the most important aspects when studying ecosystems in urban areas (Löfvenhaft, Runborg, and Sjögren-Gulve 2004, 403-427).

Currently, habitat-based studies on amphibians and reptiles in urban areas in Europe are scarce (Beebee 1979, 241-257; Kral, Pellantova, and Kokes 1983, 51-66; Banks and Laverick 1986, 44-50; Chovanec 1994, 43-54; Lehtinen, Galatowitsch, and Tester 1999, 1-12; Kühnel and Krone 2003, 299-315; Ruchin et al. 2003, 225; Ficetola and DeBernardi 2004, 219-230; Löfvenhaft, Runborg, and Sjögren-Gulve 2004, 403-427) and in Bulgaria such studies are largely absent (Milchev 1985, 195-203).

In Table 9-1 we present the habitat distribution of the amphibians and reptiles in Plovdiv City, their composition in the three urban zones (urban, suburban, rural), and their ecological characteristics according to the habitat selectivity and level of synanthropy. Six species of amphibians (*Bufo bufo, Bufotes viridis* complex, *Pelobates syriacus, Hyla arborea* complex, *Rana dalmatina* and *Pelophylax ridibundus*) were found in a total of 15 types of urban habitats, and eight species of reptiles (*Mediodactylus kotschyi, Lacerta viridis, Lacerta trilineata, Podarcis tauricus, Emys orbicularis, Natrix natrix, Natrix tessellata* and *Dolichophis caspius*) were recorded in 24 types of urban habitats.

Comparative analysis of the urban habitats based on qualitative faunistic similarity. The cluster analysis of the urban habitats occupied by amphibians based on presence/absence data resulted in groupings of two main clusters: aquatic and semi-aquatic habitats and terrestrial habitats with a faunistic similarity of about 15% (Fig. 9-1).

Table 9-1. Habitat distribution of the amphibians and reptiles in the city of Plovdiv. *Legend:* habitats' names and abbreviations are given in Table 5-1.

Species	Urban habitats																								
	Vpsv	Vvsv	Vrp	Vnk	PVkvf	PVktf	PVzk	Ssts	Svts	Sesnh	Sbh	Snik	Szks	Shog	Svog	Sgp	Smpg	Sg	Svpmb	Siz	Srs	Svgss	Sjsg	Sjss	Ssiz
Amphibia																									
Bufo bufo	+	+	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-
Bufotes viridis complex	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	+	+	+	+	+	+	-	-	-	-
Pelobates syriacus	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hyla arborea complex	+	+	+	+	+	+	+	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-
Rana dalmatina	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pelophylax ridibundus	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Reptilia																									
Mediodactylus kotschyi	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	+	+	+	-	-	+	+	+	+
Lacerta viridis	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	-	-	+	+	-	-	-	-
Lacerta trilineata	-	-	-	-	-	-	-	+	-	+	+	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Podarcis tauricus	-	-	-	-	-	-	-	+	-	+	+	+	+	-	-	+	+	-	+	+	+	-	-	-	-
Emys orbicularis	+	-	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Natrix natrix	+	-	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Natrix tessellata	+	-	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dolichophis caspius	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	+	-	-	-	+	-	-	-	-	-

Of the aquatic and semi-aquatic habitats, the rivers and streams (Vrp) are clearly distinguished at a 60% similarity level. The rivers and streams frequently hold predatory fish. To coexist with predators, special adaptations are required in amphibians, such as behavioral avoidance using chemical cues, toxic compounds and phenotypic changes in the body. These adaptations are efficient only if the aquatic habitat is complex enough to allow amphibians to use them as *"refugia"* (Hartel, Öllerer, and Nemes 2007, 109-132).

The other aquatic habitats were divided further into two groups at about 70% similarity – constant and temporary standing ponds and rice fields (Vpsv, Vvsv, PVzk) and irrigation canals with riparian plant communities (Vnk, PVkfv, PVktf). In the temporary ponds, where the predation risk is generally low (Sheffer et al. 2006, 227-231), intra- and inter-specific larval competition interactions with other abiotic and biotic conditions strongly influence growth rate, larval period, body size at metamorphosis and survival (Wilbur 1997, 2279-2302). Amphibians adapted for successful reproduction in temporary ponds are known as rapid colonizers of the available ponds, with multiple breedings through the year, rapid larval growth rates and flexible larval development (Laurila and Kujasalo 1999, 1123-1132; Loman 1999, 421-430; Merila et al. 2000, 18-24).

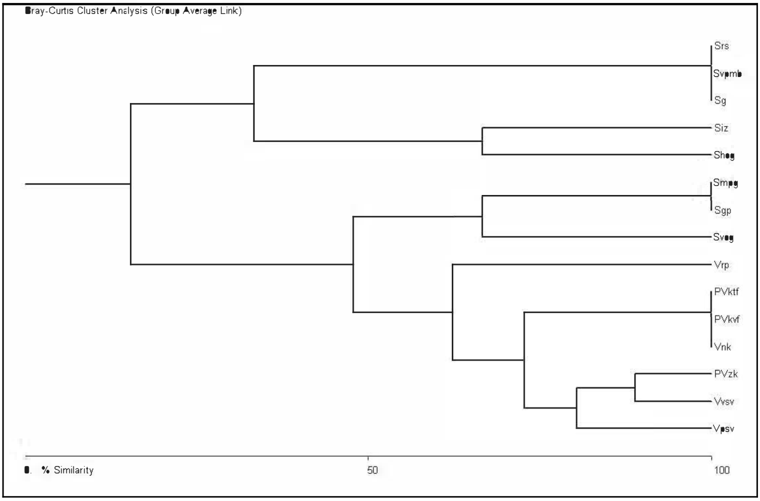

Fig. 9-1. Classification of the urban habitats in the city of Plovdiv, based on presence-absence similarity of amphibians (Bray-Curtis index). *Legend:* habitats' names and abbreviations are given in Table 5-1.

On the other hand, urban terrestrial habitats, inhabited by amphibians, were divided into three groups: the first two (about 40% of faunistic similarity) were the groups of the inner spaces between buildings, courtyards and the ruderal communities (Srs, Svpmb, Sg) and the abandoned lands (Siz) and vineyards (Shog). The third cluster of terrestrial habitats was composed by the small and large urban parks and high-fruit orchards (Svog, Sgp, Smpg) with close faunistic similarity to the aquatic and semi-aquatic habitats. This can be explained by the fact that most of the orchards are located along irrigation canals, and within the city parks there are temporary standing ponds used for breeding by some amphibians. The large part of the active season of the post-reproductive explosive breeder amphibians is spent in terrestrial habitats around the ponds. Moreover, the terrestrial habitats are important dispersion areas for juveniles (important for the regional maintenance of amphibian species and communities) and hibernation habitats (such as inner spaces between the buildings and interior courtyards) for some species. Due to the life cycle characteristics and the spatial heterogeneity of the habitats required to complete it, amphibians are especially sensitive to habitat loss and fragmentation (Hartel, Öllerer, and Nemes 2007, 109-132).

The urban habitats inhabited by reptiles in Plovdiv were divided into terrestrial and aquatic and semi-aquatic habitats, with a faunistic similarity of 1-2% (Fig. 9-2). Although only three species of the recorded reptiles are typical aquatic species (*Emys orbicularis, Natrix natrix* and *Natrix tessellata*), some terrestrial species of reptiles such as *Lacerta viridis* and *Dolichophis caspius* inhabited moist habitats near ponds, rivers and irrigation canals. Therefore, semi-aquatic habitats (PVktf, PVkvf) were differentiated from the typical aquatic ones (Vpsv, Vrp, Vnk, PVzk) at about 60% faunistic similarity.

Urban terrestrial habitats that are inhabited by reptiles were divided into two major groups at approximately 27% of faunistic similarity. The first group included residential buildings, inner spaces between buildings, courtyards, inner open rocky slopes and old industrial areas (Sg, Svgss, Sjsg, Sjss, Ssiz, Svpmb), which were mainly inhabited, and some exclusively by the Kotschy's gecko (*Mediodactylus kotschyi*). The second group was divided into three subgroups. The first of them (approximately 46% similarity) includes orchards and wet grasslands (Svog, Shog, Svts), inhabited mainly by the green lizard (*Lacerta viridis*). The second group of higher faunistic similarity (around 65%) consists of urban parks and agricultural areas (Sgp, Szks, Smpg, Snik), which apparently provide similar environmental conditions for certain species such as *Lacerta viridis* and *Dolichophis caspius*. The third group has a higher faunistic similarity (around 77%) and includes abandoned lands, grasslands and barbed bushes (Siz, Sesnh, Srs, Sbh, Ssts), which are preferred by the Balkan wall lizard (*Podarcis tauricus*) and the striped lizard (*Lacerta trilineata*). From all identified urban habitats, the reptiles were absent only in temporary standing freshwater ponds (Vvsv).

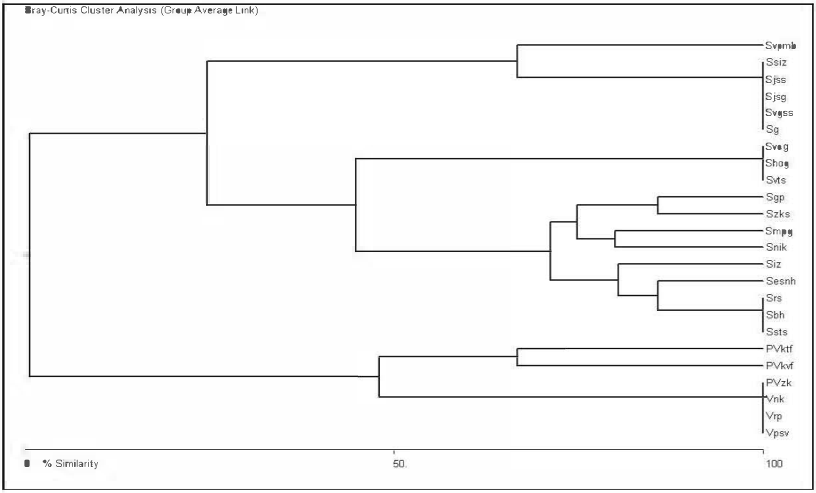

Fig. 9-2. Classification of the urban habitats in the city of Plovdiv, based on presence-absence similarity of reptiles (Bray-Curtis index). *Legend:* habitats' names and abbreviations are given in Table 5-1.

Those landscape elements that are not used as habitats but may play a major role in determining the success of movements (migrations) of some amphibians and reptiles represent the "*matrix*" (Kindlmann, Aviron, and Burel 2005, 150-158). A matrix with high permeability assures good movement conditions, which are high quality and safe areas (corridors). Human-made structures such as roads, railroads, fences, intensively treated agricultural lands, etc. may cause severe mortality of the individuals that cross them, and for many species represent an impermeable matrix (Hein et al. 2004, 411-420). Due to this fact, amphibian and reptile populations may decline because of either the loss of critical habitats (these may be the reproduction, summer and/or hibernation habitats) or the loss of connectivity between critical habitats (Hartel, Öllerer, and Nemes 2007, 109-132).

Species richness in the urban habitats. For the amphibians, the most species-rich habitat is "temporary standing, freshwater ponds" (Vvsv) with

5 species and the highest indices of diversity (Table 9-2, Fig. 9-3). This is expected, considering that this type of pond is used for the breeding of all identified species of amphibians and is the most common type of water basin in the city. At the same time, this is the most vulnerable urban habitat type and conservation measures should be applied to preserve temporary ponds in urban areas. The next richest habitats are the permanent standing freshwater ponds (Vpsv, PVzk) and rivers and streams (Vrp). Riparian and terrestrial urban habitat types were significantly poorer in species.

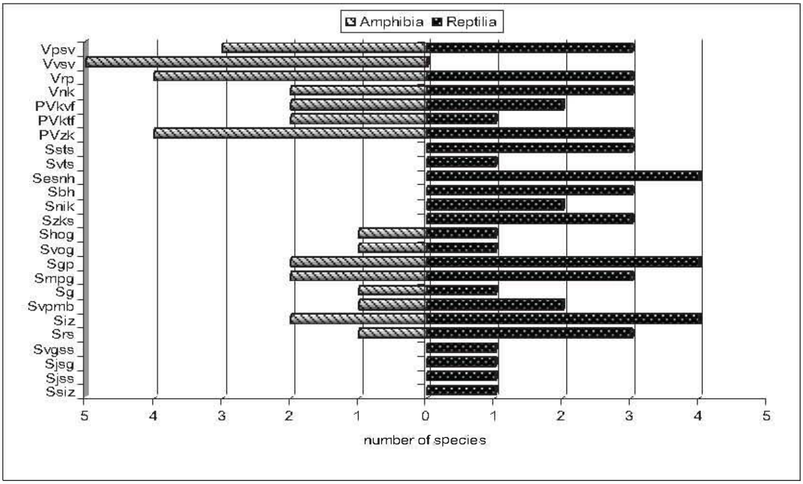

Fig. 9-3. Number of species of amphibians and reptiles in the studied urban habitats. *Legend:* habitats' names and abbreviations are given in Table 5-1.

Unlike amphibians, the reptiles had the highest species richness in terrestrial habitats: "dry European communities of low bushes" (Sesnh); "large urban parks" (Sgp) and "abandoned lands" (Siz), followed by the aquatic and semi-aquatic habitats (Table 9-2, Fig. 9-3). With only one species recorded per habitat, the habitats with the lowest species richness were: "gardens and courtyards" (Sg); "internal bare rock slopes" (Svgss); "residential buildings" (urban and rural type) (Sjsg, Sjss) and "old industrial areas" (Ssiz), occupied only by the Kotschy's gecko (*Mediodactylus kotschyi*).

Table 9-2. Diversity indices (Hill numbers) of the studied urban habitats (sorted in descending species richness). *Legend:* H_0 – number of species; H_1 – Exponential function of the Shannon-Wiener diversity index (exp(H’)); H_2 – reciprocal value of the Simpson diversity index. Habitats’ names and abbreviations are given in Table 5-1.

Urban habitats	**H_0**	**H_1**	**H_2**
	Amphibia		
Vvsv	5	14.709	0.125
Vrp	4	10.660	0.083
PVzk	4	10.660	0.045
Vpsv	3	7.039	0.333
Vnk	2	3.922	0.071
PVkvf	2	3.922	0.063
PVktf	2	3.922	0.056
Sgp	2	3.922	0.038
Smgp	2	3.922	0.036
Siz	2	3.922	0.031
Shog	1	1.143	0.043
Svog	1	1.143	0.042
Sg	1	1.143	0.034
Svpmb	1	1.143	0.033
Srs	1	1.143	0.030
	Reptilia		
Sesnh	4	10.660	0.043
Sgp	4	10.660	0.027
Siz	4	10.660	0.021
Vpsv	3	7.039	0.333
Vrp	3	7.039	0.167
Vnk	3	7.039	0.111
PVzk	3	7.039	0.067
Ssts	3	7.039	0.056
Sbh	3	7.039	0.038
Szks	3	7.039	0.032
Smpg	3	7.039	0.025
Srs	3	7.039	0.020
PVkvf	2	3.922	0.091

Snik	2	3.922	0.036
Svpmb	2	3.922	0.023
PVktf	1	1.443	0.083
Svts	1	1.443	0.053
Shog	1	1.443	0.031
Svog	1	1.443	0.030
Sg	1	1.443	0.024
Svgss	1	1.443	0.020
Sjsg	1	1.443	0.019
Sjss	1	1.443	0.019
Ssiz	1	1.443	0.019

Perhaps, of the terrestrial urban habitats, the most vulnerable are the abandoned lands, which are rapidly being overbuilt. They are essential for the existence of most of the reptile species in the city and important for the dispersal and migrations of the amphibians in the post-breeding periods.

CHAPTER TEN

DYNAMICS IN THE HERPETOFAUNA ALONG THE URBAN-TO-RURAL GRADIENT

Most of the ecological characteristics of a big city vary in a directional way from the periphery to the city center, thus forming the so-called “urban-to-rural” gradient (Klausnitzer 1990, 1-246). Further, the concept of the “urban-to-rural” gradient was developed by McDonnell and Picket (1990, 1232-1237) and is largely used in urban ecological studies. The main criteria used to determine the *“urban”*, *“suburban”* and *“rural”* zones in the study area were the distance from the city center and the type and density of the residential buildings (urban or rural type). The “urban” zone includes the entire area of the administrative city center (≈2 km radius from the city center). The “suburban” zone includes the area between the outer border of the urban zone and the administrative border of the city. The “rural” zone includes the area between the outer borders of the suburban zone and the border of the study area, determined by the UTM grid (Fig. 6-1).

Both the amphibians and the reptiles showed a similar distribution pattern along the urban-to-rural gradient (Table 10-1). In both cases, a decrease of the species richness is observed from the periphery to the city center. The Sørensen Similarity Index confirmed this distribution pattern, showing the highest similarity between the suburban and the rural zones and a slightly lower similarity between the urban and the suburban zones. The similarity between the urban and rural zone showed the lowest values.

The only exception is the green toad that is distributed in the urban and suburban areas, but not outside the city. Four reptile species are recorded in all three areas (*L. viridis, P. tauricus, E. orbicularis* and *D. caspius*), three species (*L. trilineata, N. natrix, N. tessellata*) are absent from the center of the city and only one species (*M. kotschyi*) is absent from the rural areas. The Sørensen Similarity Index confirms this pattern of distribution, showing the highest similarity between the suburban and rural areas and slightly less similarity between the urban area and the suburban area. The similarity between the urban and rural zone showed the lowest values.

Table 10-1. "Urban-to-rural" composition and ecological classification of the amphibians and reptiles in the city of Plovdiv.

Species	Zone			Sørensen Similarity Index (S), %		
	Urban	Suburban	Rural	Urban/Suburban	Suburban/Rural	Urban/Rural
Amphibia						
Bufo bufo	-	+	+	75.00	80.00	50.00
Bufotes viridis complex	+	+	-			
Pelobates syriacus	-	+	+			
Hyla arborea complex	+	+	+			
Rana dalmatina	-	-	+			
Pelophylax ridibundus	+	+	+			
Reptilia						
Mediodactylus kotschyi	+	+	-	76.92	93.33	66.67
Lacerta viridis	+	+	+			
Lacerta trilineata	-	+	+			
Podarcis tauricus	+	+	+			
Emys orbicularis	+	+	+			
Natrix natrix	-	+	+			
Natrix tessellata	-	+	+			
Dolichophis caspius	+	+	+			

In order to track the grouping of communities by quantitative similarity, a cluster analysis was performed based on the species populations' sizes in the explored park fragments and biotopes with the Bray-Curtis index. From the obtained dendrogram (Fig. 10-1) it is clear that the park fragments are divided into two main groups with a similarity of about 3%. One main group is that of the fragments consisting mainly of terrestrial habitats – Plovdiv hills, urban and cemetery parks – and the other group consists of water habitats. The first main group is subdivided into two subgroups, one of which combines “Mladezhki hulm” Hill and “Hulm Bunardzhik” Hill (U_MH and U_HO, respectively) and “Tsar Simeonova Gradina” Park (U_TSG) with a similarity of around 42%, all of which are located in the very center of the city. The other park fragments are further divided by approximately 15% similarity into two subgroups – one cluster is formed with two of the hills – “Trihalmie” Hill (U_Tri) and “Danov Hulm” Hill (U_DH) – and Rogosh Graveyard Park (SU_Rog), where the distance from the center of the city is increasing. The second sub-cluster is formed by “Lauta” Park (SU_Laut) and “Otdih i Kultura” Park (SU_OK), both of which are located in the suburban area (in opposite parts of the city, in a west-east direction).

In the second main group, there was also a division into two subgroups, with approximately 37% similarity. One subgroup is formed by the Maritza River (U_Mar, SU_Mar), the irrigation canals located in the southern area outside the city (RU_NK3, RU_NK4, RU_NK5) and the Parvenetska River (RU_Par); the other irrigation canals (SU_NK1, SU_NK2), located in the suburbs in the northern part of the city, together with the "Plovdiv" Rowing Base (SU_GB), Plovdiv State Fishery (RU_Rib) and the rural parts of the Maritza River (RU_Mar) represent the second subgroup.

From the performed cluster analysis it becomes clear that the amphibian and reptile communities in the city of Plovdiv and the surrounding areas are divided mainly into “park” (forest) and “aquatic” ones. More precise conclusions about the forest fragments would not be entirely correct as all the parks studied are located only in the central part of the city and in the suburbs. For the aquatic communities of amphibians and reptiles, except for the Maritsa River, which forms an autonomous gradient (see Chapter 12), the remaining water basins are grouped on a geographic basis – the southern and the northern groups.

Figure 10-2 presents a table obtained from the classification of communities by cluster analysis by the divisional method based on indicator species (TWINSPAN). The result is very similar to that obtained from a cluster analysis of faunistic similarity (Fig. 10-1).

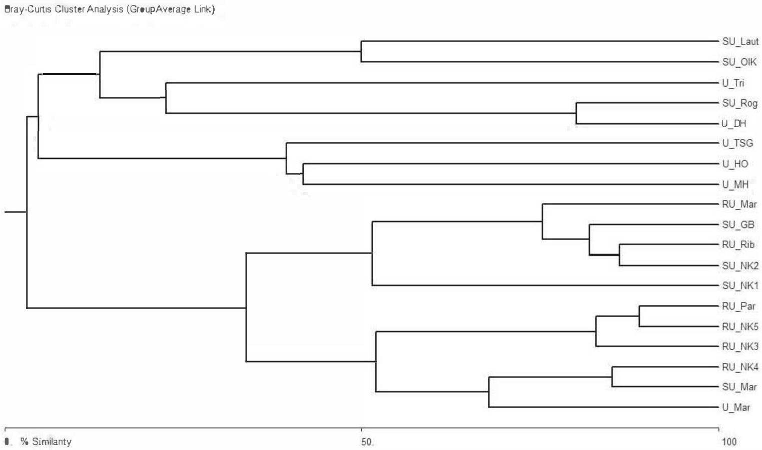

Fig. 10-1. Similarity of the herpetofauna in the habitat fragments along the urban-to-rural gradient (Bray-Curtis index, unpaired per group average, quantitative data, explanations and abbreviations are in the text).

```
                 1111  111  11   1
               1784578906923134562

  3 P_syriac   1------------------   000
 11 Emys_orb   11--1-1-1----------   000
 12 Nat_natr   11-111-------------   000
 13 Nat_tess   111111-------------   000
  1 Bufo_buf   ----1---11---------   001
  5 Rana_dal   ---------11--------   001
  6 Pelo_rid   11111111111--------   001
  9 L_trilin   ---------11--------   001
  4 Hyla_arb   ---11111-111-1-----   01
  8 L_virids   11111111-111111---1   01
 14 Dol_casp   -11-------11-------   01
  2 Bufo_vir   ---------1-1111111-   1
  7 M_kotsch   11---------11--1111   1
 10 P_tauric   ----------111-1----   1

               0000000000011111111
               0000001111110000111 1
               00011100011
```

Fig. 10-2. TWINSPAN table of amphibians and reptiles based on quality data from explored habitat fragments. *Legend*: Habitat fragments (first row): 1 – U_Mar; 7 – SU_Mar; 18 – RU_NK5; 14 – RU_Mar; 15 – RU_Rib; 17 – RU_NK4; 8 – SU_NK1; 9 – SU_NK2; 10 – SU_GB; 16 – RU_NK3; 19 – RU_Par; 2 – U_MH; 3 – U_HO; 11 – SU_OIK; 13 – SU_Laut; 4 – U_DH; 5 – U_Tri; 6 – U_TSG; 12 – SU_Rog. (explanations and abbreviations are given in the text). Species (first column): *1 – Bufo bufo; 2 – Bufotes viridis* complex*; 3 – Pelobates syriacus; 4 – Hyla arborea* complex*; 5 – Rana dalmatina; 6 – Pelophylax ridibundus; 7 – Mediodactylus kotschyi; 8 – Lacerta viridis; 9 – Lacerta trilineata; 10 – Podarcis tauricus; 11 – Emys orbicularis; 12 – Natrix natrix; 13 – Natrix tessellata; 14 – Dolichophis caspius.*

In the first grouping of amphibian and reptile communities (Fig. 10-2), there are two groups that are separated one is of the aquatic habitats and the second group is of forest fragments in the central part of the city and the suburbs (colored with dark shading). All parts of the Maritza River are separated, together with Plovdiv State Fishery and Irrigation Canals No. 4 and 5. In a separate group, the other water basins are differentiated, but this grouping is different from that obtained from the cluster analysis (Figs. 9-1 and 9-2). The "Mladezhki hulm" Hill and "Hulm Bunardzhik" Hill parks are grouped together with the "Lauta" park and "Otdih i Kultura" park, while "Danov hulm" Hill and the "Trihulmie" Hills are grouped with the "Tsar Simeonova Gradina" park and "Rogosh" Cemetery Park.

		231	
1	Bufo_buf	11-	0
3	P_syriac	11-	0
5	Rana_dal	-1-	0
9	L_trilin	11-	0
12	Nat_natr	11-	0
13	Nat_tess	11-	0
4	Hyla_arb	111	10
6	Pelo_rid	111	10
8	L_virids	111	10
10	P_tauric	111	10
11	Emys_orb	111	10
14	Dol_casp	111	10
2	Bufo_vir	1-1	11
7	M_kotsch	1-1	11
		001	

Fig. 10-3. TWINSPAN table of amphibian and reptile communities based on quality data from the three urban areas.
Legend. City zones (*first row*): 1 – Urban; 2 – Suburban; 3 – Rural. Species (*first column*): 1 – *Bufo bufo*; 2 – *Bufotes viridis* complex; 3 – *Pelobates syriacus*; 4 – *Hyla arborea* complex; 5 – *Rana dalmatina*; 6 – *Pelophylax ridibundus*; 7 – *Mediodactylus kotschyi*; 8 – *Lacerta viridis*; 9 – *Lacerta trilineata*; 10 – *Podarcis tauricus* 11 – *Emys orbicularis*; 12 – *Natrix natrix*; 13 – *Natrix tessellata*; 14 – *Dolichophis caspius*.

According to the TWINSPAN analysis, indicator species for the urban aquatic areas are the marsh frog (*P. ridibundus*) and the tree frog (*H. arborea* complex) from the amphibians *E. orbicularis*, and the two species of aquatic snakes (*N. natrix* and *N. tessellata*) from the reptiles. Despite its widespread distribution throughout the aquatic habitats, the green lizard (*L. viridis*) cannot be identified as an indicator species for aquatic habitats, as it is not less common in terrestrial fragments. For park (forest) fragments, indicator species are the green toad (*Bufotes viridis* complex) from the amphibians and the Kotschy's gecko (*M. kotschyi*) from the reptiles. In general, for the central and suburban zones, indicator species are *Bufotes viridis* complex and *M. kotschyi*, and for the rural zone it is *R. dalmatina* (Fig. 10-3).

The diversity indices of the amphibian and reptile communities for each zone show that the urban zone is the most diverse (Table 10-2). All indices show very close values for the suburban and rural zones, which are also characterized by low evenness, suggesting the dominance of one or two species in these communities, a claim confirmed by the high value of the Berger-Parker Index of dominance for these two zones.

Table 10-2. Indices of diversity, evenness and dominance of the amphibian and reptile communities in the three urban-rural gradient zones.

Zone / Index	Urban	Suburban	Rural
Simpson (1-D)	0.6841	0.2445	0.2096
Simpson Evenness (E)	0.3431	0.1667	0.1436
Shannon (H)	1.3280	0.6063	0.5441
Equitability (J)	0.5539	0.2528	0.2190
Berger-Parker	0.3915	0.8662	0.8867

According to McKinney (2008, 161-176) and Hammer and McDonnell (2008, 2432-2449), based on data from 24 independent studies, the species richness, abundance, and diversity of amphibian and reptile communities are declining along the urban-rural gradient from the periphery to the center of the city. This is due to the increase in anthropogenic influence towards the city center and the increasing loss and degradation of habitats for amphibians and reptiles. The main reason for the observed phenomenon in Plovdiv City is the presence of a rich heterogeneous mosaic of habitats, namely in the center of the city and the suburbs. The location of the Plovdiv hills in the center of the city, the presence of several large urban parks in the center and the suburbs, as well as the course of the Maritsa River through the whole city, have led to the observed increase in the diversity of the amphibian and reptile communities in the urban zone (see also Chapter 8).

The above data gives us reason to believe that the urban environment has led to the formation of a particular type of "urban communities" characterized by the dominance of one or two species and the predominance of widespread adaptive species. Remarkable for the city of Plovdiv is that there is no formation of the so-called "communities of the peripheral zone", which are transient between urban and suburban areas. There are clear communities in the central parts of the city and in the rural areas. In this sense, the city of Plovdiv could be considered as an example of poorly developed amphibian and reptile communities in the suburban zone of the urban-rural gradient (McDonnell and Pickett 1990, 1232-1237).

According to our results, the urban aquatic communities are divided into three large groups of water basins – the first is the Maritsa River, which is an autonomous gradient in the west-east direction; the basins on the southern side of the city form the second group, and those on the northern side form the third group. This separation is probably due to the geographic proximity of these basins to the different sources of colonization, in one case the river tributaries coming from the Rhodopes Mts., and in the other case, the ones from the Sredna Gora Mts. and the Stara Planina Mts.

CHAPTER ELEVEN

ECOLOGICAL AND ZOOGEOGRAPHIC CLASSIFICATION OF THE URBAN HERPETOFAUNA

Ecological Classification of the herpetofauna in the City of Plovdiv

In the current monograph, the ecological groups of amphibians and reptiles are classified by the following: 1) ecological plasticity and habitat preferences; 2) temperature mode; 3) humidity; and 4) level of synanthropization. For the categorization, existing classifications given by Angelov and Kalchev (1961, 18-21), Kamenov (1988, 1-432), Klausnitzer (1990, 1-246), Beshkov and Nanev (2002, 1-120) and others were used, modified for the conditions of the city of Plovdiv.

Ecological classification according to ecological plasticity and habitat preferences. From the amphibians, three species (*B. viridis* complex, *H. arborea* complex and *P. ridibundus*) can be classified as "polytopic". Two of them – *H. arborea* complex and *P. ridibundus* – inhabit all kinds of aquatic and semi-aquatic habitats, while *B. viridis* complex is well adapted to terrestrial habitats as well. The remaining three amphibian species recorded in the city of Plovdiv (*B. bufo, P. syriacus* and *R. dalmatina*) are considered "stenotopic".

From the registered reptiles four species can be classified as "polytopic" – *M. kotschyi, L. viridis, P. tauricus* and *E. orbicularis.* The species that occupies most habitats is the green lizard, which exhibits a preference for semi-wetland habitats. The other lizards found, on the other hand, prefer dry and warm habitats. However, the Kotschy's gecko exhibits greater specialization in terms of habitats and is registered in habitats that are "uninhabitable" for the other recorded reptiles in the city. *L. trilineata, N. natrix, N. tessellata* and *D. caspius* can be classified as "stenotopic". *L. trilineata* is found in habitats similar to those inhabited by the green lizard, but adheres to drier habitats and is absent from the inner parts of the city. *D. caspius* inhabit the ecotone zones between woodlands and open spaces in the city. That is why the species is registered in a relatively small number of habitat types and has a limited distribution in the city.

When comparing the number of stenotopic and polytopic species from both classes in the city and its surroundings, it is visible that, for the amphibians, the number of polytopic species in both zones is equal (three species), while stenotopic species are absent from the city and are only found in its vicinity (Fig. 11-1). The reason for this is either the absence or the excessive transformation, fragmentation and degradation of suitable habitats for these species in the city. Suitable habitats for amphibians are preserved to some extent only in the surroundings of the city.

We observe the same trend for the reptiles as well – an increase of the number of polytopic species and a reduction of the number of stenotopic species from the surroundings to the city center.

For more information on the habitat distribution of the amphibians and reptiles in the city of Plovdiv, see Chapter 9.

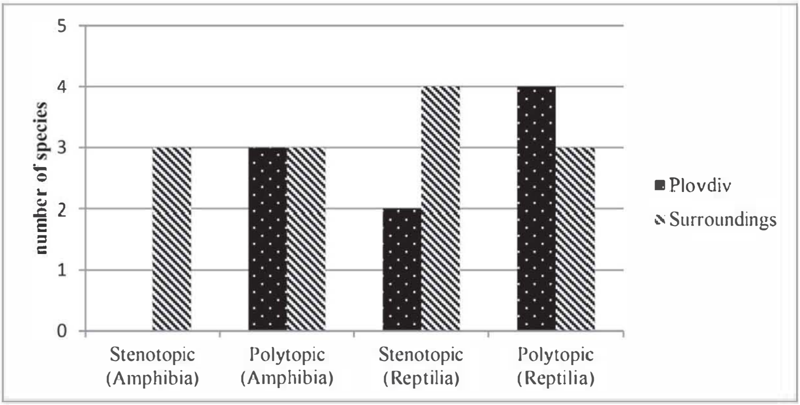

Fig. 11-1. Comparison between the amphibians and reptiles, regarding their habitat distribution in the city of Plovdiv and its surroundings.

Ecological classification according to the temperature regime. Being ectothermic (poikilothermic) animals, amphibians and reptiles are hard to classify in terms of temperature. Therefore, there is no universally accepted classification for these two classes of animals with regard to their requirements for environmental temperature. We propose the following classification in terms of temperature requirements in urban environments for the amphibians and reptiles registered in the current study:

1. *Thermophiles* – species which prefer dry and hot habitats, usually with temperatures of 40-45°C and beyond. In the city of Plovdiv, there is only one species which prefers such conditions and can be classified as "thermophile" – the Kotschy's gecko (*M. kotschyi*). On the hills of Plovdiv, this species was frequently observed on sunny rocks and walls, usually with southern and eastern exposure.

2. *Mesothermophiles* – species which prefer warm habitats, usually with temperatures between 30-40°C. From the recorded species in the study area, three lizard species from the Lacertidae family can be classified as "mesothermophiles" – *L. trilineata, L. viridis,* and *P. tauricus.* All three species usually inhabit dry, sunny habitats (except for *L. viridis,* which prefers slightly humid habitats) and are most active at higher air temperatures.

3. *Mesothermic species* – species preferring moderate temperature values, usually between 20-30°C, which are less adapted to colder environments and usually inhabit forest habitats. From the amphibian species recorded in the study area, the mesophilic ones are *H. arborea* complex, *R. dalmatina, P. ridibundus* and *P. syriacus.* From the reptiles, they are *E. orbicularis, N. natrix, N. tessellata* and *D. caspius.* All the above-mentioned amphibians cannot tolerate heat and usually inhabit mid-humid habitats with moderate temperatures. From the reptiles, the mesophilic ones are all species related to some extent to water and the *D. caspius,* which stays close to humid and forest habitats.

4. *Mesopsychrophiles* – species which prefer slightly cooler habitats, generally temperatures between 10-20°C. In the city of Plovdiv and its surroundings, we recorded only two such species of amphibians – *B. bufo* and *B. viridis* complex. Both toad species tolerate lower than moderate temperatures and their breeding season begins very early, before all other registered amphibians in the research area, in February-March (Beshkov and Nanev 2002, 1-120).

At lower temperatures, all species of reptiles and amphibians fall into a hibernation state and therefore they do not exist as typical psychrophiles (cryophiles).

When comparing the number of species of amphibians and reptiles belonging to the four above-mentioned ecological groups of animals in terms of the temperature in the city of Plovdiv and its surroundings, there is a significant difference between the two classes of animals (Fig. 11-2). There are no thermophilic and mesothermophilic amphibian species, and in the surroundings there are twice as many mesothermic species than in the city. The number of mesopsychrophilic species in the city and in the surroundings is equal.

For the reptiles, there is a pattern that thermophilic and mesothermophilic species prefer the central urban areas, and there is an approximately equal distribution in the city and in the surroundings of the mesothermic species. This pattern could be explained by the so-called "*urban heat island effect*" – the temperature in the center of big cities is a few degrees higher in comparison with its surroundings (Oke 1982, 1-24) due to the change in the nature of the land cover. Because of this, in the city, only those reptiles that prefer higher temperatures and that are better adapted to such conditions are found.

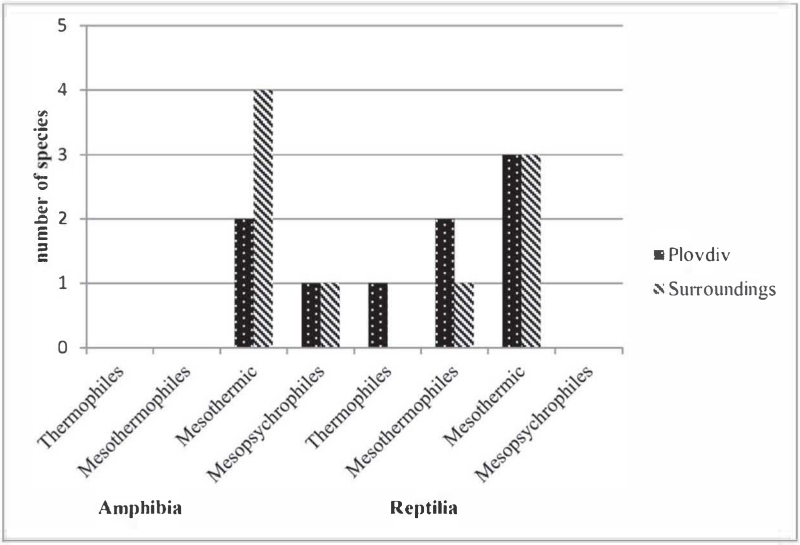

Fig. 11-2. Distribution of the ecological groups of amphibians and reptiles according to temperature in the urban part of the city of Plovdiv and its surroundings.

Ecological classification according to the humidity regime. Anurans can be classified into three ecological groups, regarding their requirements for humidity (after Angelov and Kalchev 1961, 18-21). We adopted these classifications with few changes regarding the urban environment. In our opinion, the categories presented below can be applied to reptiles as well, with some additions.

1. Hydrophiles – species that are strongly connected to the water basins and almost never leave them or stick close to them. From the amphibians, recorded in Plovdiv, the only such species is the marsh frog (*P.*

ridibundus). From the reptiles, the European pond turtle (*E. orbicularis*) belongs to this group.

2. *Mesohydrophiles* – species that do not live permanently in the water, but always adhere to damp places. From the amphibians, such species are the agile frog (*R. dalmatina*) and the European tree frog (*H. arborea* complex). From the reptiles, there are two such species – the two aquatic snakes (*N. natrix* and *N. tessellata*). The dice snake and the grass snake, however, can be attributed to an intermediate group in this classification between this ecological group and the next, as in some cases both can be found and spend considerable time away from any water basins (Beshkov and Nanev 2002, 1-120).

3. *Mesophilic* – species that enter the water only for reproduction, and which spend the rest of the time in terrestrial habitats with moderate humidity. From the amphibians, such species are two species of toads (*B. bufo, B. viridis* complex) and the Balkan spadefoot toad (*P. syriacus*). The latter species can again be classified into the intermediate level between this group and the previous one, as spadefoot toads stick to moderately moist habitats, while both toad species are extremely drought resistant and can spend a long time in fully dry areas, without proximity to water basins (Beshkov and Nanev 2002, 1-120). From the reptiles, the green lizard (*L. viridis*) and the Balkan wall lizard (*L. trilineata*) as well as *D. caspius* can be classified in this group.

4. *Xerophiles* – drought-resistant species that avoid wetland habitats and are well adapted to hot and dry conditions. There are no amphibian species registered in the city of Plovdiv that can be classified in this category. From the reptiles, *P. tauricus* and *M. kotschyi* are xerophilic. Both are extremely well adapted to the hot and dry habitats that abound in city centers.

When comparing the number of species of amphibians and reptiles that belong to the four above-mentioned ecological groups of animals in the city of Plovdiv and the surrounding area, there is again a significant difference between the two classes (Fig. 11-3). For the amphibians, which are more dependent on the availability of water, there was no significant difference in the number of species in the city and surrounding areas, as ponds and wetland habitats are located downtown as well as in the surrounding areas of the city (see Mollov and Velcheva 2010, 25-38). For the reptiles, however, there is a visible trend of reducing hydrophiles and increasing xerophiles in the direction of the urban center. It is a known fact that, in urban areas, higher levels of drainage of rainwater and higher levels of evaporation due to impervious surfaces are observed (Leopold 1968, 1-18; Arnold and Gibbons 1996, 243-258). Therefore habitats in the city, with the exception of those located in the vicinity of permanent waters, have low to moderate humidity. The reptile species which are not directly related to water but stick to humid habitats remain, for the most part, in the suburban and rural parts of the city. In the drier habitats in the central part remain only species that are well adapted to such conditions. Therefore xerophilic species are not recorded in the surroundings of the city.

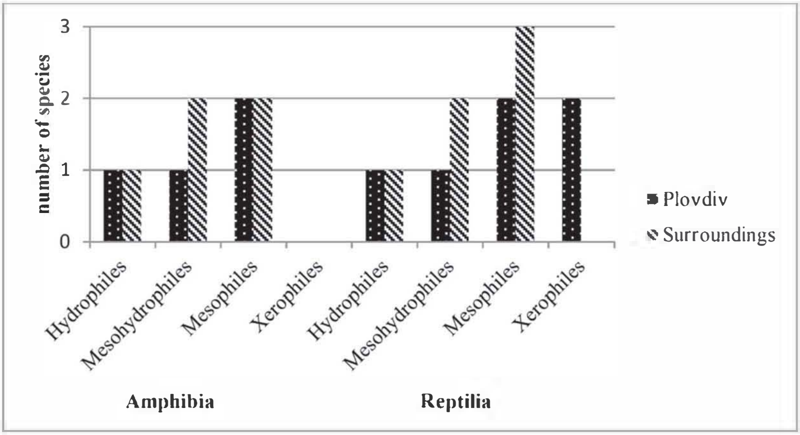

Fig. 11-3. Distribution of the ecological groups of amphibians and reptiles according to humidity in the urban part of the city of Plovdiv and its surroundings.

Ecological classification according to the level of synanthropy. According to the classification given by Klausnitzer (1990, 1-246) there are four ecological groups of animals in subordination to their level of synanthropy: *hemerophobes* – species which avoid the urban environment; *hemerodiaphores* – species whose existence does not depend on the anthropogenic transformation of the landscape; *hemerophiles* – species which prefer habitats made by humans; and *synanthropes* – species which are directly connected with habitats made by man and whose existence depends on human activity. Synanthropes, on the other hand, are *obligate* and *facultative*. Obligate synanthropes are species that occur in a (micro) climatic zone in anthropogenic conditions only in urban areas, usually within human settlements, and they do not or rarely occur elsewhere in nature. Facultative (optional) synanthropes are species found in urban areas and human settlements, where they find optimal conditions for existence, while they can also form natural populations in natural biotopes.

According to Klausnitzer's classification, from the amphibians, there were no species that could be classified as "synanthropes". One species (*Bufotes viridis* complex) is considered "hemerophilic", because it occurs mainly in the urban and suburban zones of the city and is highly ecologically adaptive and occurs in a wide variety of habitats (polytopic species). Two species (*Hyla arborea* complex and *Pelophylax ridibundus*) are also considered as polytopic and they occur in all three zones, which make them "hemerodiaphores". Three species (*Bufo bufo, Pelobates syriacus* and *Rana dalmatina*) were recorded only in the rural and suburban zones in very few habitat types (stenotopes) and are considered as "hemerophobes".

From the reptiles, one species (*Mediodactylus kotschyi*) showed characteristics of a typical synanthrope and polytopic species, inhabiting a wide variety of urban habitat types, some inhabitable for any other reptilian species. There were no reptilian species recorded which can be classified as "hemerophyles". Four species (*Lacerta viridis, Podarcis tauricus, Emys orbicularis* and *Dolichophis caspius*) were recorded in all three zones in the city and occurred in a wide range of urban habitats (except for *D. caspius,* which has more specific habitat preferences and it is a stenotopic species), which makes them "hemerodiaphores". Three species (*Lacerta trilineata, Natrix natrix* and *Natrix tessellata*) were absent from the urban zone and occur in few urban habitat types (stenotopic species), and they are considered to be "hemerophobic".

For a full classification of the amphibians and reptiles registered in the city of Plovdiv, based on their level of synanthropy, see Mollov (2014, 109-112).

Zoogeographic structure of the herpetofauna in the city of Plovdiv

In the present work, two alternative approaches were used to determine the zoogeographic structure of the herpetofauna in Plovdiv.

One approach is the classification of the species in faunistic complexes using classification elements proposed by Gruev and Kuzmanov (1999, 1-344). This classification is further supplemented with data from the works of Beškov and Beron (1964, 1-39) and Gruev (2000, 73-94; 2002, 31-40), with amendments. For the classification of individual amphibian and reptile species, their general distribution (Gasc et al. 1997), their ecological requirements and their alleged center of origin are used.

The second approach follows the chorotype classification of Vigna Taglianti et al. (1999, 31-59), which is based on the distribution of species (including many amphibian and reptile species) in the western Palearctic. This classification was supplemented and applied to Bulgarian species by Petrov (2007, 85-107). The classification of amphibians and reptiles in this study for the individual chorotypes and zoogeographic categories of the two classifications is given in Table 11-1.

As an element of the zoogeographic structure of the studied animal groups, we have presented their degree of endemism (after Petrov 2007, 85-107).

Zoogeographic structure by faunistic complexes and elements. From the recorded 6 species of amphibians in the surveyed area, 3 of them (50%) belong to the Siberian faunistic complex, 2 (33.3%) to the European faunistic complex and 1 (16.7%) to the Southwest Asian complex. With regard to the elements, the most widely represented one is the European-Asian Palearctic faunistic element, to which most species belong, but it is the second largest in numbers. Higher in terms of number is the Sub-Iranian element, to which the marsh frog belongs.

Out of the 8 registered reptile species, 3 (37.5%) belong to the Mediterranean faunistic complex, 2 (25%) to the Eurasian complex and 1 (12.5%) to the European, Siberian and Southwest Asian faunal complexes, respectively. The most common faunistic elements are the Pontic (to which the most numerous species of lizards and snakes belong – *P. tauricus* and *D. caspius,* respectively) and the East Mediterranean element (to which *M. kotschyi* belongs, which is a synanthropic species and one of the species with the highest numbers in the city).

It is noteworthy that, for the amphibians, the European-Asian Palearctic element is predominant, and it is not accidental, since most species of Bulgarian amphibians are more widespread in the Palearctic and belong to the Siberian and European complexes (Beškov and Beron 1964, 1-39; Gruev and Kuzmanov 1999, 1-334). Amphibians in the country generally lack Mediterranean species. For the reptiles, on the other hand, the Mediterranean elements predominate; as an explanation for this, we can cite the favorable geographical features of the city: the low altitude and the relative proximity of the Samena and Sashtinska Sredna Gora Mts., the Chirpan Heights and the northern slopes of the Rhodopes Mts., and the influence of the Maritsa River, which plays a role in the penetration of Mediterranean and sub-Mediterranean influence (Gruev 2000, 73-94; Stanev 2003, 1-191).

Zoogeographic structure by chorotypes. The chorotypic structure of the herpetofauna in the studied region is presented in Table 11-1.

Table 11-1. Zoogeographic structure of the amphibians and reptiles in the city of Plovdiv and its surroundings.

Species	Chorotype (after Petrov 2007)	Faunistic complex	Faunistic element	Faunistic subelement	Author
Amphibia					
Bufo bufo	European	Siberian	Euroasian-Palearctic	Trans-Palearctic	Gruev and Kuzmanov (1999, 1-344)
Bufotes viridis complex	Turanian-European-Mediterranean	Siberian	Euroasian-Palearctic	Trans-Palearctic	Gruev and Kuzmanov (1999, 1-344)
Pelobates syriacus	Turanian-Mediterranean	European	Sub-Mediterranean	-	Gruev (2000, 73-94)
Hyla arborea complex	Euro-Mediterranean	Siberian	Euroasian-Palearctic	Euro-Siberian	Beškov and Beron (1964, 1-39)
Rana dalmatina	South European	European	Mid-European	-	Beškov and Beron (1964, 1-39)
Pelophylax ridibundus	Turanian-Euro-Mediterranean	South Asian	Sub-Iranian	-	Beškov and Beron (1964, 1-39)
Reptilia					
Mediodactylus kotschyi	East-Mediterranean	Mediterranean	East Mediterranean	-	Beškov and Beron (1964, 1-39)
Lacerta viridis	South European	European	Sub-Meditteranean	-	Beškov and Beron (1964, 1-39)
Lacerta trilineata	East-Mediterranean	Mediterranean	East Mediterranean	-	Beškov and Beron (1964, 1-39)
Podarcis tauricus	East-Mediterranean	Euroasian Steppe	Pontic	-	Gruev (2002, 31-40)
Emys orbicularis	Turanian-Euro-Mediterranean	Mediterranean	Holo-Mediterranean	-	Beškov and Beron (1964, 1-39)
Natrix natrix	Central Asia-Euro-Mediterranean	Siberian	Euroasian-Palearctic	Euro-Siberian	Beškov and Beron (1964, 1-39)
Natrix tessellata	Central Asia-European	South Asian	Sub-Iranian	-	Beškov and Beron (1964, 1-39)
Dolichophis caspius	Turanian-Mediterranean	Euroasian Steppe	Pontic	Pontic-Sub-Mediterranean	Beškov and Beron (1964, 1-39)

Similarly to the results of classification by complexes and elements, in the horotypic structure, there is a predominance of European chorotypes for the amphibians and Mediterranean for the reptiles. According to Petrov (2007, 85-107), the predominant share of the 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, 1-24; Camilloni and Barros 1997, 665-681). According to this theory, the temperature in the center of the city is higher by several degrees, compared to the surroundings of the city. This fact and the low humidity in the city caused by the presence of impervious surfaces contribute to the establishment of good conditions for the existence of warm-loving species (e.g. *M. kotschyi*).

Level of endemism. The level of endemism of the amphibians and reptiles in the studied area is low. Similar to the data for Bulgaria in general, in the studied area, there are no endemic species among the amphibians. Among the reptiles, only one subspecies (*Mediodactylus kotschyi rumelicus*) is endemic for Bulgaria, and two others (*Lacerta trilineata* and *Lacerta viridis meridionalis*) are subendemic to the Balkan Peninsula (Petrov, 2007, 85-107).

Comparative analysis of the zoogeographic structure of the herpetofauna along the urban-rural gradient

When comparing the results of the city with those from the surrounding area, no concrete conclusions can be drawn about any pattern of increasing or decreasing percentage participation of one or another zoogeographic complex. The reason for this is that the differences are minimal – the Euroasian-Palearctic element is represented only by one species more in the urban area compared to the rural area and the Sub-Mediterranean and Central European species are absent from the city. For the reptiles, with the exception of the East Mediterranean element (which is represented more widely in the city) and the European-Asian Palearctic element (which is absent from the city), the other zoogeographic elements are presented equally in the city and in the surrounding area.

Almost identical are the results obtained by comparing the chorotypes in the reptiles of the city with those from the surrounding area. For the amphibians, there is more of a Tourano-European-Mediterranean appearance in the city than in the surrounding area, and there is an absence of Tourano-Mediterranean and Southern European species in the city. Reptiles are distributed completely equally in urban and rural areas.

The zoogeographic structure of the herpetofauna of Plovdiv City and its surroundings is characterized with some homogeneity. The reason for this, on the one hand, is probably the small number of species of amphibians and reptiles in the city, most of which are common species with a wide distribution in Europe and the Palearctic (Beškov and Beron 1964, 1-39; Beshkov and Nanev 2002, 1-120). On the other hand, the presence of green areas and large urban parks, from the periphery to the very center of the city (see Chapter 9), favors the penetration and dispersal of species inward into the "unfavorable" urbanized area.

European species are predominant, because those are usually species with high ecological plasticity, as are some warm-loving Sub-Mediterranean and East Mediterranean species. The percentage of the Siberian faunistic complex is considerable, most of which, due to their high ecological plasticity, have Holarctic distribution and are highly adaptable to urban environments. Currently, the herpetological literature lacks data on the zoogeographic structure of amphibians and reptiles in cities.

According to Antonova and Penev (2006), the prevalence of widespread Holarctic species in urban environments may serve as an indicator of urbanization pressure, due to the fact that only species with high ecological plasticity can successfully adapt to urban conditions.

CHAPTER TWELVE

THE IMPORTANCE OF THE MARITSA RIVER AND OTHER WETLANDS IN THE CITY OF PLOVDIV

Altogether, six species of amphibians and eight reptile species have been recorded in all surveyed water basins (see Chapter 4). The survey of the Maritsa River and the other water basins in the city of Plovdiv and its surroundings was conducted in 2007.

Maritsa River

The largest river passing through the studied area is the Maritsa River and that is why the main focus of this research falls mainly on it. Table 12-1 presents the environmental factors (air and water temperatures, water pH, the type of coastal vegetation and the presence of a supporting wall) measured along the thirteen-kilometer section of the Maritsa River in the city of Plovdiv during the study.

Table 12-1. Values of some major abiotic factors and habitat characteristics along the studied 13-kilometer stretch of the Maritsa River in the studied region. *Legend:* G – grass; BT – bushes and trees.

Kilometer No.	**KM1**	**KM2**	**KM3**	**KM4**	**KM5**	**KM6**	**KM7**	**KM8**	**KM9**	**KM10**	**KM11**	**KM12**	**KM13**
Air temperature, °C	14.9	14.7	15.0	15.2	15.5	16.6	18.0	17.8	17.3	16.8	16.2	15.9	15.5
Water temperature, °C	12.7	12.5	12.8	13.1	12.6	15.5	15.2	15.3	14.9	14.6	13.9	13.5	13.2
Water pH	7.4	7.4	7.4	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.4	7.4	7.4
Type of vegetation	G	G	BT	BT	BT	G	G	BT	BT	BT	BT	G	G
Support wall	-	-	-	-	+	+	+	+	+	-	-	-	-

The species composition and distribution of the amphibians and reptiles registered along the Maritsa River (13 kilometers) in the studied region are presented in Table 12-2.

From the amphibians, only one species (*P. ridibundus*) occurs along the whole stretch of the river within the research area. This is also the species with the largest population size. The other two recorded amphibians (*H. arborea* complex and *P. syriacus*) are rare for the investigated stretch and are found only with one specimen, in one transect. The reptiles are not recorded in all transects, but the species found in most transects (in six) is *N. natrix,* while *D. caspius* was recorded in only one transect. The remaining registered reptiles were found in four transects (Table 12-2).

Table 12-2. Species composition, abundance and distribution of the amphibians and reptiles in the surveyed 13-kilometer stretch of the Maritsa River in the studied region.

Species	KM1	KM2	KM3	KM4	KM5	KM6	KM7	KM8	KM9	KM10	KM11	KM12	KM13
Amphibia													
Pelophylax ridibundus	5	3	7	20	55	322	127	85	53	29	26	7	5
Hyla arborea complex	-	1	-	-	-	-	-	-	-	-	-	-	-
Pelobates syriacus	-	-	-	-	-	1	-	-	-	-	-	-	-
Reptilia													
Lacerta viridis	-	-	2	-	-	1	1	2	-	-	-	-	-
Natrix tessellata	1	-	-	1	-	1	-	-	-	-	-	1	-
Natrix natrix	2	-	1	-	1	1	1	-	-	-	-	-	1
Emys orbicularis	-	-	-	2	4	1	-	2	-	-	-	-	-
Mediodactylus kotschyi	-	-	-	-	-	1	4	1	1	-	-	-	-
Dolichophis caspius	-	-	-	-	-	-	-	-	1	-	-	-	-

Of the 13 one-kilometer transects surveyed, the most amphibians and reptiles were found in the sixth kilometer (center of the city), followed by the first, third, fourth, fifth, seventh and ninth kilometers (in the suburban area), and the least species were recorded in the rural area – the second, tenth, eleventh, twelfth and thirteenth kilometers (Table 12-2).

The Principal Component Analysis (PCA) and Spearman correlation rank were performed to trace the impact of the five factors studied on the abundance of the recorded amphibians and reptiles. Species of which only one specimen was found – *H. arborea* complex, *P. syriacus* and *D. caspius* – were excluded from the analysis. Both tests were done once for the aquatic and semi-aquatic species (*P. ridibundus, N. natrix, N. tessellata* and *E. orbicularis*), following the effect of air and water temperature, water pH and the type of coastal vegetation on the size of their populations (Fig. 12-1, Tables 12-3, 12-4). Both tests were performed for the terrestrial species found in the studied region of the river as well – *L. viridis* and *M. kotschyi* – but this time included only the influence of air temperature, coastal vegetation type and the presence or absence of a supporting wall (Fig. 12-2, Table 12-5).

Table 12-3. Factorial coordinates of the variables based on the PCA correlations based on the abundance of the aquatic and semi-aquatic amphibians and reptiles in the Maritsa River in the studied region.

	Factor 1	Factor 2	Factor 3	Factor 4
Pelophylax ridibundus	0.71*	0.24	-0.33	0.57
Natrix natrix	0.59	-0.44	0.67	0.11
Natrix tessellata	0.70*	-0.29	-0.39	-0.53
Emys orbicularis	0.35	0.84*	0.31	-0.30

* statistically significant values (p>0.70)

Table 12-4. Spearman correlation rank of the four major abiotic factors and the number of aquatic and semi-aquatic amphibians and reptiles recorded in the Maritsa River in the studied region.

	Pelophylax ridibundus	*Natrix natrix*	*Natrix tessellata*	*Emys orbicularis*
Air temperature, °C	0.810*	-0.241	-0.268	0.074
Water temperature, °C	0.755*	-0.185	0.000	0.063
Water pH	0.827*	-0.139	-0.051	0.606*
Type of vegetation	0.269	-0.417	-0.356	0.353

* the correlation is statistically significant (p<0.05)

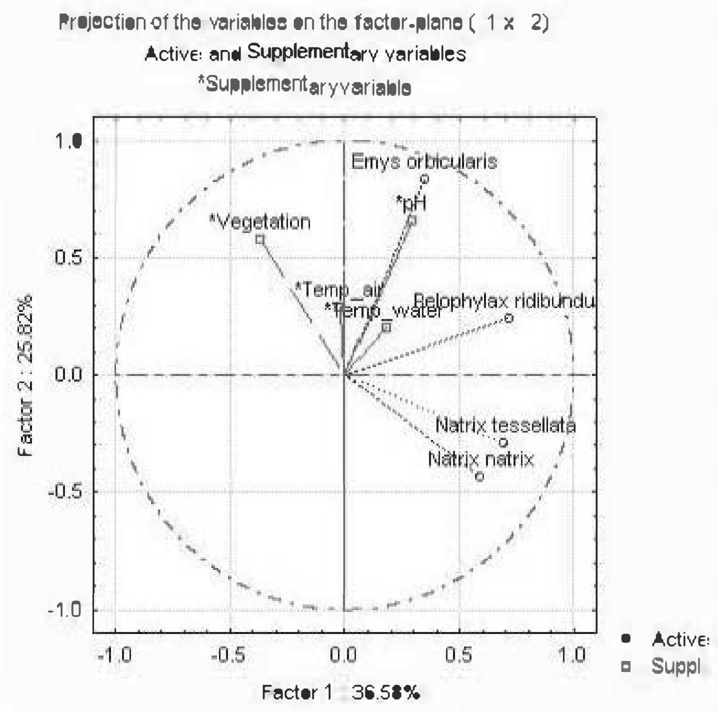

Fig. 12-1. PCA on the four major abiotic factors and the abundance of aquatic and semi-aquatic amphibians and reptiles found in the Maritsa River in the studied area. *Legend*: *Temp_air* Air temperature, °C; *Temp_water* Water temperature, °C; *pH* Reaction (pH) of the water; *Vegetation* Type of vegetation (grassy or shrubs-trees)

For the aquatic and semi-aquatic amphibians and reptiles, it is noteworthy that the population of the marsh frog is influenced mainly by the temperature of the air and the water and the pH of the water, while the coastal vegetation has no significant influence (Table 12-4). For this species the PCA showed a statistically significant value only for the first factor (Table 12-3), which explains about 37% of the results (Fig. 12-1). There is no significant dependence on either species of aquatic snakes in relation to any of the considered factors. Only the *N. tessellata* shows a statistically significant value with respect to the first factor (Table 12-3). For *E. orbicularis*, a statistically significant value was found for the second factor (Table 12-3), which explains about 26% of the results (Fig.

12-1). 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 12-4).

For the terrestrial reptiles, a strong positive, statistically significant correlation was found between the air temperature and the presence of a supporting wall and the size of *M. kotschyi* populations, as was a weak correlation for the green lizard, however, with no statistical significance (Table 12-5). For both species, the PCA analysis showed statistically significant values only with respect to the first factor (0.81), which explains about 65% of the results (Fig. 12-2).

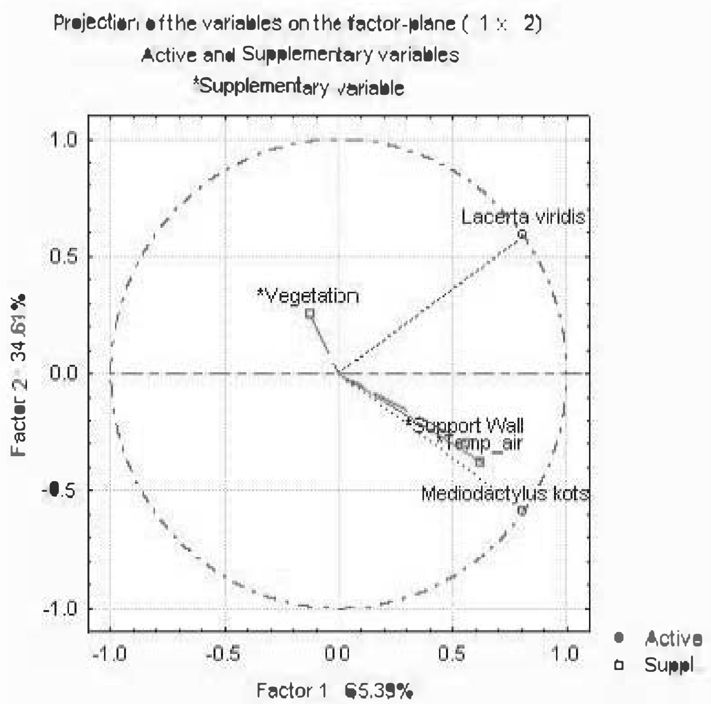

Fig. 12-2. PCA on the three main factors and the abundance of the terrestrial reptile species found in the Maritsa River in the research area. *Legend: Temp_air* – Air temperature, °C; *Vegetation* – Type of vegetation (grassy or shrubs-trees); *Support Wall* – Presence/absence of a support wall along the shore.

Table 12-5. Spearman correlation rank of the three main factors and the abundance of terrestrial reptile species found in the Maritsa River in the studied area.

	Lacerta viridis	*Mediodactylus kotschyi*
Air temperature, °C	0.278	0.772*
Vegetation type	-0.071	-0.101
Presence/absence of a support wall	0.316	0.833*

* the correlation is statistically significant ($p<0.05$)

Although we did not obtain statistically significant values and there was a poor correlation for the influence of the vegetation type on the green lizard's population size, we believe that this factor (the presence of tree-shrub vegetation) along with air temperature are the main factors that affect this species. The presence of the Kotschy's gecko on the banks of the Maritsa River is entirely due to the presence of the support wall in the center of the city, as well as the higher air temperature.

On the basis of the number of amphibians and reptiles found, a cluster analysis of the thirteen transects was done (Fig. 12-3). The figure shows that, with about 15% similarity, KM1, KM2, KM3, KM12 and KM13 are grouped together and differentiated from the rest. These are the transects located in the westernmost and easternmost parts of the city and represent the rural areas. From the remaining one-kilometer transects, KM6 is separated into a cluster with about 40% similarity, and independently it represents the urban zone. The remaining transects are grouped into a third cluster representing the suburban zones. In the suburban zones, transects are segregated into even smaller clusters, but keep the same principle from the periphery to the center of the city.

There is a clearly visible urban-rural gradient in the amphibian and reptile fauna along the Maritsa River in Plovdiv City. The habitats offered by the river (the plant formations along the river banks) change from the periphery to the center of the city, as well as the environmental factors (Table 12-1), which influence both the species composition of the amphibians and reptiles, as well as their population sizes.

Additionally, this trend is shaped by the anthropogenic factor, which has a two-sided effect. On the one hand, the construction of a supporting wall for the river in its central part and in the suburban area has provided an excellent habitat for the *M. kotschyi,* which otherwise would not be found along the river bank. On the other hand, the so-called "clearing" of vegetation from the river bed, performed regularly by the municipality officials, causes the absence of certain species, such as *L. viridis*, *E. orbicularis* and *D. caspius* on the banks of the river in several areas. An additional negative effect on the amphibian and reptile populations in the "rural" area, at both ends of the city, is the illegal extraction of aggregates and the disposal of construction waste (see Chapter 15).

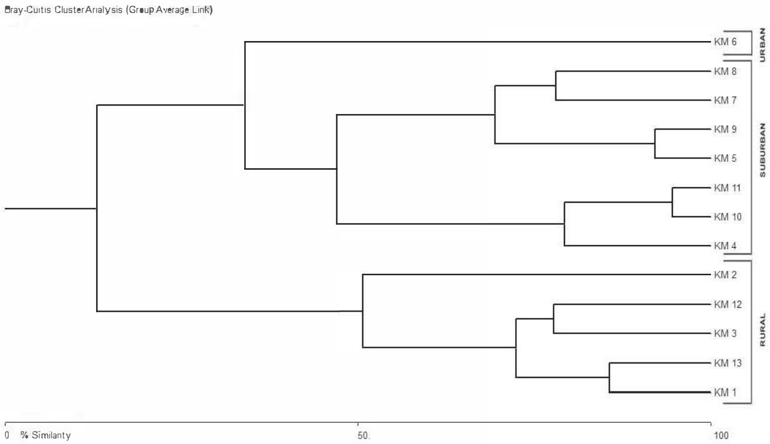

Fig. 12-3. Cluster analysis of the 13 one-kilometer transects from the Maritsa River, based on the number of amphibian and reptile species found (Bray-Curtis Index, Group Average link).

Other running water basins

Abundance. Table 12-6 gives the abundance of the species of amphibians and reptiles found in all the studied water basins in Plovdiv City and its surroundings.

The amphibian species with the highest abundance is again the marsh frog (*P. ridibundus*), which has its highest abundance in irrigation canal No. 4. This is due to the fact that this canal has the highest water level of all of the studied canals, and its shores, as well as some parts of the canal, are heavily overgrown with vegetation. Furthermore, the canal is located in the southern part of the research area and the anthropogenic pressure in this area is the lowest. For comparison, Popgeorgiev (2009, 1-40) indicates the following values for the *Pelophylax ridibundus* abundance from anthropogenically unaffected regions of the Eastern Rhodopes – Kostikovo Village (Ab=1.65 ind./1000 l.m.) and Gorno Lukovo Village (Ab=0.22

ind./1000 l.m.). Milchev (1985, 195-203) points out that in Sofia the marsh frog is found only in large or very large ponds. According to the same author, since it is a typical "aquatic" species, it is not found in temporary ponds, a fact that we have also confirmed (see Chapter 11). The abundance of the marsh frog, as an aquatic species, is mainly determined by the characteristics and conditions of the water basin, parts of the coastal vegetation and, to some extent, direct human disturbance, but not by the location of the ponds. For this reason, this species is distributed all along the Maritsa River and all the other studied water basins. A similar distribution of this species was recorded by Milchev (1985, 195-203) in Sofia City.

Table 12-6. Abundance (ind./1000 l.m.) of the amphibian and reptile species found in the studied water basins in the research area.

Species	Maritsa River	Parvenetska River	Irrigation Canal 1	Irrigation Canal 2	Irrigation Canal 3	Irrigation Canal 4	Irrigation Canal 5
Zone	-	Rural	Rural	Rural	Suburban	Rural	Rural
Amphibia							
Bufo bufo	-	-	-	-	0.122	-	-
Bufotes viridis complex	-	-	-	-	0.488	-	-
Hyla arborea complex	0.077	0.727	0.277	0.277	0.244	0.357	-
Pelobates syriacus	0.077	-	-	-	-	-	-
Pelophylax ridibundus	57.231	21.273	3.636	9.722	17.923	74.643	48.696
Rana dalmatina	-	0.364	-	-	0.366	-	-
Reptilia							
Lacerta viridis	0.461	3.818	0.454	0.277	1.098	2.143	3.043
Lacerta trilineata	-	0.364	-	-	0.122	-	-
Podarcis tauricus	-	0.182	-	-	-	-	-
Natrix natrix	0.538	-	-	-	-	0.357	-
Natrix tessellata	0.308	-	-	-	-	0.357	0.435
Emys orbicularis	0.692	-	0.454	-	-	-	-
Mediodactylus kotschyi	0.538	-	-	-	-	-	-
Dolichophis caspius	0.077	0.364	-	-	-	-	0.435

Our results for *P. ridibundus* confirm those mentioned by Milchev (1985, 195-203), in that this species can inhabit ponds significantly modified by humans, and even those in close proximity to human settlements and buildings. Similar observations exist in other parts of the species' distribution, where the marsh frog has a higher abundance in cities (Gladkov and Rustamov 1975, 1-220; Kubanchev and Zhukova 1982, 46-51). According to Vershinin (2006, 197-200), the occurrence of polymorphism in this species is directly dependent on the conditions of the environment and the anthropogenic pressure. For example, the same author argues that individuals of the "striata" morph (individuals with a light longitudinal strip on the dorsal side of the body) are much better adapted to anthropogenically affected areas (pollution, agriculture, urbanization). Our study attempted to trace the percentage of individuals of this morph while counting the frogs, but this proved to be an extremely difficult task since the time for surveying individuals was too short before the frogs jumped back into the water. For this reason, without being able to give specific values, we can only point out that according to our general observations, the individuals of the "striata" morph were predominant in the central urban areas and suburbs of the Maritsa and Parvanetska Rivers, and in the rural parts their percentage is comparatively lower than individuals belonging to other morphs.

Both species of toads were recorded only in Irrigation Canal No. 3, but it should be clarified that the toads were located in a small standing pond near the irrigation canal and not in the canal itself. According to the literature, both species have a preference for standing water basins (Bisserkov et al. 2007, 1-196) and finding them in the irrigation canal would be unlikely or an exception. They are absent from both rivers in the city. The reason for this is probably the absence of appropriate shelters, as they enter the water only to lay their eggs (Buresh and Tsonkov 1942, 68-165).

The tree frog (*H. arborea* complex) is found in all water basins, with the exception of Irrigation Canal No. 5, and its abundance is relatively low. The highest peak is recorded in the Parvenetska River, probably due to the fact that in the studied area it is the water reservoir with the best preserved coastal shrub and tree vegetation. The Syrian spade-foot toad and agile frog are rare species for the surveyed area, as *P. syriacus* was recorded only at the Maritza River at the bridge of the "VHVP" (see Chapter 6), and the agile frog only in the Parvanetska River and Irrigation Canal No. 3, and in both places its abundance has similar low values. Milchev (1985, 195-203) also reports that he recorded *Rana dalmatina* only in parks in the vicinity of Sofia City, in semi-natural pools with low numbers. The author also notes that the agile frog does not occur in areas near human settlements and buildings. Our data and the data from Milchev (1985, 195-203) confirm the opinion of other authors that brown frogs avoid the central parts of cities (Vershinin 1990, 67-71; Pawlowski 1993, Mazgajska 1996, 245-257).

From the reptiles, the only species found on the banks of all of the studied rivers and canals was the green lizard (*L. viridis*). This species prefers damp habitats, as it is found in larger quantities, namely in herbaceous bush habitats along river banks and irrigation canals, and with a lower abundance in dry habitats, e.g. the Plovdiv hills and in urban and cemetery parks (see Chapter 13). The highest abundance was recorded in the Parvenetska River, for *L. trilineata*, and this is the only basin in which *P. tauricus* was registered. The reason for this is again the well-preserved shrub-tree vegetation on the banks of this river, as compared to the other studied water basins. Nevertheless, our calculated values for the abundance of the green lizard are significantly lower than those reported by Popgeorgiev (2009) from an anthropogenically non-influenced region of the village of Rogozhinovo (Sakar) – Ab=23.31 ind./1000 l.m.; for *L. trilineata* this was Ab=8.45 ind./1000 l.m. and, for *P. tauricus,* Ab=12.01 ind./1000 l.m. from the same location. This shows that all three lizard species do not find optimal conditions for their development in the urbanized area.

The two species of aquatic snakes (*N. natrix* and *N. tessellata*) were recorded only in the Maritsa River and Irrigation Canals Nos. 4 and 5 (Table 12-3). The highest abundance of *N. natrix* was recorded in the Maritsa River, and of *N. tessellata* in Irrigational Canal No. 5. The abundance values obtained by us are similar to those obtained by Popgeorgiev (2009, 1-40) for *N. natrix* from natural areas of the Eastern Rhodopes Mts. – Kolets Village Ab=0.18 ind./1000 l.m.; Ostar Kamyk Village – Ab=0.05 ind./1000 l.m.; and Srem Village – Ab=0.11 ind./1000 l.m. As already mentioned, both species inhabit only those parts of the Maritsa River located in the "rural" zone, where the two irrigation canals are also located. Both species are more sensitive to the higher temperature in the central parts of the city ("urban heat island effect" – see Chapter 3) and especially to direct human disturbance, as they are absent from the "urban" zone.

The only species of terrestrial snake – *D. caspius* – is located on the Adata Island on the Maritsa River, the banks of the Parvanetska River and Irrigational Canal No. 5, where there is the highest abundance. Similar values for the abundance of this species were also obtained by Popgeorgiev (2009, 1-40) from natural areas in the Eastern Rhodopes Mts. – Srem Village – Ab=0.29 ind./1000 l.m.; Kostilkovo Village – Ab=0.33 ind./1000 l.m.; and Gorno Lukovo Village – Ab=0.40 ind./1000 l.m. In general, this species does not adhere to wetlands. Its presence in the three water basins can be explained by the presence of suitable shrub-tree vegetation at certain places along the river banks, which is used for refugia by this species (Bisserkov et al. 2007, 1-196), as well as the presence of certain species of small rodents and lizards in these places that provide a good food base.

E. orbicularis is found only in the Maritsa River and Irrigation Canal No. 1, with higher abundance in the Maritsa River. 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 Kotschy's gecko is located only in the central part of the Maritsa River in Plovdiv; the only reason for the existence of this species here is the construction of a supporting wall.

Age structure of the populations. For some species, the age structure of their populations has been successfully determined by dividing them into three size-age groups – adults, subadults and juveniles. The age structure was studied for the populations of the marsh frog (*P. ridibundus*), the green lizard (*L. viridis*) and *E. orbiculars*. For the other species, we either did not have enough observations or all observed specimens were only adults.

The age structure of the populations of the marsh frog is presented in Fig. 12-4. The ratio of the three size-age groups (adults:subadults:juveniles) is 1:1.59:2.46 and was registered in the Maritsa River, with a pronounced predominance of the juveniles and subadults (χ^2=88.72; df=2; $p \leq 0.05$). The same pattern is observed in the other studied water basins, with the exception of Irrigational Canal No. 5 (where adult predominance is observed), as follows: Parvenetzka River – 1:1.18:3.14 (χ^2=34.82; df=2; $p \leq 0.05$); Irrigation Canal No. 1 – 1:0.5:2.5 (χ^2=6.50; df=2; p=0.04); Irrigation Canal No. 2 – 1:1.5:1 (χ^2=1.43; df=2; p=0.49); Irrigation Canal No. 3 – 1:0.5:2.5 (χ^2=17.43; df=2; p=0.00016); Irrigation Canal No. 4 – 1:1.09:1.52 (χ^2=7.42; df=2; p=0.0024); and Irrigation Canal No. 5 – 1:0.53:0.58 (χ^2=9.98; df=2; p=0.0068). A statistically insignificant difference from the 1:1:1 age structure is found only in the Irrigation Canal No. 2 population.

According to Begon, Harper, and Townsend (1986, 1-876), such a distribution of age groups in a population, namely predominantly of juvenile and subadult individuals, is a sign of a growing population. It seems that the marsh frog is well adapted in the research area and, thanks to the network of rivers and irrigation canals, it is found throughout the urbanized territory with solid and stable populations.

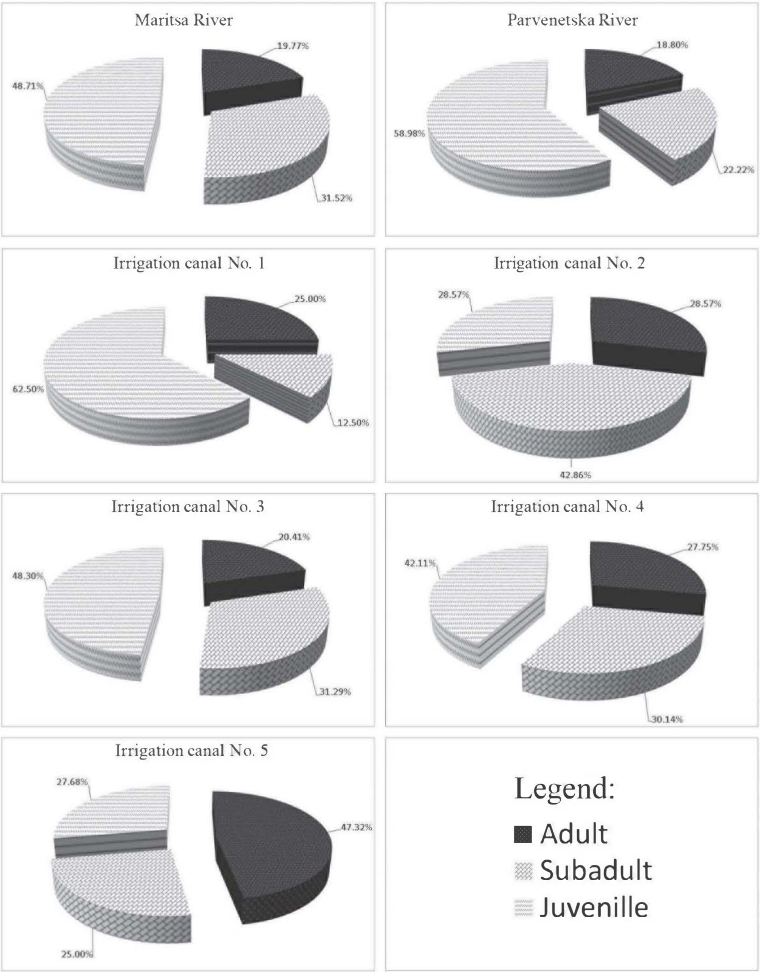

Fig. 12-4. Age structure of the populations of the marsh frog (*Pelophylax ridibundus*) from the studied water basins in the researched area.

For the populations of the green lizard (*L. viridis*), the following age structures are recorded (Fig. 12-5): Parvenetska River – 1:0.88:0.44 (χ^2=2.00; df=2; p=0.37); Irrigation Canal No. 1 – 1:0.4:0.4 (χ^2=2.00; df=2; p=0.37); Irrigation Canal No. 4 – 1:1.5:0.5 (χ^2=1.00; df=2; p=0.61); and Irrigation Canal No. 5 – 1:0.2:0.2 (χ^2=4.58; df=2; p=0.101).

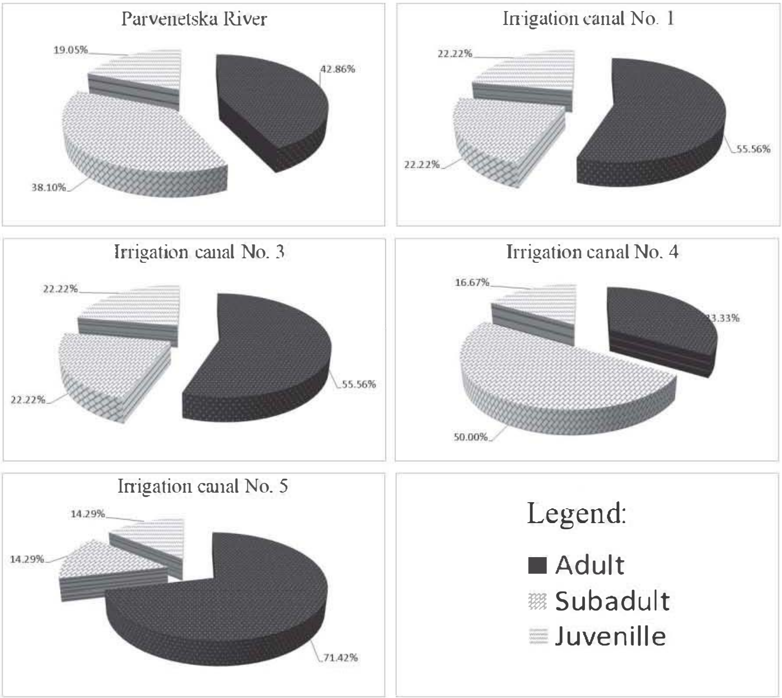

Fig. 12-5. Age structure of the populations of the green lizard (*Lacerta viridis*) from the studied water basins in the research area.

In all the studied water basins, the populations of the green lizard have an age structure close to the equal distribution of 1:1:1, with a slight prevalence of the adults and the subadults, with no statistically significant difference in any of the cases. Popgeorgiev (2009, 1-40) also recorded the age structure of a green lizard population near the village of Gorno Lukovo (Eastern Rhodopes Mts.), where, in a fire-affected area and in the control (unburned) area, he recorded a predominance of adults and juveniles in a ratio of 1.03:1 and, for another population in Rogozinovo Village (Sakar Mts.), he recorded a slight prevalence of adults and juveniles with a ratio of 1.66:1 in the burned territory and 1.26:1 in the natural territory. It seems that the normal state of the age structure of the populations of this species is for a slight predomination of adults. The probable reason for fewer juvenile specimens being reported in our study is their small size and the fact that their color blends perfectly with the environment, making them difficult to spot.

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 (χ^2=0.67; df=2; p=0.72). This age structure shows that the population of this species is likely to decrease in the city.

Sex structure of the populations. The sex structure is defined only in some of the populations of the green lizard (*L. viridis*), since it is only for this species that males and females are clearly distinguishable in morphology and coloration and enough specimens were observed to determine the sex structure of the population. The sex structures of the populations of the remaining amphibian and reptile species found in the studied water basins were not considered because some of the animals were not identified by sex, and this could have led to errors in the analysis. The ratio of the sexes in the green lizard in the Parvenetska River is 1.5:1 in favor of the males, with no statistically significant difference from the normal ratio of 1:1 (χ^2=0.2; df=1; p=0.65). The populations of Irrigation Canals Nos. 1 and 3 have a ratio of 1:3 in favor of females (χ^2=1.00; df=1; p=0.32). However, because of the small number of specimens analyzed, no in-depth conclusions can be drawn regarding the sex structure.

Characterization of the communities. In general, the amphibian and reptile communities in the seven water basins in the studied area are characterized by low diversity and species richness. The highest values of diversity indices are in Irrigation Canal No. 1, but their values in the other water basins are similar. Evenness indices show low values everywhere (Table 12-7), which is typical for monodominant communities. Such types of communities are typical for urban ecosystems (Varsinin 1997, 1-47), where one or two species have a considerably higher abundance than others. In this case, the dominant species are the marsh frog (*P. ridibundus*) from the amphibians and the green lizard (*L. viridis*) from the reptiles. These results are also confirmed by the high values of Berger-Parker's index of dominance.

Standing water basins

The only large standing water reservoirs (over 1 km^2) in the studied area are the Rowing Canal and Plovdiv State Fishery. The area of the Rowing Canal is 1.25 km^2 and the total area of the fishponds is 1.46 km^2. The species composition and average density of the amphibians and reptiles registered in the two basins are presented in Table 12-8.

Table 12-7. Indices of diversity, evenness and dominance of the amphibian and reptile communities in the studied water basins.

Index	Maritsa River	Parve-netska River	Irriga-tion Canal 1	Irriga-tion Canal 2	Irriga-tion Canal 3	Irriga-tion Canal 4	Irriga-tion Canal 5
Simpson (1/D)	1.099	1.568	1.664	1.116	1.285	1.087	1.162
Simpson (E)	0.122	0.314	0.333	0.223	0.257	0.217	0.232
Shannon (H)	0.118	0.770	0.800	0.248	0.546	0.213	0.316
Shannon (J)	0.123	0.396	0.577	0.226	0.280	0.133	0.228
Berger-Parker (d)	0.953	0.785	0.762	0.946	0.880	0.959	0.926

Table 12-8. Average density (ind./m^2) of the amphibian and reptile species found in the two large standing water basins in the study area.

Species	Rowing Canal	Plovdiv State Fishery
Amphibia		
Bufo bufo	**0.008**	**0.007**
Hyla arborea complex	-	**0.014**
Pelophylax ridibundus	**0.400**	**0.280**
Reptilia		
Lacerta viridis	-	**0.007**
Natrix natrix	-	**0.007**
Natrix tessellata	-	**0.007**
Emys orbicularis	**0.008**	**0.014**

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. Of all the species of amphibians that have been recorded, the marsh frog has the highest density in both places, and from the reptiles, *E. orbicularis* had the highest population density. The data for the average density of *P. ridibundus* from the anthropogenically non-influenced region of Rogozinkovo Village (Sakar Mts.) shows a value of Ds=0.0269 ind./m^2 and, for *H. arborea* complex, Ds=0.0137 ind./m^2 (Popgeorgiev 2009, 1-40).

According to Vershinin (1990, 1-47), the water basins of large cities usually have between one and three species of amphibians. According to the same author, in Sverdlovsk City, the amphibians avoid the central city areas. However, amphibians have been found, for example, in water basins in the central urban areas of Wroclaw (Mazgajska 1996, 245-257) and Poznan (Pawlowski 1993), as well as in this study. The amphibians and reptiles recorded in the suburban and rural zones have similar values in population abundance and density, compared to the same species from anthropogenically un-influenced areas. The species richness and abundance of amphibians and reptiles in the studied area is influenced mainly by the environmental factors and the characteristics of the water basins, as well as their location on the urban-rural gradient. Similar results are also obtained from Werner et al. (2007, 1697-1712). From this point of view, amphibians and reptiles can be used as indicators for assessing stress or change in the environment (Vitt et al. 1990, 418; Hall and Henry 1992, 65-71; Olson 1992, 55-62). Amphibian and reptile monitoring can help land management decisions to be made in order to maintain ecosystem functions, as well as to protect areas with important habitats and other organisms in the urban environment.

CHAPTER THIRTEEN

THE IMPORTANCE OF THE PLOVDIV HILLS AND THE URBAN PARKS

Species composition and distribution of the herpetofauna

During the survey period, the Plovdiv hills and all the bigger parks in the territory of the city were surveyed for the presence of amphibians and reptiles. Further analysis excludes areas where amphibians and reptiles were absent or recorded with a single observation. In the following hills and urban parks – "Mladezhki hulm" Hill, "Hulm Bunardzhik" Hill, "Danov hulm" Hill, "Tsar Simeonova Gradina" Park, "Otdih i Kultura" Park, "Lauta" Park and "Rogosh" Cemetery Park, random transects were followed (see Chapter 5), constructed depending on the size of the surveyed area and the peculiarities of the terrain. Two amphibian species and four reptile species were recorded in the studied parks (Table 13-1). The registered amphibian species represent 33.33% of the amphibians occurring in the city of Plovdiv, and the reptiles 50.00% of all reptiles occurring in the city (see Chapter 7).

Three species of reptiles reported in earlier study (*A. kitaibelii, L. trilineata* and *P. muralis*) were not recorded in the Plovdiv hills (Mollov, 2005b, 79-94) in the course of this study. In our opinion, these species have not disappeared from the studied areas, but they probably remained unregistered due to their extremely low abundances.

Distribution and ecological characteristics of the recorded amphibian and reptile species in the urban parks and green areas

Green toad (*Bufotes viridis* complex)

Distribution. The green toad was recorded in four of the studied urban green areas – "Mladezhki hulm" Hill NM, "Hulm Bunardzhik" Hill NM, "Tsar Simeonova Gradina" Park and "Lauta" Park. In the territory of

"Mladezhki hulm" Hill NM, the species inhabits solely the southern part of the hill, not being recorded on its high parts or on the north side (Appendix 2-2). In the territory of "Hulm Bunardzhik" Hill NM, the species is concentrated mainly around the top of the hill and its southern part, and single specimens are also registered among the houses in the northern part. Given the fact that the two hills are close in height, the climbing of frogs to the high parts does not seem to be a problem. The difference lies in the fact that at the top of "Hulm Bunardzhik" Hill NM there are several fountains and ponds used by this species for breeding, whereas in "Mladezhki hulm" Hill NM such ponds are at the base of the hill. In "Tsar Simeonova Gradina" Park the species is found only in and around some of the fountains in the park. In "Lauta" Park, two specimens were found along the alleys in the western part of the park.

Table 13-1. Species composition of the amphibian and reptile species recorded in this study in the parks and green areas surveyed in Plovdiv City. *Legend:* MH – "Mladezhki hulm" Hill NM, HB – "Hulm Bunardzhik" Hill NM, DH – "Danov hulm" Hill NM, TSG – "Tsar Simeonova Gradina" Park, OKP – "Otdih i Kultura" Park, LP – "Lauta" Park and RCP – "Rogosh" Cemetery Park.

Species	Surveyed urban parks in the current study						
	MH	HB	DH	TSG	OKP	LP	RCP
Area (daa)	362	220	53	116	604	711	136
Bufotes viridis complex	+	+	-	+	-	+	-
Hyla arborea complex	+	-	-	-	-	-	+
Mediodactylus kotschyi	+	+	+	+	-	-	+
Lacerta viridis	+	+	-	-	+	+	+
Podarcis tauricus	+	+	-	-	+	+	-
Dolichophis caspius	+	-	-	-	-	+	-

Habitats. The green toad inhabits the yards of the houses situated near the hills, where there is plenty of food and shelter. When breeding, it enters the hills where it uses small, often temporary standing ponds full of rain water for copulation and the laying of the eggs. The same behavior was observed in "Tsar Simeonova Gradina" Park, where the toads use other temporary and permanent shelters around and in the park.

24-hour and seasonal activity. The green toad is a predominantly nocturnal species, but as also noted by Beshkov and Nanev (2002, 1-120), it can often be observed during the day, depending on the periods of breeding, foraging, etc. Our data from the two studied hills in Plovdiv City shows that the majority of our observations on this species were made after 8:00 PM (Fig. 13-1). The green toad showed bimodal seasonal activity, with the first peak being associated with spring reproduction from March to May, and the second peak with autumn migrations to wintering sites from September to October (Fig. 13-2).

Population density. The abundance and the ecological density of the green toad populations in the four studied areas are presented in Table 20. The density of the "Mladezhki huhn" Hill population is higher compared to the population of "Huhn Bunardzhik" Hill (Table 13-2), but both values are significantly lower than the density recorded for the population from the "Tsar Simeonova Gradina" Park, with the t-test showing statistically significant differences in all comparisons (Table 13-3).

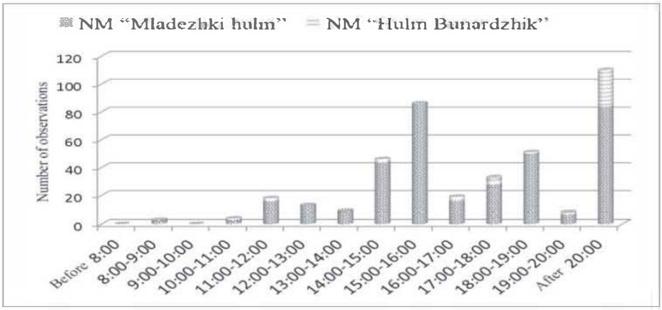

Fig. 13-1. The 24-hour activity of *Bufotes viridis* complex populations in both protected areas throughout the study period.

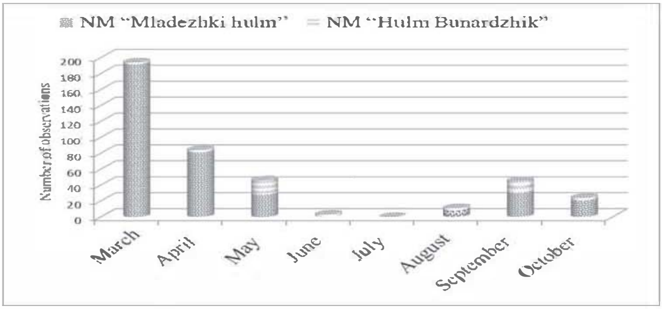

Fig. 13-2. The seasonal activity of *Bufotes viridis* complex populations in both protected areas throughout the study period.

For the two-year study period (2007-2008), a slight decrease in the population abundance in the two protected areas was also recorded (Table 20) and there was a significant decrease in the population abundance in "Tsar Simeonova Gradina" Park.

Table 13-2. Abundance (Ab, ind./1000 l.m.) and ecological density (De, ind./ha) in the four studied urban green areas in Plovdiv City.

Transects	**Year**			
	2007		**2008**	
	Abundance (Ab)	Ecological density (D_e)	Abundance (Ab)	Ecological density (D_e)
"Mladezhki hulm" Hill				
Transect №1	2.22	72.00	5.56	180.00
Transect №2	5.00	50.00	22.50	225.00
Transect №3	60.63	388.00	5.00	32.00
Mean	22.62	170.00	11.02	145.67
"Hulm Bunardzhik" Hill				
Transect №4	18.33	66.00	5.00	18.00
Transect №5	1.39	45.00	4.44	144.00
Mean	9.86	55.50	4.72	81.00
"Tsar Simeonova Gradina" Park				
Transect №7	133.75	214.00	7.50	12.00
"Lauta" Park				
Transect №11	-	-	0.36	28.00

Table 13-3. Results of the t-test for independent samples when comparing the population abundance in the three studied urban green areas in Plovdiv City[1].

	t-value	p
"Mladezhki hulm" Hill vs. "Hulm Bunardzhik" Hill	2.090	0.038
"Tsar Simeonova Gradina" Park vs. "Mladezhki hulm" Hill	-2.637	0.009
"Tsar Simeonova Gradina" Park vs. "Hulm Bunardzhik" Hill	2.090	0.038

The green toad is the most common amphibian species in all of the studied parks and the population density is relatively high. According to

[1] "Lauta" Park was excluded from the test due to the small sample size.

Beshkov and Nanev (2002, 1-120) the green toad is more common and numerous in cities than in natural habitats. According to Marchenkovskaya (2005, 136-139), the population of *B. viridis* complex from a canal between the Dnieper and Donbass Rivers in Ukraine has a density of 80-350 ind./ha. According to Kühnel and Krone (2003, 299-315), the populations of this species in Berlin in most ponds have up to 20 adult individuals; there are significantly less with between 20 and 200 adult individuals and only one with over 200. From the above data, we can conclude that the density of the populations of this species in Plovdiv City is high and even exceeds that of natural populations of the species, for example, from the Eastern Rhodopes Mts., where in places Popgeorgiev (2009, 1-40) reports only single specimens in anthropogenically unaffected regions.

In the three studied parks in Plovdiv City, for the first time, the average density of green toad populations was also measured with the method of marking and re-capturing. An innovative approach was applied to tagging and individually recognizing individuals using photographic images on the dorsal side of the individuals' body which were subsequently processed with the I3S Interactive Individual Identification System software v.2.0 (Speed, Meekan, and Bradshaw 2007). Although software studies have already been conducted on photo-based photo-processing programs (Vörös, Szalay, and Barabás 2007, 97-103), this software allows the use of natural spot coloration for individuals to automatically be recognized, similar to fingerprints (Fig. 13-3). An important condition is that the photos are taken at an angle of more than 40 degrees to avoid distortion and hence a greater error of recognition. In each comparison, the program also allows a visual comparison of the two individuals to be done for greater accuracy. The software was originally developed for automatic recognition of tiger sharks, but according to the authors it can be used successfully for any animal with spot coloring. For the first time, "I3S" software was used for the green toad in this study, with the following modifications. The three control points on which the spotted fingerprints are created are located under the left and right eye and the cloaca, and for each individual an additional 30 points are made, each on the more clearly defined tubercle from the dorsal side (Fig. 13-3). For short-term studies (1-2 years), this way of recognizing individuals can be applied successfully.

The results from the mark-recapture study of the three populations of the green toad in Plovdiv City are presented in Table 13-4.

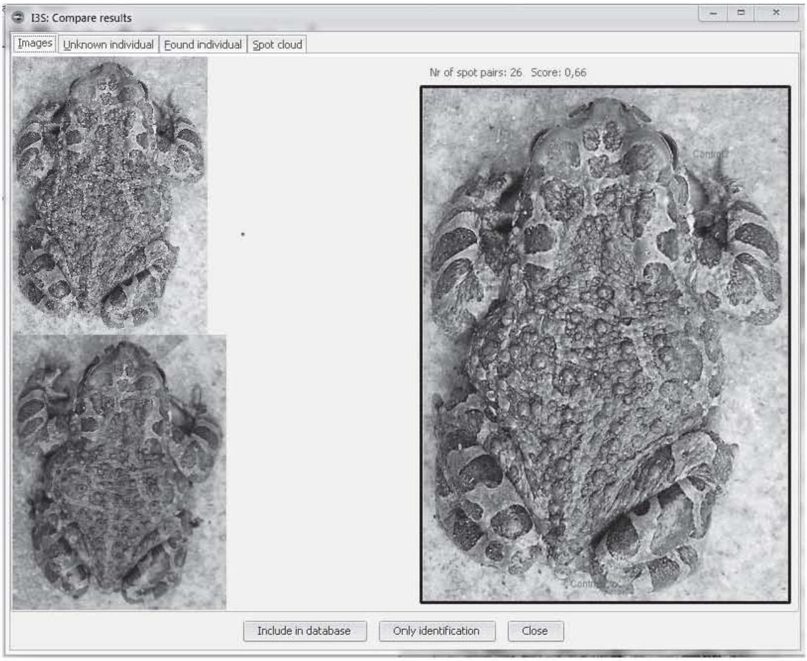

Fig. 13-3. An example of a visual comparison of two *Bufotes viridis* complex individuals with the "I3S" software v.2.0 (explanations are in the text). *See colour centerfold for this image in colour.*

Using the Lincoln-Petersen Index (Sutherland 2000, 1-278), the population size and the average density (Ds) were calculated for each of the marked populations. The average density was calculated by dividing population size by the area of the water basins that the green toad is using for breeding in the three parks. The area of the fountains in "Tsar Simeonova Gradina" Park is 8800 m^2, in "Mladezhki hulm" Hill – 153.86 m^2 and in "Hulm Bunardzhik" Hill – 250 m^2. The calculated average population density for "Tsar Simeonova Gradina" Park is Ds=0.010 ind./m^2 (Ds(♂)=0.006 ind./m^2 and Ds(♀)=0.006 ind./m^2) respectively; on "Mladezhki hulm" Hill – Ds=14.061 ind./m^2 (Ds(♂)=13.115 ind./m^2 and Ds(♀)=0.676 ind./m^2) and for "Hulm Bunardzhik" Hill – Ds=0.204 ind./m^2 (Ds(♂)=0.068 ind./m^2 and Ds(♀)=0.086 ind./m^2).

Despite the large difference in the area of the water basins used for breeding in the three studied areas, it is evident that the population in "Mladezhki hulm" Hill NM has the highest average density, while the males have a significant prevalence over the females. In "Hulm Bunardzhik" Hill NM the opposite situation is observed, and in "Tsar Simeonova Gradina" Park the average density of the two sexes is almost equal.

Table 13-4. Results of the mark-recapture study of green toad populations in the three studied urban green areas in Plovdiv City (2007-2008).

No. of visits	**Date**	**Number of marked captured individuals**							
		Marked animals		**Second time**		**Third time**		**Total**	
		♂	♀	♂	♀	♂	♀	♂	♀
"Tsar Simeonova Gradina" Park									
1	09.8.2007	32	10					32	10
2	10.8.2007	17	7	11	5	2	0	30	12
3	11.8.2007	5	6	8	0	0	0	13	6
Total by sexes		54	23	19	5	2	0	75	28
Total		77		24		2		103	
"Mladezhki hulm" Hill NM									
1	02.4.2007	6	3						
2	28.2.2008	49	5	0	0	0	0	49	5
3	29.2.2008	20	0	2	0	0	0	22	0
4	01.3.2008	8	1	0	1	0	0	8	2
5	18.4.2008	19	5	1	0	0	0	20	5
6	16.5.2008	1	2	1	0	0	0	2	2
Total by sexes		103	16	4	1	0	0	107	17
Total		119		5		0		124	
"Hulm Bunardzhik" Hill NM									
1	28.9.2007	8	4						
2	17.5.2008	3	8	1	1	0	0		
Total by sexes		11	12	1	1	0	0	12	13
Total		23		2		0		25	

We do not have data from other studies done on green toad populations using this methodology with which to compare our results. From the results of the marking, it is also clear that the toads do not migrate from one park to another because no marked individuals from one territory are found in another. This means that the populations of the species in the studied urban parks are closed and the road network around them plays the role of an impervious barrier (see Chapter 15).

Sexual structure. The ratio between the sexes (obtained by the line transect method) in the green toad populations in two of the surveyed urban green areas was strongly displaced in favor of the males – "Mladezhki hulm" Hill NM – 3.68:1 (χ^2=52.08, df=1, $p<0.05$); "Tsar Simeonova Gradina" Park – 2.78:1 (χ^2=23.58, df=1, $p<0.05$) – but in "Hulm Bunardzhik" Hill NM, the ratio is close to the normal distribution (1:1) – 0.95:1 (χ^2=0.27, df=1, $p=0.87$). When analyzing the sexual structure of the three populations based on the data from the mark-recapture method, almost identical results were obtained – "Mladezhki hulm" Hill NM – 6.29:1 (χ^2=65.32, df=1, $p<0.05$); "Tsar Simeonova Gradina" Park – 2.68:1 (χ^2=21.45, df=1, $p<0.05$) and "Hulm Bunardzhik" Hill NM – 0.92:1 (χ^2=0.4, df=1, $p=0.84$). A similar gender ratio (strongly displaced in favor of the males) is common in this type of urban environment. Mazgajska (1996, 245-257) reported a ratio of close to 7:1 in favor of the males from Wroclaw (Poland). Similar results are reported by Kühnel and Krone (2003, 299-315) for populations of the green toad from Berlin. A ratio of 3.6:1 in favor of the males is reported by Milchev (1985, 195-203) from Sofia. Zhelev (2011, 129-139) registers the gender structure of this species from natural habitats in favor of the males, and from anthropogenically polluted area in favor of the females. We can assume that a gender structure shifted in favor of males is normal for the species.

In many species of anurans with a prolonged reproduction period, the number of males exceeds that of the females (Alcantara, Lima, and Bastos 2007, 406-410; Eggert and Guyétant 2003, 46-51) and for this reason males spend longer time in the water, giving them a greater opportunity for multiple copulations (Wells 2007), and a chance for greater spread of their genes. Several factors may lead to population sex structure in favor of the males (see Hartel, Öllerer, and Nemes 2007, 109-132), and such a ratio may lead to strong intra-species competition among males, but our observations and those of other authors (Kovács and Sas 2010, 73-77) show that male green toads are rarely aggressive (Castellano et al. 2000, 1129-1141).

Age structure. Significant differences in the age structure of *B. viridis* complex populations were registered in the three studied urban green areas (Fig. 13-4).

Fig. 13-4. Age structure of the populations of the green toad in the three studied urban green areas in Plovdiv City for the entire study period.

In the population from "Mladezhki hulm" Hill NM, the largest percentage is taken by the adults and the juveniles, and the lowest by the subadults in a ratio of 1:0.08:0.9 (χ^2=119.2, df=2, p<0.05). Several successful reproductions of the species in "Mladezhki hylm" Hill NM were registered during the study period. For the population of "Hulm Bunardzhik" Hill, the highest percentage is for the adults, followed by the subadults, and the lowest percentage was found in the juveniles in a ratio of 1:0.45:0.03 (χ^2=31.52, df=2, p≤0.05). No juvenile specimens were found in 2008. In this year, no reproduction was recorded on this hill. The existing water basins remained dry throughout the year and this prevented the breeding of the toads or forced them to look for breeding ponds outside the area of the hill. In "Tsar Simeonova Gradina" Park, the adults have the highest percentage, followed by the juveniles and subadults in the ratio of 1:0.009:0.09 (χ^2=158.90, df=2, p≤0.05). Because of the fact that in the urban environment the green toad is an "explosive" opportunistic breeding species (Mazgajska 1996, 245-257; Kühnel and Krone 2003, 299-315), we think an age structure where adults and juvenile specimens predominate, as observed on "Mladezhki hulm" Hill and "Tsar Simeonova Gradina"

Park, is normal for the species. We do not have data from natural populations to make comparisons.

Breeding peculiarities (phenology). During the survey period, we managed to make enough observations to present the phenology and the selection of ponds for reproduction in two of the studied parks – "Mladezhki hulm" Hill and "Tsar Simeonova Gradina" Park. The data is presented in Table 13-5.

Table 13-5. Phenology of the breeding of the green toad populations in two of the studied parks in Plovdiv City (2007-2008).

"Mladezhki hulm" Hill NM								
	March 2007	April 2007	May 2007	June 2007	July 2007	August 2007	Sept. 2007	Oct. 2007
Males calling	+	+	+			+		
Couples in amplexus	+	+	+			+		
Eggs/Embryos		+	+			+	+	
Larvae			+	+			+	
	March 2008	April 2008	May 2008	June 2008	July 2008	August 2008	Sept. 2008	Oct. 2008
Males calling	+	+	+					
Couples in amplexus	+	+	+					
Eggs/Embryos	+	+	+					
Larvae		+	+					
"Tsar Simeonova Gradina" Park								
	March 2007	April 2007	May 2007	June 2007	July 2007	August 2007	Sept. 2007	Oct. 2007
Males calling			+			+		
Couples in amplexus			+			+		
Eggs/Embryos			+	+		+	+	
Larvae				+	+		+	
	March 2008	April 2008	May 2008	June 2008	July 2008	August 2008	Sept. 2008	Oct. 2008
Males calling		+	+					
Couples in amplexus		+	+					
Eggs/Embryos		+	+	+				
Larvae				+	+	+		

The breeding season of the green toad on the "Mladezhki hulm" Hill begins immediately after the melting of the snow (February-March) and the warming of the weather at air temperatures of 12-15°C and water temperatures of 10-13°C. The males always enter the breeding ponds first and stay there for a long time. Females enter the water only for copulation and the laying of the eggs within 3-4 days, then leave it. The first songs of the males were recorded in March 2007 at "Mladezhki hulm" Hill and even at the end of February in 2008. The breeding season for the population at "Tsar Simeonova Gradina" Park began a month later, which was directly related to the availability of water in the fountains in the park, which the species uses for reproduction. In both parks, two breeding periods were reported in 2007 – one in the spring (March-May) and one in the late summer (August-September). In 2008 only one breeding period was recorded in the two studied parks: at "Mladezhki hulm" Hill in the spring (March-May), as in "Tsar Simeonova Gradina" Park – in the summer (May-August).

Similar breeding behavior of the green toad was also reported by Sicilia et al. (2006, 107-117) on two Sicilian islands – La Fossa and Ustica – in natural populations. Kovács and Sas (2010, 73-77) also reported two breeding seasons of *B. viridis* complex from a population in Oradea (Romania), where the first breeding period began in April but lasted until June as the water level was constant, and a second breeding period in August. Each female lays two long lines (about 5 m) of eggs containing an average of 4,500-5,000 eggs. Similar observations on the reproduction of the green toad are also provided by Milchev (1985, 195-203) from Sofia City. Metamorphosis occurs extremely rapidly (up to 30 days). In some cases, due to the drying of water reservoirs, metamorphosis is interrupted at a very early stage. According to Beshkov and Nanev (2002, 1-120), the natural metamorphosis of this species takes about 45-65 days, with cases of accelerated metamorphosis being known for dry water basins in central Asia. With the constant decrease of water in the basins, the density of the larvae populations of the green toad probably also increases, which, after reaching a certain stage, unlocks physiological mechanisms that affect both the rate of metamorphosis and their population size. Kovács and Sas (2009, 206-208), for example, reported a case of cannibalism among the larvae of *B. viridis* complex in Oradea (Romania), pointing to the lack of a sufficient food base on the one hand and a sharp increase of the population on the other.

In both studied parks, the green toad uses mainly artificial ponds with a concrete bottom and no vegetation (mainly park fountains) for reproduction. An exception is made only by one large, temporary pond, of natural origin, in the southern part of "Mladezhki hulm" Hill, where rainwater is collected. Data on the characteristics of two main water basins in which breeding was observed in both parks and a temporary standing water pond, near Irrigation Canal No. 3 (see Chapter 12), is presented in Table 13-6.

Table 13-6. Characteristics of the water basins used for breeding of the populations of green toad in two of the parks studied in Plovdiv[2].

Parameters / Water basins	Air temperature (°C)	Water temperature (°C)	pH	Dissolved O_2, mg/l	Depth	Area (m^2)	Type of coastal vegetation	Type of bottom
"Mladezhki hulm" – pond	15.1	13.3	7.1	6.3	42	140	grassy-shrub	rocks
"Tsar Simeonova Gradina" – "Singing" fountains	15.4	12.7	7.4	6.1	50	7000	-	concrete
Pond near Irrigation Canal No. 3	15.6	13.7	7.0	10.8	30	50	grass	muddy

According to Ensabella et al. (2003, 396-400), in Rome the green toad prefers to breed in ponds that are fish-free, low in nitrates and chlorides. The distance to the center of the city and the presence of competing species (such as *Bufo bufo*) also play their role. According to Milchev (1985, 195-203), more than half of the ponds which this species uses for reproduction in Sofia City have a concrete bottom and a small area. The author also notes that the species has not been found in entirely natural ponds. Our results confirm the results of Milchev (1985, 195-203) – in Plovdiv City, the green toad mainly uses small water basins with a concrete bottom (urban fountains) and, in rare cases, temporary ponds of natural and semi-natural nature. None of the ponds surveyed by us were loaded with fish and there are no competitive species. In our opinion, the main factor that attracts green toads to a particular type of water basin is the retention of the water level over a long period of time. Such behavior was also observed by Milchev (1985, 195-203) in Sofia City.

Mortality. The causes of mortality of the green toad in the area studied are presented in Chapter 15.

Conclusions. The green toad (*Bufotes viridis* complex) is one of the most adapted species of amphibians for an urban environment. The species

[2] The given values are averaged for the whole period of study.

uses different mechanisms that allow it not only to survive in urban areas but also to adapt perfectly to these conditions. Some of these mechanisms are: extremely high resistance to drought (Sosovskyi 1983, 1-144), which allows it to occupy habitats that other amphibian species cannot (Christaller 1984, 115-121; Ensabella et al. 2003, 396-400); a population structure shifted in favor of the males, which provides for the possibility of multiple copulations and better gene spraying (Kovács and Sas 2010, 73-77); several breeding periods during the year (Sicilia et al. 2006, 107-117); an accelerated period of metamorphosis (Banikov et al. 1985, 1-399); and high fertility and population density (Beshkov and Nanev 2002, 1-120). Despite the few risks and threats related to urbanization, this species will continue to be one of the most common species in Plovdiv City.

Tree frog (*Hyla arborea* complex)

Distribution. During our study, the tree frog was observed only in "Mladezhki hulm" Hill NM (Annex 2-3) of the surveyed urban green areas. It is noticeable that this species inhabits a relatively small amount of territory, in the southern part of the hill, near standing water basins. It is missing from the periphery of the hill and the built-up area. According to Mollov (2005b, 79-94), the tree frog has also been found in the territory of "Hulm Bunardzhik" Hill NM and "Tsar Simeonova Gradina" Park, but it was not recorded again there in the current survey.

Habitats. According to our observations, the tree frog exhibits an affinity for habitats with moderate humidity, with predominantly bush and tree vegetation. Reproduction takes place in temporary standing water basins.

Population density. The tree frog was recorded only in Transect No. 3. The abundance and the population density at "Mladezhki hulm" Hill NM is presented in Table 13-7 and is significantly lower than the population density of the green toad.

The total area of the water basins that the tree frog uses for reproduction in the protected area is 314 m^2.

The abundance of the *H. arborea* complex population at "Mladezhki hylm" Hill NM is much higher than the population in the suburbs (Irrigation Canal No. 3 – 0.244 ind./1000 l.m.) and the rural zone (Parvenetska River – 0.727 ind./1000 l.m.; Irrigation Canals Nos. 1, 2 and 4 – 0.277, 0.277 and 0.357 ind./1000 l.m., respectively). The reason for this is the relatively small territory in the southern part of the hill where the tree frog finds both enough ponds for breeding and the availability of suitable habitats for food, shelter and hibernation. These same conditions exist in only a thin strip on both sides of the above-mentioned canals, which is also the reason for the lower abundance of this species in the suburbs and outside the city.

Table 13-7. Abundance and population density of the tree frog (*Hyla arborea* complex) in "Mladezhki hulm" Hill NM.

Year	Ecological density (D_e), ind./ha	Mean density (D_s), ind./m^2	Abundance (Ab), ind./1000 l.m.
2007	12.00	0.03	6.00
2008	14.67	0.04	7.33
Total	26.67	0.06	13.33

According to Milchev (1985, 195-203), the population size of the tree frog in the studied water basins in Sofia in "50% of the localities is *low* (up to 25 ind.) and in 40.7% of the localities are *small in size*". Our results for Plovdiv City confirm these conclusions.

When comparing the average population density and the abundance of the tree frog from "Mladezhki hulm" Hill, compared to the anthropogenically uninfluenced areas of the Eastern Rhodopes Mts. and Sakar Mts., we registered higher values for the urbanized territory, calculated in a similar area and by the same methodology (Popgeorgiev, 2008b, 1-228; 2009, 1-40) – Rogozinovo Village, Sakar Mts. (Ds=0.0137 ind./m^2); Ostar Kamak Village, Eastern Rhodopes Mts. (Ds=0.0076 ind./m^2) and in terms of abundance – Srem Village, Eastern Rhodopes Mts. (Ab=0.37 ind./1000 l.m.); village of Kostilkovo, Eastern Rhodopes Mts. (Ab=0.56 ind./1000 l.m.); village of Gorno Lukovo, Eastern Rhodopes Mts. (Ab=0.54 ind./1000 l.m.).

Sex structure. The sex ratio of the tree frog's population has a slight predominance to the males – 1.43♂:1♀ (10♂, 7♀, and 1 juvenile), but there is no statistically significant difference from the normal 1:1 distribution (χ^2=0.53, df=1, p=0.47).

Age structure. The age structure of the population is 5:3:1 with the highest percentage ratio being the adults (55.56%), followed by the subadults (33.33%) and the juveniles (11.11%). There was no statistically significant difference from the 1:1:1 distribution of the three age groups (χ^2=2.67, df=1, p=0.10).

Conclusions. Factors influencing the populations of the tree frog worldwide are predation (Bronmark and Edenhamm 1994, 841-845), competition (Fog 1988, 122-123; Pavignano, Giacoma, and Castellano 1990, 311-324), water pollution (Stumpel and Hanekamp 1986, 409-411), eutrophication (Fog 1988, 122-123), natural succession (Grosse 1994; Geiger 1995) or simple habitat destruction. Additional negative factors, reported by other authors, such as water pollution, eutrophication and natural succession have not been registered in the protected area. The only real threat to this species is direct disturbance and mortality caused by humans, as well as the destruction of the breeding ponds.

In addition, factors acting onshore on a local scale around breeding ponds may also affect the populations of the tree frog. For example, food availability, disturbances and the reduction of appropriate ground-based habitats are cited most often by many authors (Tester 1990; Stumpel 1993, 47-54). On a wider scale, factors such as the isolation of breeding ponds (Tester 1990; Edenhamm 1996; Vos 1999) also have an impact. The loss of landscape dynamics and/or the disappearance of certain structural elements such as shrubs or forest stands would be potentially influencing factors for the tree frog and for some other amphibians (Pope, Fahrig, and Merriam 2000, 2498-2508). Most likely, a combination of all these factors, including some unknown causes, leads to the reduction and even disappearance of tree frog populations in many places in this area. According to Beshkov (1993b, 567-584), *H. arborea* complex has stable populations in the country and is one of the most frequently met and most common amphibian species. Beshkov and Nanev (2002, 1-120) reported that the tree frog is a species that is not uncommon for human settlements. Considering that this is a species that is well adapted to land life and is also not demanding for breeding ponds (Milchev 1985, 195-203), we can conclude that the tree frog finds good conditions for existence in the urban environment.

The Kotschy's Gecko (*Mediodactylus kotschyi*)

Distribution. The Kotschy's gecko was recorded in the territory of all three of the Plovdiv hills, as well as in "Tsar Simeonova Gradina" Park and Rogosh Cemetery Park (Appendix 2-8). In "Mladezhki hulm" Hill NM, the species is distributed mainly in the eastern part and around the top of the hill and is not recorded in the periphery and in the built-up area. In "Hulm Bunardzhik" NM its distribution is more homogeneous, and in the area of "Danov hulm" Hill NM, the species inhabits solely the southern part of the hill, and again is not registered in the built-up area on the periphery. In "Tsar Simeonova Gradina" Park the species is located only on the walls of residential buildings, in the southern part of the park, and in Rogosh Cemetery Park it is recorded on slopes between the marble slabs, throughout almost the whole territory of the park. We also have some other observations on geckos from residential buildings, close to the parks that are being explored, which are included in the analysis.

Habitats. An entirely synanthropic species. It almost exclusively inhabits human buildings. Even in the interior of the hills, which are considered to be places where "wild populations" can be seen (Beshkov and Nanev 2002, 1-120), geckos can be seen more often in man-made habitats (houses, support walls along alleys, etc.) than on rocks in the open (Fig. 13-5).

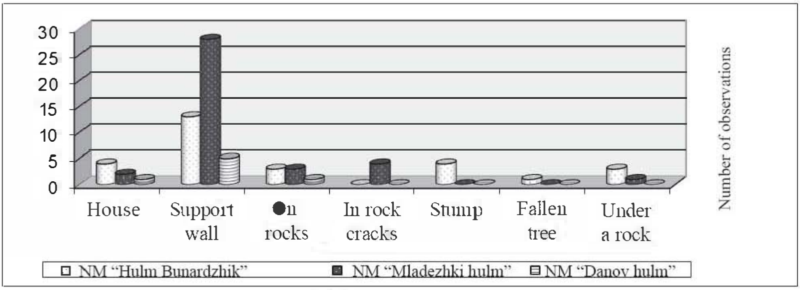

Fig. 13-5. Micro-habitats used by *Mediodactylus kotschyi* in the three surveyed territories.

The most frequent hiding places and micro-habitats used by the Kotschy's gecko are the support walls along the alleys on the hills. This pattern is most visible in "Mladezhki hulm" Hill NM, probably due to the larger area of this hill and therefore the larger number of support walls. The second most frequently used micro-habitats are the rocks in the open and cracks between larger rocks. The use of houses, as micro-habitats or hiding places from geckos, was evident to the greatest extent in "Hulm Bunardzhik" Hill NM. Also, this hill is the only place where we found geckos under the bark of stumps and fallen trees or under stones. We suppose the last mentioned hiding places are rather random and are only used temporarily by geckos. According to Semenov and Shenbrod (1988, 65-71), the Kotschy's gecko is a polytopic species and inhabits an extremely wide variety of habitats. In nature, in Italy, the species inhabits xerophilous habitats with rocks and rock scales (Scillitani, Picariello, and Maio 2004, 107-111), and the same authors report that geckos can be observed on buildings, stone walls, farms and even graveyards.

For two of the studied hills – "Mladezhki hulm" Hill and "Hulm Bunardzhik" Hill – we traced the geckos' preference for the exposure of the used habitats (Fig. 13-6).

From the results, it is clear that on “Mladezhki hulm” Hill, the geckos prefer slopes with eastern and southern exposure more than northern and western, and on “Hulm Bunardzhik” Hill the majority of the observed geckos are registered on slopes with western and southern exposure.

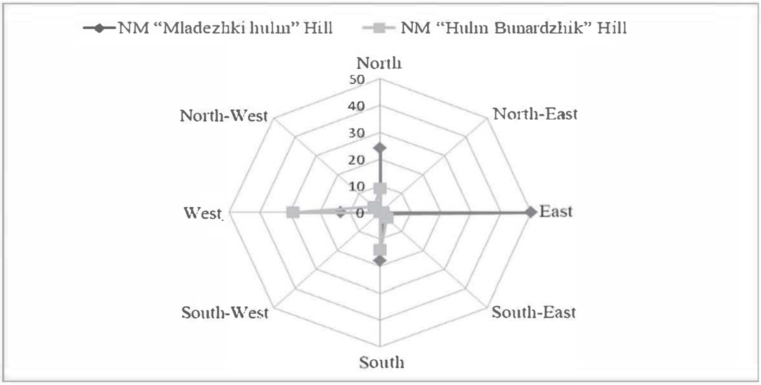

Fig. 13-6. Preference, from the point of view of slope exposure, of the populations of *Mediodactylus kotschyi* on the two studied hills throughout the study period.

24-hour and seasonal activity. The Kotschy’s gecko is a predominantly nocturnal species, but, as noted by Beshkov and Nanev (2002, 1-120), it can often be observed during the day, near its shelters. Our data from “Mladezhki hulm” Hill and “Hulm Bunardzhik” Hill also shows this as the majority of our observations on this species were done after 8:00 PM (Fig. 13-7). Sterbak (1960, 1390-1397) notes that the first geckos appear after sunset until midnight.

Our observations also show that the activity of the geckos strongly decreases after midnight, which may be related to the fall of the air temperature during the night. It is not uncommon for geckos to be observed during the day even in the heaviest heat, as Müller (1939, 1-17) noted, as he captured geckos in the middle of the day from the Plovdiv hills in the midday sun.

The Kotschy’s gecko shows bimodal seasonal activity, the first peak being in April, which is possibly related to the beginning of the breeding season of the species (Sterbak and Golubev 1986, 1-233), and the second peak being in August when the juveniles hatch (Fig. 13-8). According to Scillitani, Picariello, and Maio (2004, 107-111), the Kotschy’s gecko is active from April to October in Italy, and according to Shterbak (1960, 1390-1397), from May to September on the Crimean Peninsula. According to unpublished data by Dobrev (personal communication), the earliest observation of geckos in Bulgaria was on 31.03.1983 in the town of Elhovo and 12.10.1984 at the latest in Tsarevo Town. In 2007, due to the unusually warm winter and the significant rise in temperatures in January, active geckos were observed on the "Hulm Bunardzhik" Hill in Plovdiv in 2007. Of course, this happens extremely rarely and exceptionally; otherwise, according to our observations, the geckos in Plovdiv emerge in March and are active through to the end of September.

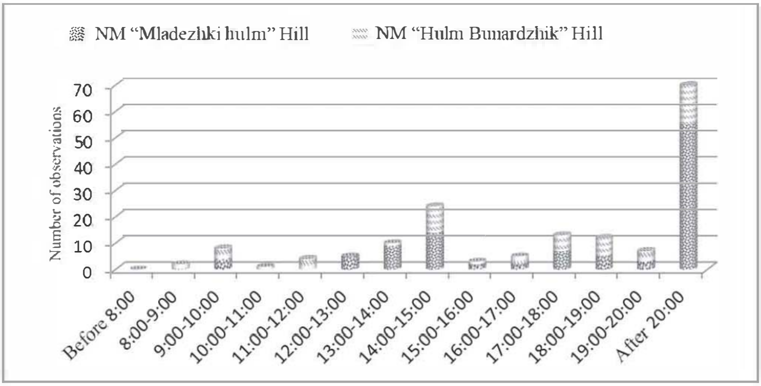

Fig. 13-7. Daily activity of the populations of *Mediodactylus kotschyi* on both studied hills throughout the study period.

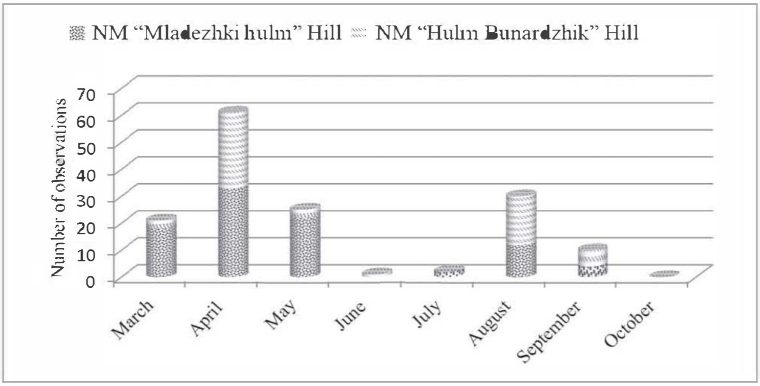

Fig. 13-8. Seasonal activity of the populations of *Mediodactylus kotschyi* on both studied hills throughout the study period.

More unusual activity of *M. kotschyi* during the winter is described by Mollov, Georgiev, and Basheva (2015, 1-3).

Population density. The abundance and ecological density of the Kotschy's gecko populations in the studied parks are presented in Table 13-8.

Table 13-8. Abundance (Ab, ind./1000 l.m.) and ecological density (De, ind./ha) of the populations of the Kotschy's gecko in the four studied parks.

Transect	Year			
	2007		2008	
	Abundance (Ab)	Ecological density (De)	Abundance (Ab)	Ecological density (De)
"Mladezhki hulm" Hill NM				
Transect No. 1	6.67	216.00	3.89	126.00
Transect No. 2	14.00	140.00	11.50	115.00
Transect No. 3	2.50	16.00	9.38	60.00
Mean	7.72	124.00	8.25	100.33
"Hulm Bunardzhik" Hill NM				
Transect No. 4	19.17	69.00	7.50	27.00
Transect No. 5	0.56	18.00	6.94	225.00
Mean	9.86	43.50	7.22	126.00
"Danov hulm" Hill NM				
Transect No. 6	3.33	12.00	11.67	42.00
"Tsar Simeonova Gradina" Park				
Transect No. 7	2.50	4.00	-	-
Rogosh Cemetery Park				
Transect No. 12	-	-	7.60	118.75

The abundance and ecological density of the Kotschy's gecko populations reported by us in the investigated urban parks have close values, both when comparing each individual park as well as between the first and second years of the survey. There were no statistically significant differences found when comparing the four populations. The only exception is "Danov hulm" Hill, where there was a significant increase in abundance and density in the second year of study.

According to Semenov and Shenbrod (1988, 65-71), the density of natural populations of the Kotschy's gecko from Uzbekistan varies from

1-16 ind./ha. Kukushkin (2009, 27-36) reported that geckos inhabiting rocky habitats in a forest massif in the Crimea Peninsula have a population density of 3.5 ind./ha. The density of the gecko's populations in Plovdiv City is higher than in natural populations. According to Beutler (1981, 53-74) and Scillitani, Picariello, and Maio (2004, 107-111), one of the reasons for the high density of the Kotschy's gecko in some cities is the absence of other gecko species such as *Hemidactulys turcicus* and *Tarentola mauretanica,* which are its direct competitors, and also because the Kotschy's gecko is much more adapted to anthropogenic pressure.

Any differences in the reported density, according to Kukushkin (2009, 27-36), may be due to both the surveying method (plot surveys or line transect method) and the type of the surveyed area. For a more accurate representation of the quantification of the populations in similar kinds of research, it is probably more appropriate to use other indicators in parallel with density, such as abundance.

Sex structure. The sex ratio of the Kotschy's gecko populations recorded on the three hills of Plovdiv is close to 1:1 – "Mladezhki hulm" Hill NM, 1♂:0.59♀ (χ^2=2.81, df=1, p=0.093); "Hulm Bunardzhik" Hill NM, 1♂:0.88♀ (χ^2=0.59, df=1, p=0.81); "Danov hulm" Hill NM, 1♂:1.33♀ (χ^2=0.28, df=1, p=0.59) – but there is no statistically significant difference from the normal 1:1 distribution ($p>0.05$ in all cases). Similar results were obtained by other authors (Sterbak 1966; Sharyigin 1977, 158-203; Sterbak and Golubev 1986, 1-233; Dobrev – personal communication), but Scillitani, Picariello, and Maio (2004, 107-111) reported that, in stable populations of the Kotschy's gecko from anthropogenically influenced/uninfluenced areas, the normal sex ratio was 1:4 in favor of females. According to the same authors, females are structured in "harems", usually four, with one dominant male actively guarding their territory. Such behavior of guarding the territory was also recorded by us, as the males produce a strong, distinctive "ticking" sound.

Age structure. The age structure of the population of *M. kotschyi* from "Mladezhki hulm" Hill NM and "Hulm Bunardzhik" Hill NM shows that in both populations the largest proportion is that of the adult specimens. On "Mladezhki hulm" Hill the subadults take second place followed by the juveniles in a ratio of 1:0.19:0.06 (χ^2=106.44, df=2, $p<0.05$), while at "Hulm Bunardzhik" Hill the subadults have the lowest percentage and the ratio is 1:0.1:0.34 (χ^2=37.27, df=2, $p<0.05$). No juvenile and sub-adult specimens were found either on "Danov hulm" Hill or in the other two studied parks.

According to Beutler (1981, 53-74), the ratio of adults to juveniles is always higher (skewed towards the adults), based on several studies.

Breeding. The breeding season is likely to begin at the end of April or early May, but this period, including the egg incubation, may be quite long (Sterbak and Golubev, 1986, 1-233). The laying of eggs takes place in August. The earliest deposited eggs observed by us were registered on 05.08.2008 at "Danov hulm" Hill, and on 25.08.2008 shell eggs from "Mladezhki hulm" Hill were observed. This means that the laying of eggs on the Plovdiv hills starts probably in July, and embryonic development is over by the end of August. This proves that the geckos from the hills of Plovdiv are breeding successfully.

The Kotschy's gecko is the only lizard occurring in Bulgaria which lays eggs with calcareous shells (Undzhian 2000, 1-88). So far, data about the egg size is quite scarce in the herpetological literature. Partial data about the eggs' size, incubation period, growth rates, etc. can be found in the works of Shterbak (1960, 1390-1397; 1961, 942; 1965, 1421), Shterbak and Golubev (1986), Valakos and Vlachopanos (1989), Undjian (2000), Beshkov and Nanev (2002) and others. Currently, there is only one study giving data about the egg size of *Mediodactylus kotschyi daniliewskii,* conducted in Bulgaria (Undzhian 2000, 1-88).

We examined nine gecko eggs from four clutches – two from "Danov halm" Hill and two from "Mladezhki halm" Hill. The material was collected on 25.08.2008 from "Mladezhki halm" Hill, and on 23.04.2008 and 05.08.2008 from "Danov halm" Hill.

Literary data about the Kotschy's gecko egg sizes of *M. k. daniliewskii* from Bulgaria are given by Unzhian (2000, 1-88) based on 11 eggs from the South Black Sea Coast. We were able to take more precise measurements of another 15 *M. k. daniliewskii* eggs from a photograph with a size marker from the same author (Undzhian 2000, Fig. 40) from Sozopol (Bulgaria). For the analysis, we also used data given by Shterbak (1961, 942; 1965, 1421) for the same subspecies from Sevastopol (Ukraine) and by Shterbak and Golubev (1986, 1-233) from Hersones, Sevastopol (Ukraine) and for *M. kotschyi* (unknown subspecies) from Naxos Island, Greece (Valakos and Vlahopanos 1989, 179-184).

Egg characteristics are presented in Table 13-9. Apparently *M. k. rumelicus* lays eggs that are longer and wider than *M. k. daniliewskii* from Bulgaria and Ukraine. In terms of egg volume, *rumelicus* also exhibits the biggest eggs (Table 13-9). The two subspecies have relatively similar egg sizes, but the differences in the egg volume are more clearly visible. The mean clutch size for *M. k. rumelicus* recorded in this study is 2.3 eggs, for *M. k. daniliewskii* from Sevastopol it is 2 eggs (Shterbak 1961) or 1.67 eggs (Shterbak 1965, 1421) and for the same subspecies from Hersones, Sevastopol it is 1-2 eggs (Shterbak and Golubev 1986, 1-233). Valakos and Vlahopanos (1986, 179-184) give a mean clutch size of 2.25 eggs for *M. kotschyi* from Naxos Island.

The cluster analysis of the egg volume size showed that *M. k. rumelicus* from Plovdiv shows closer values to the volume size of *M. k. daniliewskii* from the Black Sea Coast (Bulgaria) at about 80% similarity. The egg volume size of *M. k. daniliewskii* from Sevastopol clusters with the one of *M. k. daniliewskii* from Herones, Sevastopol at about 90% similarity. *M. k. daniliewskii* from Sozopol shows the closest similarity (about 80%) to *M. kotschyi* from Greece (Fig. 13-9).

The Kotschy's gecko is a small lizard species, which carries and lays only one or two (rarely three) eggs with hard calcareous shells during the reproduction period, similar to other primitive geckos (Kratochvíl and Lukáskubicka 2007, 171-177). The clutch size in the two studied subspecies is very similar, but they differ concerning the egg size and volume. Since the current study is just a short note, based on a small number of studied eggs and available literary data, generalized conclusions about the egg size differences between the two subspecies cannot be made. However, based on the data of Müller (1939, 1-17), who reports that *M. k. rumelicus* is slightly bigger than *M. k. daniliewskii* ($SVL_{rumelicus}$=48-52 mm, $SVL_{daniliewskii}$=45-49 mm), it is fair to assume that the bigger egg size in that subspecies is due to the bigger size of the females. We also suppose that, to some extent, the larger size of the eggs in *M. k. rumelicus* can be partially explained by the urban heat island effect (Oke 1982, 1-24; Camilloni and Barros 1997, 665-681). Perhaps the higher environmental temperatures in the center of the big city (Plovdiv), where the studied sites are situated, influence the size of the hatched eggs.

In our opinion, further studies on the egg sizes and reproduction of the Kotschy's gecko are needed. Interesting results could be obtained from a comparison of the sizes between the three subspecies of *M. kotschyi* that occur in Bulgaria, based on larger samples of eggs, as well as a comparison of the egg sizes and shell structure of populations from different climatic regions in Bulgaria in order to determine any differences based on the climatic conditions or the taxonomical affiliation.

Behavior. To measure the effect of temperature on the activity of the Kotschy's gecko, measurements of air temperature, rock temperature, and the temperature inside the shelter were made (Table 13-10).

According to Beutler (1981, 53-74), *M. kotschyi* is often active during the day, much more so than other European geckos. Especially in the morning and late afternoon, animals are often seen to be active, even at effective temperatures of 50°C (measured in the sun).

Table 13-9. Egg and clutch characteristics of the two subspecies of *M. kotschyi* from the current study and comparison with literary data.

Egg characteristics	*M. k. rumelicus* Plovdiv, Bulgaria (current study)	*M. k. danilewskii* Sozopol, Bulgaria (Uniiian, 2000)	*M. k. danilewskii* South Black Sea Coast, Bulgaria (Uniiian, 2000)	*M. k. danilewskii* Sevastopol, Ukraine (Shterbak 1961; 1965)	*M. k. danilewskii* Hersones, Sevastopol, Ukraine (Shterbak and Golubev 1986)	*M. kotschyi* Naxos Island, Greece Valakos and Vlahopanos (1986)
Egg length (mm)						
Mean±SE	9.87±0.25	7.55±0.09	9.55	8.75±0.24	8.60	7.05
SD	0.74	0.37	-	0.80	-	-
Range (min-max)	9.30-11.50	7.00-8.10	9.30-9.80	7.50-9.70	7.50-9.70	7.00-7.10
Egg width (mm)						
Mean±SE	8.35±0.11	6.11±0.09	7.55	7.60±0.17	6.95	4.49
SD	0.34	0.34	-	0.57	-	-
Range (min-max)	7.90-8.80	5.20-6.90	7.30-7.80	6.60-8.20	5.80-8.10	4.48-4.50
Egg volume (mm^3)						
Mean±SE	361.80±15.02	147.53±3.60	361.41	268.20±16.85	284.94	116.85
SD	45.08	13.93	-	55.88	-	-
Range (min-max)	307.17-424.87	113.26-174.50	330.58-392.23	171.06-334.46	170.82-399.05	115.45-118.25
Total clutch volume (mm^3)						
Mean±SE	814.05±100.05	-	-	491.71±49.41	-	-
SD	200.12	-	-	121.02	-	-
Range (min-max)	646.11-1099.68	-	-	334.46-604.85	-	-
Number of eggs studied	9	15	11	11	-	-
Number of clutches	4	-	-	6	-	-
Mean clutch size	2.25	-	-	1.67-2.00	1.00-2.00	2.25

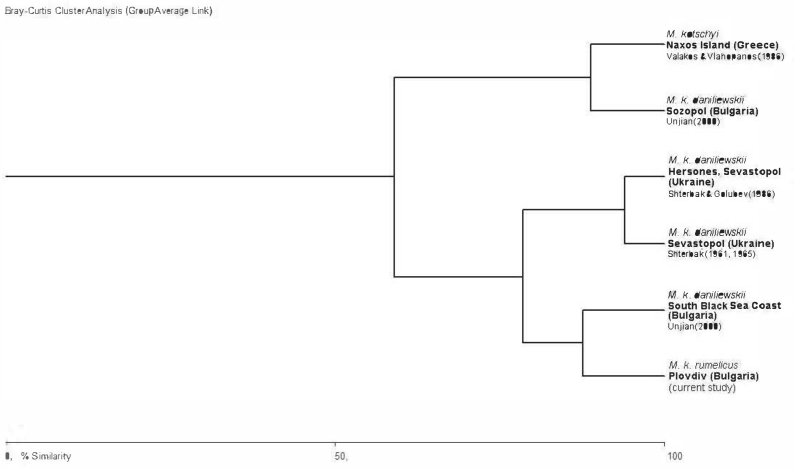

Fig. 13-9. Cluster analysis of the egg volume sizes of the three subspecies of *M. kotschyi* from the current study and comparison with literary data.

Table 13-10. Descriptive statistics of air temperature, temperature of the rock and inside the shelters of *M. kotschyi* from the three studied hills (August 2008).

Parameter	Mean	Minimum	Maximum	Std. Dev.	Std. Err.
Air temperature, °C	29.98	21.90	36.10	3.97	0.89
Temperature of the rock, °C	32.22	22.70	41.30	5.26	1.18
Temperature inside the shelter, °C	31.95	24.90	37.70	4.07	0.91

The highest air temperature measured by us was 36.1°C, but the temperature of the substrate (rock) was 41.3°C. In any case, the temperature measured inside the gecko's shelter was always 0.5 to 1-2 degrees below the temperature of the rock, but always higher than the air temperature. Holfert (1999, 57-60) reported a maximum measured air temperature during the activity of geckos on rocks south of Sozopol Town of 43°C. The same author reports that the temperature inside the gecko's shelters varied from 26.7°C (8:00 AM) to 36.5°C (at 12:00 PM) and even 38.2°C at 7:00 PM). According to Sterbak and Golubev (1986, 1-233), the minimum temperature at which geckos are observed active was 12-14.5°C, and the maximum was 34-40°C, as the optimal temperature for the highest activity in geckos is considered to be 26°C. According to the same author, incubation of the eggs takes place at temperatures of 18-35°C. In addition, Mollov (2005b, 79-94) also established a variation in the color, which varies from light, ash-gray to dark brown (almost black), depending on the light and temperature. Geckos from shadows micro-habitats are lighter in color, and those in sunny places are darker in color. This variability was also observed by other authors (Beutler 1981, 53-74). According to Petrov, Stoev, and Beshkov (2001, 127-153), the peculiarities in climatic conditions (mostly temperature) are the main factor limiting the distribution of the Kotschy's gecko outside of the human settlements in Bulgaria. It seems that the so-called "urban heat island effect" (Oke 1982, 1-24; Camilloni and Barros 1997, 665-681) plays an even more important role for the existence of geckos in the cities. In Greece, where average annual temperatures are higher, more gecko populations are reported outside human settlements and at higher altitudes (Valakos and Valchnopanis 1986, 179-184), compared to the Bulgarian populations.

Conclusion. The Kotschy's gecko is the only synanthropic species found in the research area. Its populations are stable and high density. The geckos are successfully breeding on the hills of Plovdiv and probably elsewhere in the city. Although there are certain threats to the species, such as predation (mainly by domestic cats) and competition (possibly with *P. thauricus*), special measures for its conservation in the urban environment at this stage are not necessary. The species is relatively resistant to anthropogenic pressure (though not as much as other species of geckos) and survival in the urbanized territory is certain. Plovdiv hills have played a key role in preserving this species in the city of Plovdiv, both in past geological times (see Chapter 14) and at present.

The Balkan wall lizard (*Podarcis tauricus*)

Distribution. Podarcis tauricus is located in the territory of the "Mladezhki hulm" Hill, "Hulm Bunardzhik" Hill and "Lauta" Park (a single specimen) with the impression that, in both studied protected areas, the lizards inhabit only the top of the hills as they were not recorded in the periphery or beyond (Appendix 2-11). In the area of "Mladezhki hulm" Hill, the Balkan wall lizard occurs mainly in the southern part of the hill and partly in the western part, and in some cases in the eastern and northern parts. In the territory of "Hulm Bunardzhik" Hill the species is found exclusively in the southern part of the hill and is absent elsewhere.

Habitats. 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 will discuss 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. 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. At the beginning of the 20th century and afterward the indigenous vegetation was gradually displaced by many decorative shrub and tree species, used widely in gardens and the city parks (Dimitrov et al. 2002, 1-80).

The single specimen found in "Lauta" Park was located on the periphery of the park, in the ecotone area between the park vegetation and the open spaces between the blocks of flats. In our opinion, the park itself does not offer the right conditions for the existence of this species; it probably inhabits open, abandoned lands and the spaces in between the blocks of flats.

In nature, the Balkan wall lizard inhabits lowlands with scarce vegetation: lawns with *Amorpha frueticosa* and *Marsdenia erecta* shrubs (Kabisch and Engelmann 1970, 104-107); sand dunes with quite meager vegetation, consisting of grasses and *Artemisia sp.* as the dominant plant (Nöllert 1983, 26-29) in Bulgaria; 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 and Lykakis 1983, 991-1001). Similar habitats are described by Undzhian (2000, 1-88), Beshkov and Nanev (2002, 1-120) and Schlüchter (2006, 80-88) from other natural sites in Bulgaria.

Coloration and adaptations. The Balkan wall lizard shows a certain degree of variation in its coloration, which was also observed by us on the Plovdiv hills. There are various hypotheses about the changing color of the dorsal medial strip. Some authors believe that the green color is the so-called "breeding color" of this lizard. Other authors associate the variability of the color to the soil microelements' composition (Shargyin 1979, 46-52). In our opinion and according to our observations, the changing coloration of the dorsal stripe is seasonal. In the spring to mid-summer the color is grassy green, gradually changing to brownish with the fall of autumn, and in September-October, it is completely brown. Similar observations have been made by Chondropoulos and Lykakis (1983, 991-1001) in Greece, who added that the green color persists until the main vegetation is green and that the change of color is directly related to the surrounding vegetation.

Diurnal and seasonal activity. The Balkan wall lizard shows a bimodal daily activity pattern, with one peak in the morning and a second in the afternoon (Fig. 13-10). The seasonal activity also shows a bimodal activity pattern (Fig. 13-11) with one peak in the spring (March-May) and a second peak in the autumn (August-September).

According to our observations, the diurnal and seasonal bimodal pattern of the lizard's activity is more vividly expressed in the population of "Hulm Bunardzhik" Hill NM, which is probably due to the different microclimatic conditions. Similar daily activity cycles strongly influenced by weather conditions were reported by Chondropoulos and Lykakis (1983, 991-1001) for *Podarcis tauricus* in Greece, by Cruce (1970, 467-472) for a natural population in Romania and Avery (1978, 143-158) 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, 703-720; Busack 1976, 826-830) but not by the degree of urbanization in particular.

Population density and abundance. The ecological density of the population of the Balkan wall lizard from "Mladezhki hulm" Hill was D_e=10.81 ind./ha, and for "Hulm Bunardzhik" Hill it was D_e=5.0 ind./ha. The density of the two populations is relatively low. For comparison, for the natural populations of the same species from Haskovo Town, Tzankov (2005) reported 27 ind./ha. Cruce and Leonte (1973, 593-600) report much higher values for a population in Romania of 45.4 ind./ha, and Cruce (1977, 621-636) reported a value of 100 ind./ha as the average density for another Romanian population.

The abundance of the population at "Mladezhki halm" NM is higher, compared with the abundance of the population at "Hulm Bunardzhik" NM, but there are no statistically significant differences (t-test, $p>0.05$). There is also a visible pattern of decreases in the population abundances on both hills for the two year period (Table 13-11), but only the population from "Halm Bunardzhik" NM has statistically significant differences (t-test, $t=2.57$, $p=0.02$). The only other place (with the exception of several single specimens reported in the spaces in between the blocks of flats in the southern suburbs of the city) where the Balkan wall lizard is recorded is the Parvenetska River (see Chapter 12). The abundance of the population there is Ab=0.182 ind./1000 l.m., which is considerably less than what we account for in the two protected areas in the city center.

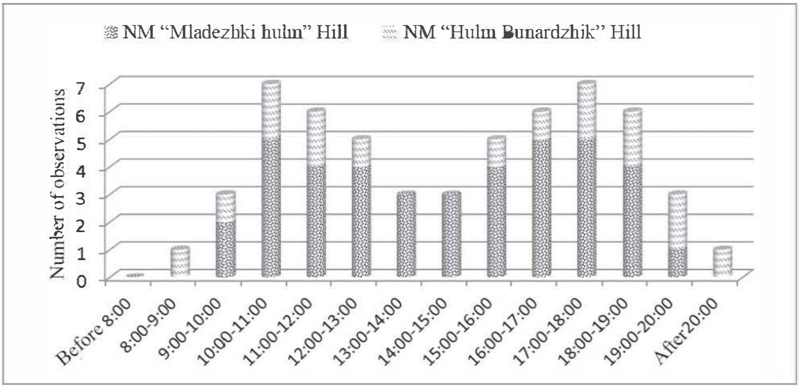

Fig. 13-10. Diurnal activity of the two populations of *Podarcis tauricus* in both protected areas throughout the study period.

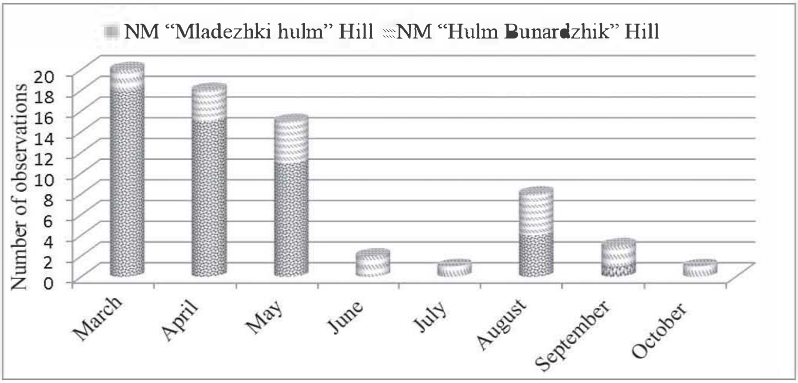

Fig. 13-11. Seasonal activity of the two populations of *Podarcis tauricus* in both protected areas throughout the study period.

Table 13-11. Abundance (ind./1000 l.m.) of both populations of *Podarcis tauricus* in Plovdiv for the two-year period.

Site	2007	SD	2008	SD
"Mladezhki halm" Hill NM	3.12	4.58	3.00	3.33
"Halm Bunardzhik" Hill NM	1.87	0.99	0.62	0.92

We recorded a decrease in the average population density 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 Balkan wall lizard in Plovdiv City does not follow the generally established trend for many species of reptiles (McKinney 2008, 161-176; Hammer and McDonnell 2008, 2432-2449), where the population density and abundance decrease from the periphery to the center of the city. However, the abundance of *P. tauricus* populations reported in this study in an urban environment is significantly lower compared to native populations. Popgeorgiev (2009, 1-40) reported values from 0.52 to 12.04 ind./1000 l.m. in several populations of the Eastern Rhodopes Mts. and 12.01 ind./1000 l.m. from another population in the Sakar Mts.

The lower population density at "Hulm Bunardzhik" Hill NM could be explained by the smaller size of the hill and the higher anthropogenic pressure (Mollov 2005b, 79-94). 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 2005b, 79-94).

Sex structure of the populations. In both populations, our study shows a sex ratio close to 1:1 with a slight deviation towards the females. However, all these deviations from the 1:1 ratio are not significant (χ^2-test, df=1, p>0.05). The sex ratio in the population from “Mladezhki hulm” Hill NM is 1:1.29 (χ^2=0.64, df=1, p=0.42) and the sex ratio in the population from “Hulm Bunardzhik” Hill NM is 1:1.28 (χ^2=0.25, df=1, p=0.61), skewed towards the females.

The normal sex ratio of the natural populations of *Podarcis tauricus* is close to 1:1, as reported by Cruce (1977, 621-636) for Romania and Chondropoulos and Lykakis (1983, 991-1001) 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 by the “urban heat island theory” (Oke 1982, 1-24; Camilloni and Barros 1997, 665-681). The sex determination in reptiles (including lizards) is strongly influenced by the temperature of the surrounding environment (Harlow and Shine 2006, 205-212; Warner and Shine 2008, 566-568). At higher environmental temperatures in the center of the city, where the studied sites are situated, perhaps more females are hatched.

Age structure of the populations. The age structure in both populations is almost identical. The highest percentage is taken by the adults, followed by the subadults and the juveniles (“Mladezhki hulm” Hill NM: adults – 42.86%, subadults – 36.73%, juveniles – 20.41%; “Hulm Bunardzhik” Hill NM: adults – 45%, subadults – 35%, juveniles – 20%). The deviation of the equal distribution of the age groups (1:1:1) is not significant on both hills – “Mladezhki hulm” Hill NM (χ^2=3.96, df=2, p=0.13) and “Hulm Bunardzhik” NM (χ^2=1.90, df=2, p=0.38).

The age structure showed a 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 by 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 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 (Begon, Harper, and Townsend 1986, 1-876), more adults, or more juveniles, depending on mortality and fecundity schemes. Unfortunately, our results are insufficient to determine any certain population trends.

Escape behavior 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 "Mladezhki hulm" Hill NM, 4.08% of the lizards were with broken tails and 2.04% with regenerated tails, and at "Hulm Bunardzhik" Hill NM, 15% were with broken tails and 10% with regenerated tails. Both interpopulational (U-test, U=32.5, p=0.81) and intersexual (U-test, U=36.0, p=0.65) tail-break frequency differences were not significant (U-test gives $p>0.05$ in all cases), but the population from "Mladezhki hulm" Hill shows the lowest values. The comparison of the tail loss frequency between the age groups also showed no significant differences ($\chi^2=1.75$, df=2, p=0.41).

According to Pianka (1970, 703-720), the 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 "Hulm Bunardzhik" Hill NM. 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 use tail-breaking for escaping from 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* does not follow the same pattern. It seems all age groups use tail autotomy equally frequently to escape predation. Similar results are reported by Chondropoulos and Lykakis (1983, 991-1001) and Strijbosch, Helmer, and Scholte (1989, 151-174) in Greece.

Conclusion. 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 (see Chapter 14). The rapid construction around the hills regularly pushed the lizards towards the interior of the hills, fragmenting the species' populations. The gradual transformation of the habitats on the hills during the 20th century with the introduction of several decorative tree and shrubs has additionally influenced the current distribution and population density of *Podarcis tauricus* on the hills of Plovdiv.

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 has adapted successfully to the remaining suitable habitats in the interior of the hills. The fact that three of the hills of Plovdiv are declared as protected territories has also positively influenced 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.

The Green Lizard (*Lacerta viridis*)

Although it is found in five of the surveyed urban parks (Appendix 2-9), the populations of green lizards are considerably smaller than the previous species and only single specimens were found in Transect Nos. 8 and 9. Its preferable habitats include sunny places with shrubs and sprouted forests, meadows and more. According to our observations in the rest of the city, the green lizard favors semi-aquatic habitats, which are rare in Plovdiv's hills and city parks, and we presume that this is one of the reasons for its lower abundance in the parks. A role may also be played by possible competition with the Balkan wall lizard (*P. tauricus*), which is more aggressive (Beshkov and Nanev 2002, 1-120; Tsankov 2007, 1-40) and it is possible that the previous species also competes with *L. trilineata* and *P. muralis*, and the last two species were not even found on the Plovdiv hills in this study (2007-2008) (see Mollov 2005b, 79-94). Because of the small number of observed specimens in the transects, we cannot conduct a more in-depth analysis of the ecology of this species in the investigated urban parks.

Caspian Whipsnake (*Dolichophis caspius*)

The only species of snake – the Caspian whipsnake (*D. caspius*) – in the present study was recorded only in "Mladezhki hulm" Hill NM with three localities. Two of them were recorded on the basis of skin-sheds of adult specimens located in the southeastern part of the hill, and the third one was on the periphery of the northwest part of the protected area – a dead specimen killed by traffic (Appendix 2-12). We also have older data from 2004 of another skin-shed in "Lauta" Park (Irikov – personal communication), but in this study, the species was not found there. Nevertheless, in 2007, a young live specimen was found in the territory of the Agrarian University (Popgeorgiev – personal communication), which is in close proximity to the park, so it is possible that the species occurs in the area around the park. Probably on the outskirts of the park, the Caspian whipsnake predates on house mice and other small rodents directly linked to human dwellings.

Since we do not have observations on live specimens, ecological data on the species is scarce. Judging by the place where the skin-sheds from "Mladezhki hulm" Hill were found, the only place where the Caspian whipsnake has found suitable living conditions in the center of the city is precisely this hill, where it obviously prefers rare wooded slopes, with the presence of rocky places and open spaces. All other habitats of the species are in the suburban and rural areas of the city (see Chapter 12).

In the northern part of the Caspian whipsnake's range in Europe – Hungary – this species is generally rare. In Budapest, Toth (2002, 163-167) reports that the species is recorded on several hills in the city (similar to the Plovdiv hills), where it inhabits the southern slopes covered with herbaceous and bush vegetation and usually hunts lizards (*A. kitaibelii, P. muralis*, etc.). The species has already disappeared from many of the hills in Budapest, and in the few remaining localities in the city, as well as in its surroundings, it is extremely rare.

In our opinion, *D. caspius* is a species of high ecological plasticity, as this is the most common species of terrestrial snake in Bulgaria (Beshkov and Nanev 2002, 1-120), but the species seems to have difficulties in adapting to urban environments or the anthropogenic press on this species, which is greater on all snakes than on the other reptile species. As Toth (2002, 163-167) points out, the main threat to the species in Budapest is direct destruction by humans. We assume that this is the reason for the species occurring in a much smaller population size in the city center compared to the suburbs and the rural areas.

Ecological characteristics of the amphibian and reptile communities of Plovdiv hills and the urban parks

To determine the diversity of the amphibian and reptile communities in the surveyed parks, the Simpson and Shanon-Wheiner Diversity Indices and the Berger-Parker Domination Index (Table 13-12) were calculated. "Danov hulm" Hill NM was removed from the analysis as it contained only two species.

The highest values of the two diversity indices were recorded in "Lauta" Park, followed by "Hulm Bunardzhik" Hill NM and "Mladezhki hulm" Hill NM. The two hills also have the highest species richness. Evenness indices show high values (except for "Lauta" Park and "Hulm Bunardzhik" Hill NM), which suggests monodominant communities where the green toad or the Kotschy's gecko are dominant species. The Berger-Parker Index values confirm this claim.

Table 13-12. Diversity Indices of the amphibian and reptile communities in the investigated urban parks. Legend: *MH* – "Mladezhki hulm" Hill NM, *HB* – "Hulm Bunardzhik" Hill NM, *DH* – "Danov hulm" Hill NM, *TSG* – "Tsar Simeonova Gradina" Park, *OKP* – "Otdih i Kultura" Park, *LP* – "Lauta" Park and *RCP* – "Rogosh" Cemetery Park.

Diversity indices	MH	HB	TSG	OKP	LP	RCP
Simpson (1/D)	2.187	2.985	1.033	1.500	10.000	1.228
Simpson (E)	0.631	0.794	0.068	1.000	0.961	0.346
Shannon (H)	1.029	1.146	0.083	0.451	1.332	0.381
Shannon (J)	0.574	0.827	0.119	0.650	0.961	0.346
Berger-Parker (d)	0.632	0.418	0.984	0.833	0.400	0.905

Based on species abundances, a cluster analysis was also performed to determine the similarity in the fauna of the surveyed urban parks (Fig. 13-12).

There are two main clusters – the first are the two large parks located at opposite ends of the city in the suburban zone – "Lauta" Park and "Otdih i Kultura" Park – with about 5% similarity. The second cluster is further divided into two groups – the first is "Danov hulm" Hill NM and Rogosh Cemetery Park, with approximately 8-9% similarity, and the second one groups together "Mladezhki hulm" Hill NM, "Hulm Bunardzhik" Hill NM and "Tsar Simeonova Gradina" Park, with about 40% similarity. The analysis shows that these parks, which have the highest species richness (Table 32), have the highest faunal similarity and have the greatest importance for the preservation of the batraho- and herpetofauna in the city of Plovdiv.

Most species are found in "Mladezhki hulm" Hill NM (total of 6 amphibians and reptiles), followed by "Hulm Bunardzhik" Hill NM and "Lauta" Park (total of 4 species each), followed by Rogosh Cemetery Park (total of 3 species), "Tsar Simeonova Gradina" Park and "Otdih i Kultura" Park and "Danov hulm" Park (with 2 species each) (Table 13-13). One of the principles of the Island Biogeography Theory states that there is a positive correlation between the area of the "island" (city park) and the number of species occurring there (MacArthur and Wilson 1967). For Plovdiv City, we found such dependency only for the three Plovdiv hills and "Tsar Simeonova Gradina" Park. In our opinion, the differences in the species richness of the amphibians and reptiles found in the studied urban parks are due not only to the difference in their area but also to the degree of anthropogenic pressure. The hills of Plovdiv City still have preserved suitable habitats for most amphibian and reptile species, relatively close to the natural ones. That is why this principle of Island Biogeography Theory is not fully applicable in the conditions of Plovdiv City, because other factors have greater influence than the islands' area and their distance from the source of the colonists. In urban environments, factors such as the heterogeneity of the habitat mosaic and the degree of anthropogenic pressure are more important.

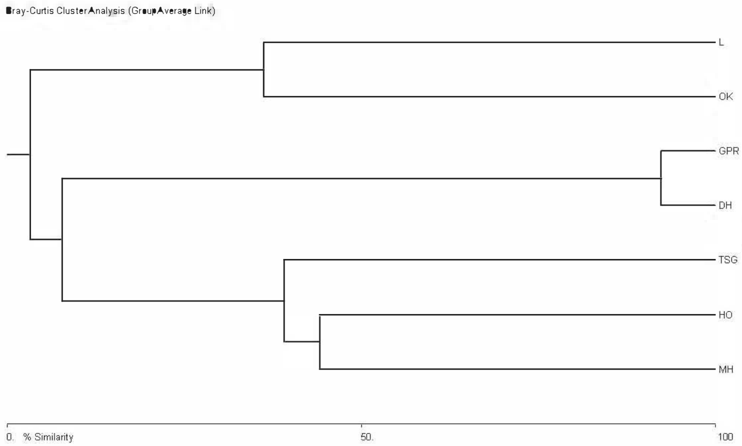

Fig. 13-12. Cluster analysis of the faunistic similarity in the studied parks and green areas in Plovdiv (Bray-Curtis Index, group average link) (see the legend of Table 13-12)

Table 13-13. Area and species richness in the studied parks and green areas in Plovdiv City (see the legend of Table 13-12).

Characteristics	**Studied parks in the current study**						
	MH	**HB**	**DH**	**TSG**	**OKP**	**LP**	**RCP**
Area (daa)	362	220	53	116	604	711	136
Number of species	6	4	2	2	2	4	3
Mean number of species in 1 daa	0.016	0.180	0.037	0.170	0.003	0.006	0.022

In our opinion, putting three of the Plovdiv hills under protection and declaring them as “nature monuments” has played and continues to play a positive role for the preservation and conservation of the amphibians and reptiles in Plovdiv City. Ordinary city parks and graveyards have a weak role in preserving the species richness and amphibian and reptile populations in the city.

Chapter Fourteen

Origins of the Urban Fauna

The origin of the herpetofauna in Plovdiv City is a consequence of a combination of processes that arose as a consequence of the geological past of the region during the history of the city, as well as the dispersal abilities of the species and the influence of the anthropogenic factor.

The current distribution and condition of the amphibians and reptiles in the city of Plovdiv can be partly explained by the geological history of the Rhodopes Mts. Boshev, Strashimirov, and Zafirov (1966, 1-383) describe the development of the area, reporting it as the oldest dry land in Bulgaria that appeared above the water at the beginning of the Paleozoic, and until the Neogene it did not re-flood. At the beginning of the upper Eocene the sinking of the eastern and middle parts of the Rila-Rhodope Massif began, as a result of which they were flooded by the Eocene Sea. During the Oligocene, the area was covered by the Pyrinean Folding Phase and its erection started again. During the Pliocene, the main structural units continued to fold, which was also associated with the formation of faults. At that time the Aegean Sea was formed.

Taking into account the fact that the tertiary climate is close to the tropical, we can assume that at that time the Rhodopes Mts. could not have been a barrier for the warm-loving species, such as the *M. kotschyi* and *P. muralis*. The cooling at the beginning of the Quaternary and the continued elevation of the area probably caused the disappearance of the gecko from the high central parts of the mountains. At the same time, the Upper Thracian lowland was above the water, and the plutons of the Plovdiv hills had already been shaped. The dry climate at the beginning of the Quaternary created good conditions for the distribution of both species in the Upper Thracian region and the slopes of the Rhodopes Mts. During the Wurm Ice Age, which is the most noticeable in the territory of the Balkan Peninsula, the Kotschy's gecko and the wall lizard may have remained in warmer climate refuges in the valley of the Chepelarska River and the Plovdiv hills, where they can still be found today.

Supporting this hypothesis is the fact that many plants recognized as tertiary relicts are also known from the same sites. There are also reptiles such as *Eryx jaculus*, *Elaphe situla* and the *Platyceps najadum*. The localities of these three species (respectively, Parvenets Village, Plovdiv County (Beshkov et al. 1967, 5-10), and Asenovgrad Town and the Asenitsa River Valley (Kovachev 1912, 1-90)) are islands far from their densely populated localities in Struma Valley, Southeastern Thrace, the Eastern Rhodopes Mts. and the Southern Black Sea Coast (Beshkov 1984, 14-34). From this data it can be assumed that the area actually had conditions for the survival of warmth-loving species during the ice age period.

Since *M. kotschyi* is the only synanthropic species that is closely related to human structures, it is presumed that it was probably transported by man to Plovdiv City. However, in our opinion, *M. k. rumelicus* is probably a tertiary relic in the Bulgarian fauna and its current distribution in Plovdiv and its surroundings is not a result of the anthropogenic transfer of the morphologically similar subspecies *M. k. bibroni* from the valley of the Struma River. The hilly habitats of the Plovdiv hills, close to the natural habitats, have helped to preserve the Kotschy's gecko, as well as the wall lizard of the hills in a locality isolated from the Rhodopes Mts.

The flat nature of the city and its surroundings is a prerequisite for the presence of a small number of species but also for such species that are typically low-land species (*B. bombina, P. syriacus*) or that prefer open, dry habitats (*B. viridis* complex, *L. trilineata, L. viridis, P. tauricus* and *D. caspius*). The well-developed network of urban parks (including the hills) in Plovdiv City, which extends from the periphery of the city's center, has also helped many species to enter the city from nearby forest habitats from the slopes of the Rhodopes Mts. and the Sredna Gora Mts. (*B. bufo, B. variegata, R. dalmatina*).

Furthermore, the presence of the Maritsa River and the Parvenetska River has enabled the dispersion of some aquatic and semi-aquatic species such as *P. ridibundus, H. arborea* complex, *E. orbicularis, N. natrix* and *N. tessellata*. Subsequently, the anthropogenic factor has played an additional positive role in the distribution of these species through the construction of a dense network of irrigation canals, a rowing canal and a fish farm.

As a result of the anthropogenic pressure and the expansion of the city, the autochthonous herpetofauna in Plovdiv has changed significantly. The fragmentation and isolation of green areas in the city are essential for turning them into small islands of suitable habitats and limiting the diversity of species. These processes also lead to the loss of natural and semi-natural biotopes and the complete destruction of their herpetofauna in some cases. By destroying these biotopes, the exchange of specimens of urban herpetofauna with those of the surrounding area is interrupted. The destruction of forest habitats in and around the city has led to the expulsion of species attached to such habitats, such as *R. dalmatina* and *B. bufo* on the outskirts of the city, where the last habitats and breeding ponds suitable for these species remain. At the same time, the discovery of new territories and the dilution of forest habitats has played a positive role in the displacement of dry-loving species that prefer open spaces, such as the green toad (*B. viridis* complex), *L. trilineata*, *L. viridis* and especially *P. tauricus*.

In our opinion, in the past, *P. tauricus* had a much wider distribution on and around the Plovdiv hills with much more numerous and denser populations. Before the intensive construction around the hills began, when the city started to grow, there was an abundance of open terrains, which this species usually inhabits in nature (Fig. 14-1A). The rapid construction around the hills gradually pushed this and other lizard species into the hills, fragmenting their populations (Fig. 14-1B). The gradual transformation of the habitats on the hills in the 20th century, with the planting of decorative, atypical shrubs and trees, has further affected the distribution and density of *P. tauricus* populations and other species of lizards on the hills today (Fig. 14-1C).

The species more sensitive to pollution, alteration and destruction of appropriate water habitats and direct anthropogenic pressure, such as the newts and both *Bombina* species, have disappeared from the city limits. Larger snakes such as *C. austriaca* and *E. sauromates*, although single specimens have been found in the city before, have now disappeared.

The anthropogenic factor has also played another "positive" role in increasing the species richness of the urban fauna. The keeping of both tortoises (*T. hermanni* and *T. graeca*) as pets and their subsequent release "within the city" has led to the repeated registration of these two species in a territory in which they were never met in the past (Beshkov 1984, 14-34). Similarly, 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.

The contemporary herpetofauna of Plovdiv City is the result of the coexistence of autochthonous species that managed to survive in the urban area after colonization and expansion, as well as due to the secondary colonization of species attached to natural, forest habitats and, lastly, the transformation of communities of open biotopes. The species found in open and semi-open natural habitats find good living conditions in urban habitats. The species composition, the structure of the populations and the communities of these species, as a rule, are not accidental, but these are a reflection of objective processes taking place in specific conditions in the urbanized territory of Plovdiv.

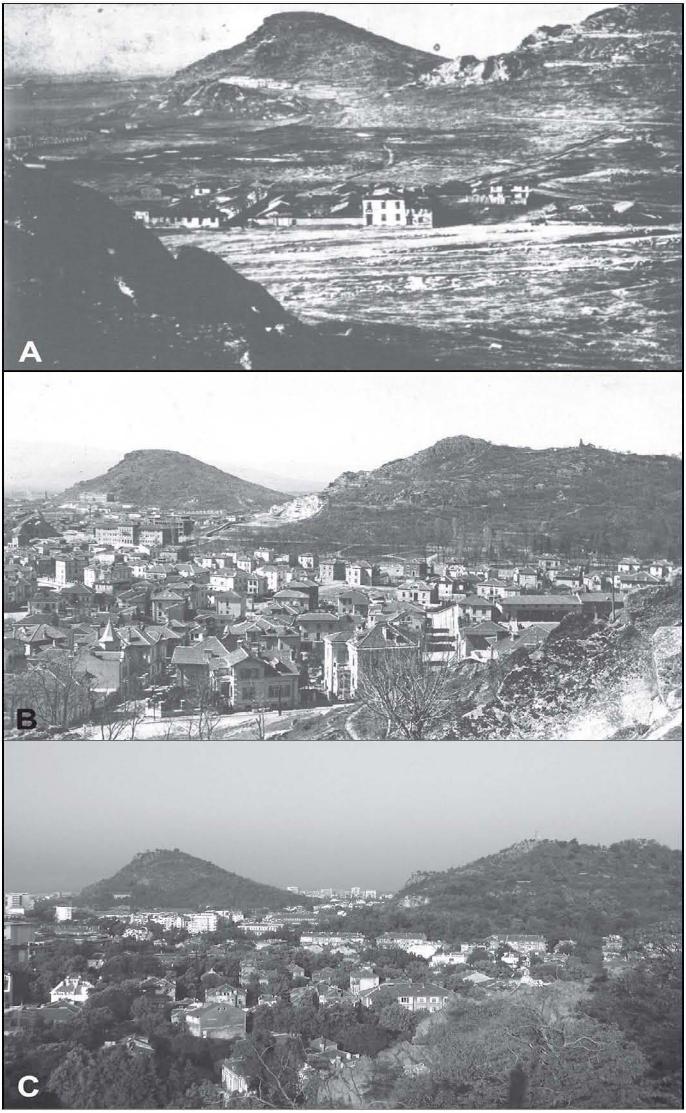

Fig. 14-1. “Mladezhki hulm” NM, a.k.a. “Dzhendem tepe” and “Hulm Bunardzhik” NM: A – a photograph of the two hills, taken in 1862; B – a photograph of the two hills taken sometime before 1957; C – a photograph of the two hills taken in 2008 (the explanations are in the text).

In conclusion, it can be said that the anthropogenic factor has played and continues to play a major role in the formation of urban fauna. In many cases, it leads to the impoverishment of indigenous fauna, but on the other hand, it also contributes to the opposite process of increasing the number of species not typical for urban conditions. The herpetofauna of the city of Plovdiv were probably formed in the above-mentioned ways and conditions, mainly due to the anthropogenic pressure combined with the gradual increase of the air temperature within the city boundaries and accompanied by the significant loss and transformation of primary natural habitats. Thus, the fauna can be seen as a result of the adaptation of the impoverished fauna of the suburban natural habitats to the remaining, preserved forest and park areas in the urbanized area.

CHAPTER FIFTEEN

CONSERVATION SIGNIFICANCE, PROBLEMS AND THREATS FOR THE AMPHIBIANS AND REPTILES IN THE CITY OF PLOVDIV

Conservation significance of the recorded amphibians and reptiles in the city of Plovdiv

Table 15-1 presents the conservation status of the amphibians and reptiles recorded in the surveyed area according to the contemporary national and international conservation legislation. Twelve species are protected under the Biological Diversity Act (2002): one species is included in Annex II – Species for the protection of which are declared protected areas for the protection of their habitats; 11 are included in Annex III – Species protected throughout the country; and one species is included in Annex IV – Species under conservation regime and regulated use by nature.

One species (*Pelobates syriacus*) is included in the Red Data Book of Bulgaria (Beshkov 1985, 2-41) under the category "threatened". A series of studies carried out on this species have shown that *P. syriacus* has a much wider distribution than previously thought and its populations are stable. This led to the exclusion of this species from the new edition of the Red Data Book of Bulgaria in 2011 (Biserkov et al. 2011). Fourteen species are included in the Convention for the Conservation of Wild European Flora and Fauna and Natural Habitats (Bern 1979); 11 are listed in Annex II as "strictly protected" and three are listed in Annex III. Twelve species are protected by Council Directive 92/43 (2006) on the conservation of natural habitats and of wild fauna and flora: one species is included in Annex II – Plant and animal species of Community importance whose storage requires the announcement of territories with a special regime of protection; 11 species are listed in Annex IV – Plant and animal species of Community interest requiring strict protection; and one species is included in Annex V – Plant and animal species of Community interest whose wildlife recall and exploitation may be the subject of management measures. All identified species are listed on the Red List of Europe, 13 of which are in the LC category – least concern (low risk) – and one in the NT category – near threatened. Twelve species are included in the Red List of Endangered Species of the World Conservation Union (IUCN 2010): eleven in the LC category and one in the NT category.

The amphibians and reptiles found in the surveyed area are characterized by high conservation significance at national and international levels. Although most of them are common species in the country, their conservation is necessary in order to preserve the native herpetofauna (as part of European and world fauna) and to preserve biodiversity in cities.

Table 15-1. Conservation status of amphibians and reptiles identified in the surveyed area. *Legend:* BDA – Bulgarian Biodiversity Act (2002); RDB – Red Data Book of Bulgaria – II. Animals (Beshkov 1985, 32-41); BERN – Convention for the Conservation of Wild European Flora and Fauna and Natural Habitats, (Bern 1979); DCE'92 – 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 (Directive 92/43 2006); European Red List – Europe's Red List (Temple and Cox 2009, 1-44; Cox and Temple 2009, 1-44); Red List IUCN – Red List of Endangered Species to IUCN, Version 2010.2, as of 30.08.2010 (IUCN, 2010).

Species	**BDA**	**RDB**	**BERN**	**DCE'92**	**European Red List**	**Red List IUCN**
Bufo bufo (L., 1758)	III	-	III	-	LC	LC
Bufotes viridis complex	III	-	II	IV	LC	LC
Pelobates syriacus Boettger, 1889	III	3	II	IV	LC	LC
Pelophylax ridibundus (Pallas, 1771)	IV	-	III	V	LC	LC
Rana dalmatina Bonaparte, 1840	-	-	II	IV	LC	LC
Hyla arborea complex	III	-	II	IV	LC	LC
Emys orbicularis (L., 1758)	II,III	-	II	II,IV	NT	NT
Mediodactylus kotschyi (Steindachner, 1870)	III	-	II	IV	LC	LC
Lacerta viridis (Laur., 1768)	III	-	II	IV	LC	LC
Lacerta trilineata Bedriaga, 1886	III		II	IV	LC	LC
Podarcis tauricus (Pallas, 1814)	III	-	II	IV	LC	LC
Dolichophis caspius (Gmelin, 1789)	III	-	II	IV	LC	-
Natrix natrix (L., 1758)	-	-	III	-	LC	LC
Natrix tessellata (Laur., 1768)	III	-	II	IV	LC	-

Conservation problems and threats for the amphibians and reptiles in the city of Plovdiv

The main threats to amphibians and reptiles in the urban environment are invariably from the influence of the anthropogenic factor. Several aspects of its impact will be addressed: loss and habitat disturbance, direct anthropogenic pressure (animal killing), and habitat pollution.

Habitat loss, disturbance, fragmentation and isolation. The survival of amphibians and reptiles in urban and suburban landscapes requires the availability of appropriate aquatic habitats, such as ponds (lakes, dams, marshes) or running water (streams and rivers), wetlands and adjacent terrestrial habitats (Wells 2007). The size and type of habitats suitable for amphibians and reptiles available in the city are affected by several processes: (1) loss of habitats; (2) fragmentation and habitat isolation; and (3) creation and restoration of habitats.

Urbanization destroys large parts of amphibian and reptile habitats. The remaining pieces of habitats are fragmented and often isolated from each other, and the remaining animal populations become smaller (Radeloff, Hammer, and Stewart 2005, 793-805).

The most vulnerable species to the loss of freshwater habitats are all amphibian. They are directly dependent on the availability of suitable breeding ponds. For most of them, this is the determining factor for their distribution and development in urban territories. All four species found in the surveyed area have adapted well to terrestrial life – *Bufo bufo, Bufotes viridis* complex, *Pelobates syriacus* and *Hyla arborea* complex. They need ponds only for breeding. For both toad species, this is a major problem. *Bufo bufo* is attached to the pond in which it metamorphosed, and when it becomes an adult it comes back to the same pond to lay its own eggs (Beshkov, Delcheva, and Dobrev 1986, 62-70). For this reason, the destruction and drainage of the marshes and ponds that this species uses for breeding in the urbanized territories also significantly reduces its chances of survival. According to Banikov and Isakov (1967, 92-96), this is the main reason for the disappearance of *Bufo bufo* from Moscow City. It is very unlikely that this species will start using new breeding sites (Milchev 1985, 195-203). That is why we believe that the expansion of the city of Plovdiv will reduce the ponds suitable for reproduction and this species will gradually disappear from the research area.

The green toad, on the other hand, uses all sorts of breeding ponds (Kühnel and Krone 2003, 299-315). Since its breeding occurs mostly in small, temporary ponds, its eggs are in the most vulnerable place of its life cycle. Many of the eggs are often destroyed due to the rapid drying of the water basins. Such cases have been observed several times in "Mladezhki hulm" Hill NM, "Hulm Bunardzhik" Hill NM and a few urban fountains in the suburbs, where we have repeatedly found dried eggs in various temporary (inappropriate) water basins.

The tree frog (*H. arborea* complex) is a species that has adapted well to urban life. It is not fussy in its choice of breeding ponds and the eggs can withstand severe drought. It only suffers from the loss of breeding grounds. An example of this is the pit that existed in place of "Danov hulm" Hill, where rainwater was collected and there were many tree frogs and green toads. After construction of the "Markovo Tepe" Mall began in 2005, the pit was destroyed, and the tree frog was not re-registered either on "Hulm Bunardzhik" Hill or in "Tsar Simeonova Gradina" Park, located next to the site.

The rest of the registered amphibian species (*P. ridibundus* and *R. dalmatina*) directly depend on the availability of water for their existence. The marsh frog is most adapted for living in the urban environment. This species inhabits all rivers, streams, irrigation canals, rice fields, etc. and, thanks to the water arteries on the territory of the city, has spread widely in the research area.

Direct anthropogenic pressure. The influence of direct anthropogenic pressure as a threat to the amphibians in the city of Plovdiv was studied in more detail for the green toad (*Bufotes viridis* complex). The observed deaths (n=42) of this species (Fig. 15-1) can be divided into the following categories: killed on the road by road traffic (n=27); killed by humans (n=13); killed by dogs (n=1) and killed by domestic cats (n=1).

Most of the mortalities were caused by automobile traffic – 65% of all recorded cases (χ^2=43.71, df=3, $p<0.05$). The majority of the recorded dead specimens were on the streets and alleys on the periphery of "Hulm Bunardzhik" Hill NM and "Mladezhki hulm" Hill NM. Single dead specimens were discovered on the streets of the Old Town (Trihalmie Hill) and Stochna Gara Station. According to Mollov (2005b, 79-94) in the city of Plovdiv, the green toad inhabits mainly the gardens and yards of houses and the open green spaces between buildings. In early spring (March-May) it migrates to the places of reproduction (usually small, temporary, standing water basins) and back again. During these migrations, the green toads need to cross roads and a considerable amount of toads get killed by the traffic. From our data, three "hot zones", where most of the mortalities are recorded, can be distinguished – the middle part of "Volga" Str. (n=8), "Capt. G. Tsanev" Str. (n=6) and "Nikola Obretenov" Str., all located in the periphery of "Halm Bunardzhik" NM. On the same spots, a large number of dead green toads were recorded in a previous study, conducted in the period 2002-2005 (Mollov 2005b, 79-94).

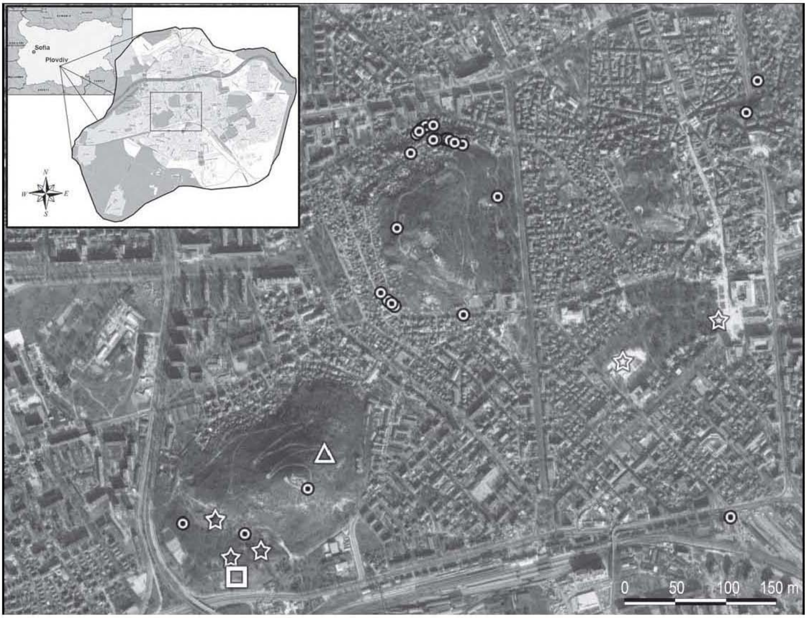

Fig. 15-1. Localities of the recorded deaths of green toads (*Bufotes viridis* complex) in Plovdiv City. Legend: ⊙ – cases of dead specimens killed by road traffic; ☆ – cases of dead specimens killed by humans; □ – cases of dead specimens killed by dogs; △ – cases of dead specimens killed by domestic cats.

For these three "hot spots", the likelihood that green toads would be killed by road traffic in the future was calculated (Table 15-2) according to the Gibbs and Shriver (2002, 1647-1652) methodology (see Chapter 5). In general, the likelihood that green toads would be killed in these three "hot zones" in the future is not very high. The greatest probability is on "N. Obretenov" Str. and the lowest is on "Volga" Str. During the migration periods (early spring and autumn), more specimens may be expected to be killed in these places by road traffic.

In relation to sexes, no statistically significant difference was detected between the dead males and females (χ^2=0.28, df=1, p=0.59). However, it is noteworthy that, for a large number of the road-killed toads (n=13), the sex could not be determined, due to the heavy damage to the toads' bodies. Some authors report that the mortality caused by automobile traffic to the amphibian populations could lead to unequal sex ratios (Cooke 1995, 87-90; Fahrig et al. 1995, 177-182). Unfortunately, our data could neither confirm nor reject this statement.

Table 15-2. Data about the road load data (number of vehicles passing per hour), lane width, kill zone and mortality probability (P_{killed}).

Street	Mean number of passing vehicles for 1 min (N)	Width of the road lane, m	Kill-zone, m (a)	Probability P_{killed}	Probability, %
"Volga" Str.	0.92	5	1	0.16	15.61%
"N. Obretenov" Str.	0.53	5	1	0.23	22.91%
"Capt. G. Tsanev" Str.	0.12	3	0.5	0.17	17.38%

On the other hand, there is a significant predominance of the recorded number of road-killed adult specimens in comparison with subadults and juveniles (χ^2=33.56, df=2, p=0.0003). It seems that the larger size of the adult animals makes them more vulnerable to collision with the automobile traffic in comparison with the subadults and the juveniles. Similar observations were made by Puky (2005, 325-368), who points out that, during most of the similar studies conducted, more road-killed specimens are recorded from species with a larger size (*Bufo bufo, Rana temporaria*) in comparison with those with a smaller size (*Lissotriton vulgaris*).

According to our results, the second major factor for green toad mortality in the city of Plovdiv is direct killing by humans (31% of all observed cases). Dead specimens killed by humans were recorded only at places heavily visited by people, namely the park area of "Mladezhki hulm" Hill NM and the central city park – "Tsar Simeonova Gradina" Park.

Due to their "unpleasant" looks (for most people) and due to some superstitions, green toads are often killed by humans, especially children. They kill not only the adult specimens but juveniles and larvae as well. Occasionally they also take out the egg cords of the green toad out of the water, which eventually dry out. Despite this, the adult specimens are the group that is most commonly subjected to this anthropogenic pressure (χ^2=14.80, df=2, p=0.0006). In relation to the sexes, we did not record any statistically significant difference between the males and females killed by humans (χ^2=0.08, df=1, p=0.78).

Our study showed that weakest impact on the green toad mortalities in the city of Plovdiv is the killing by dogs and domestic cats (2% each of all recorded cases). For the whole period of study, we observed only one attack of an adult green toad by a dog and one of a subadult specimen by a domestic cat. Both observations took place in “Mladezhki hulm” Hill NM. Dogs and domestic cats do not use green toads for food, but occasionally they attack them for play, which usually leads to the death of the toad.

For the period of study in the city of Plovdiv, we could not record any other types of green toad mortalities. It seems this species is not used for food by the birds of prey inhabiting the city, because it has not been registered so far in their pallets (D. Georgiev, Plovdiv, pers. comm., 2009) and the carnivore mammals which use it for food do not inhabit the city.

The most significant causes of death of the green toad recorded by us in the city of Plovdiv are automobile traffic and direct killing by humans. Despite the considerable amount of recorded mortalities, in our opinion, this species is not seriously threatened. As eventual conservation measures for the green toad in the city of Plovdiv, we could recommend the organization of educational campaigns (lectures, presentations) for the citizens (especially pupils) about the biology, ecology and conservation significance of the green toad, as well as the installing of information plates (boards) in the parks and park areas where the toads are reproducing and occur with higher abundance.

From the other species of amphibians recorded in the city of Plovdiv, *B. bufo* and *P. ridibundus* are subjected to direct anthropogenic pressure. Although the last species is collected by man for consumption, there is no direct danger of his disappearance. Even according to Beshkov (1993b, 567-584), the demand for frogs' legs is mainly intended for the foreign market and in recent years there has been no over-collecting of frogs in the study area or generally in the country.

For reptiles in the research area, the main threat is their direct destruction by man rather than the loss of habitats. A negative influence on their populations comes from the collecting of live specimens by private collectors.

The most adapted reptiles for existence in urban environment are *M. kotschyi* and *L. viridis*. The population sizes of both species are high and have a wide distribution in the research area. Although individual specimens are being killed by domestic cats, currently there is no real threat to them.

From the other reptiles, *D. caspius* is killed on the roads or directly by humans. Of great importance for the existence of the Caspian whipsnake and other amphibians and reptiles in the area is the preservation of the park forests, especially those forming the green belt around the city, such as “Otdih i Kultura” Park, “Loven” Park and “Lauta” Park.

The direct anthropogenic pressure also affects the aquatic reptiles. According to Beshkov (1993b, 567-584), 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.

Habitat pollution. A negative influence on all species that is directly related to water comes from the massive pollution of most of the water basins in Plovdiv City and the surrounding area. Amphibians are particularly sensitive to environmental pollutants due to their two-phase life cycle and their physiological requirements (Philips 1990, 422-424; Blaustein, Wake, and Sousa 1994, 60-71). Most ponds in the urban and suburban areas of Plovdiv City receive rainwater from a large area of impervious surfaces (roads, concrete surfaces, buildings and open spaces) containing a wide range of pollutants, including heavy metals, pesticides, unsolved substances, hydrocarbons and salts (RIEW-Plovdiv 2010).

Although this problem is not well researched in the city of Plovdiv, we assume that, except for the marsh frog (*Pelophylax ridibundus*), which has proved to be a species with a high ecological plasticity and can survive even strong contamination (Leontyeva and Semenov 1999, 269-275; Beshkov 1993b, 567-584), would be *R. dalmatina* and *Hyla arborea* complex would be more sensitive to this type of threat. For example, Snodgrass et al. (2008, 291-297) studied rainwater sludge in ponds with elevated levels of heavy metals (zinc, lead and copper). They report 100% mortality in a species that is susceptible to urbanization (*Rana sylvatica*), while *Bufo americanus*, which is more tolerant of urbanization, shows relatively low mortality. Our hypothesis is that similar results will occur in the species of toads occurring in Bulgaria (especially *Bufotes viridis* complex), which could be confirmed by more detailed research on the subject. The same authors warn that water bodies retaining polluted rainwater can become ecological traps for the amphibians that use them for breeding because they could be attractive (i.e. contain vegetation and shallow parts suitable for breeding) but at the same time, they will accumulate pollutants that may be toxic.

Recommendations and conservation measures. On the basis of the results of the present study, we can make the following recommendations for the conservation of the diversity of amphibians and reptiles in Plovdiv City.

In our opinion, all conservation measures and efforts should be directed toward preserving the habitats where most species occur or which are the so-called "herpetologically important places" (see Chapter 8).

In general, with respect to the conservation of terrestrial habitats suitable for amphibians and reptiles, it is necessary to preserve the three hills, “Lauta” Park and “Otdih i Kultura” Park, which are poorly maintained, in their current form. Parks such as “Tsar Simeonova Gradina” Park are more inappropriate because their higher attendance by people and the routine landscaping and cleaning activities have a negative impact on the amphibians and reptiles. The fountains and small artificial ponds that are built in these parks are beneficial as they are convenient for breeding the green toad. It is necessary, however, that these ponds have a low threshold and the water in them should be kept at a level of 10-15 cm for at least 30-40 days so that the metamorphosis of the species can be completed. We believe it is a good idea to place information signs of the conservation significance and ecology of this species in the proximity of these water basins in order to raise people's awareness of the protection of the amphibians in the city.

An important role for lizards is played by the so-called “abandoned lands” and the spaces between the blocks of flats (see Chapter 9). In our opinion, it is necessary to stipulate in the city plan of Plovdiv that a certain percentage of the land should remain in this form and it should not be used for agriculture or construction, as should larger inter-block spaces.

A particularly negative influence on the amphibians and reptiles 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 of all aquatic species of amphibians and reptiles 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, such as *P. syriacus*, the two species of aquatic snakes and *E. orbicularis*.

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

The main way to limit the damage from direct anthropogenic pressure on the species that occur in the city is to carry out educational campaigns and lectures among pupils, students, etc. to enhance the conservation culture of people living in large cities. An important point is to highlight the practical benefits of some species (e.g. *B. viridis* complex, *L. viridis, P. tauricus,* etc.) and their role in the city's green system.

In order to limit the harmful impact of road traffic, tunnels can be built under the road in the places where amphibian and reptile migrations most often take place. If the already built infrastructure does not allow it, the only possible measure is to place signs in these places to raise the attention of drivers.

One of the species of amphibians occurring in the city, which is also widely distributed throughout the country, is subject to economic use – this is the marsh frog (*P. ridibundus*). According to Beshkov (1993b, 567-584), the marsh frog is collected mainly for export and Plovdiv is one of the regions in the country where frogs are collected. Although the species is present in Annex IV of the Bulgarian Biodiversity Act and its collection is comparatively small (Beshkov 1993b, 567-584), we recommend that collecting frogs from nature is prohibited, at least in the breeding season (May-July).

With regard to the pollution of water basins, where amphibians and reptiles 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 amphibians and reptiles in these areas.

CHAPTER SIXTEEN

CONCLUSIONS

In the present study, 6 amphibian and 9 reptile species were recorded, of which one was invasive (*Trachemys scripta elegans)*, registered in the region of Plovdiv for the first time. According to the data for the last 100 years, the herpetofauna of the studied region is characterized by the following dynamics: 4 species of amphibians and reptiles disappeared; the number of habitats and the occurrence frequency of 1 amphibian species and 2 reptile species decreased, and those of 4 species of amphibians and 7 species of reptiles are increasing.

The highest species diversity of amphibians is found in temporary freshwater habitats, and that of reptiles is found in "dry European shrub communities", "big city parks" and "abandoned lands" followed by aquatic and semi-aquatic habitats.

The amphibian and reptile communities in the city of Plovdiv are usually mono- or bi-dominant, and their diversity is increasing along the urban gradient towards the city center, but the number of species is decreasing, and this is more pronounced in the amphibians. Indicative species for assessing the status of habitats in urban aquatic areas were the marsh frog [*Pelophylax ridibundus* (Pallas, 1771)] and the tree frog (*Hyla arborea* complex) from the amphibians, *Emys orbicularis* (L., 1758) from the reptiles, and the two species of aquatic snakes – *Natrix natrix* (L., 1758) and *Natrix tessellata* (Laur., 1768)]. For the urban green areas (park fragments), the indicator species were the green toad (*Bufotes viridis* complex and the Kotschy's gecko [*Mediodactylus kotschyi* (Steindachner, 1870)], which are indicative of the central and peripheral zones, and for the rural-forest zones, it was *Rana dalmatina* (Bonaparte, 1840).

One amphibian species is a "hemerophile", four are "hemerodiafores" and three are "hemerophobic". Only one synanthropic species [*Mediodactylus kotschyi* (Steindachner, 1870)] is registered in the reptiles; one species is a "hemerophile", four are "hemerodiafores" and two are "hemerophobes".

Of the amphibians in the studied area, the European-Asian Palearctic faunistic element is predominant, and for the reptiles, the Pontic faunistic element is predominant. European chorotypes predominate in the amphibians, and Mediterranean chorotypes in the reptiles.

The species composition of the amphibians and reptiles and the size of their populations along the Maritza River in the research area increased from the periphery to the center according to the differentiated "urban", "suburban" and "rural" zones. The Maritsa and Parvanetska Rivers, as well as the network of irrigation canals, favor the distribution of the aquatic amphibians and reptiles in Plovdiv City.

The populations of the marsh frog [*Pelophylax ridibundus* (Pallas, 1771)] are characterized as stable. We recorded the largest populations in one of the irrigation canals and the Maritsa River.

The age structure of the populations of the green lizard (*Lacerta viridis* (Laur., 1768)] is slightly pronounced over adult and juvenile specimens in almost all water basins in the studied area and does not differ significantly from the age structure of natural populations. The populations recorded in the Parvenetska River and on the banks of the studied canals in the city are more numerous than those of the city parks and the hills.

The age structure of the population of *Emys orbicularis* (L., 1758) has the highest percentage of adults and juvenile individuals, indicating that the population of this species in the city is unstable.

The populations of the green toad *Bufotes viridis* complex are the most numerous in the urban parks and the Plovdiv hills. The sex structure of the populations is strongly displaced for the benefit of the males, and the age structure of the population characterizes them as stable. For the period of study, a second breeding period at two sites was recorded, as was an extremely short metamorphosis period of up to 30 days.

The population of the tree frog (*Hyla arborea* complex) has a higher density in the center than the periphery of the city and the rural parts. The sex ratio is close to normal, and the age structure shows the largest proportion of adults and juveniles.

The populations of the Kotschy's gecko [*Mediodactylus kotschyi* (Steindachner, 1870)] in the center of the city have a higher density and abundance than the ones in the suburbs. The sex ratio is close to normal and the age structure of the populations shows a significant predominance of adults.

The Balkan wall lizard [*Podarcis tauricus* (Pallas, 1814)] has stable populations in the Plovdiv hills, but their density is lower than in natural populations. The sex structure shows a near-normal ratio, and the age indicates a predominance of adults and subadult individuals.

On the basis of the recorded low species diversity and the diversity of the communities, the parks in Plovdiv have a weak conservation role and, in fact, only the Plovdiv hills have more significance for the conservation of the herpetofauna in the urbanized territory.

The main threat to amphibians and reptiles 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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APPENDICES

Appendix 1 - UTM distribution of the amphibians and reptiles in the study area.

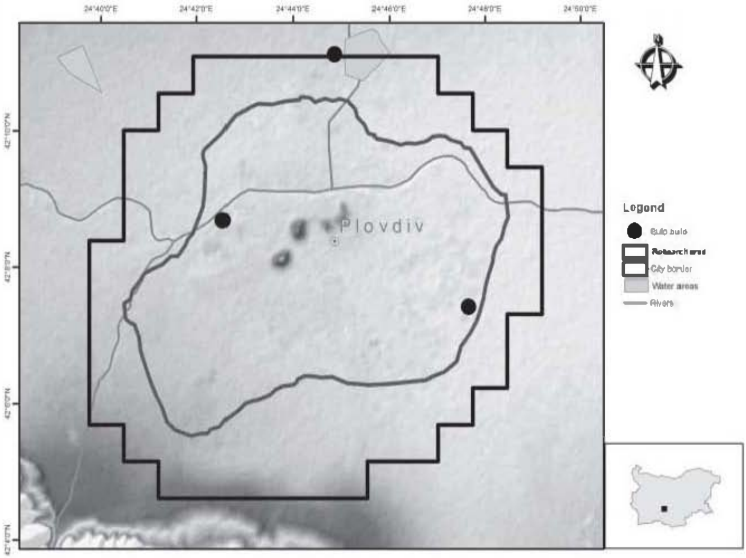
1-A. Distribution of the amphibians in the city of Plovdiv and its surroundings (1x1 km UTM grid).

Bombina bombina - LG0754; *Bombina variegata* - LG0661, LG0662; *Bufo bufo* - LG1732, LG1608, LG1676, LG1629; *Bufotes viridis* complex - LG1730, LG1624, LG1626, LG1627, LG1628, LG1636, LG1637, LG1638, LG1648, LG1674, LG1675; *Pelobates syriacus* - LG1629; *Pelophylax ridibundus* - LG0790, LG1700, LG1710, LG1720, LG1750, LG1760, LG1770, LG1741, LG1751, LG1761, LG1752, LG1762, LG0693, LG0697, LG0698, LG0683, LG0684, LG0685, LG0686, LG0687, LG0688, LG0689, LG0674, LG0675, LG0676, LG1602, LG1603, LG1608, LG1609, LG1612, LG1613, LG1617, LG1618, LG1619, LG1622, LG1623, LG1629, LG1632, LG1639, LG1642, LG1649, LG1659, LG1663, LG1664, LG1669, LG1674, LG1675, LG1676, LG1679, LG1686, LG1687, LG1689, LG1697, LG1698; *Rana dalmatina* - LG0674, LG0675, LG1685, LG1686; *Hyla arborea* complex - LG0697, LG0674, LG0675, LG1621, LG1627, LG1686, LG1697, LG1700, LG1733, LG1743, LG1751.

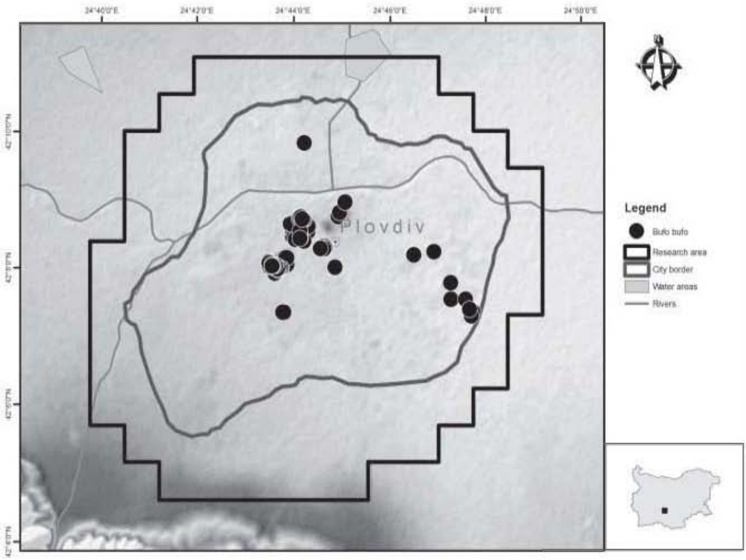
1-B. Distribution of the reptiles in the city of Plovdiv and its surroundings (1x1 km UTM grid).

Testudo graeca - LG1628, LG1687; *Testudo hermanni* - LG0697; *Emys orbicularis* - LG1710, LG1720, LG1762, LG1783, LG1607, LG1608, LG1619, LG1629, LG1649; *Trachemys scripta elegans* - LG1649, LG1648; *Mediodactylus kotschyi* - LG1616, LG1617, LG1626, LG1627, LG1628, LG1629, LG1636, LG1637, LG1638, LG1639, LG1649, LG1658, LG1659, LG1665, LG1676, LG1678; *Lacerta trilineata* - LG0674, LG0675, LG0687, LG1607, LG1608, LG1676, LG1686; *Lacerta viridis* - LG0692, LG0693, LG0697, LG0698, LG0683, LG0684, LG0687, LG0673, LG0674, LG0675, LG0676, LG1602, LG1603, LG1607, LG1612, LG1613, LG1622, LG1627, LG1629, LG1638, LG1639, LG1643, LG1649, LG1667, LG1675, LG1686, LG1697, LG1700, LG1741, LG1751, LG1760; *Podarcis tauricus* - LG0687, LG1616, LG1617, LG1625, LG1626, LG1627, LG1628, LG1667, LG1675, LG1678; *Dolichophis caspius* - LG0693, LG0694, LG0695, LG0696, LG1608, LG1612, LG1617, LG1627, LG1656, LG1657, LG1659; *Natrix natrix* - LG0689, LG0674, LG1629, LG1686, LG1752; *Natrix tessellata* - LG0675, LG0689, LG1602, LG1608, LG1611, LG1619, LG1629, LG1639, LG1752.

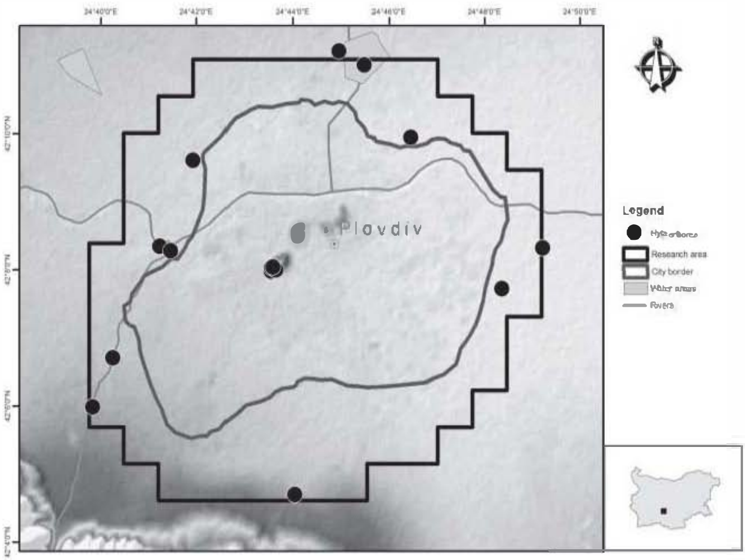
Appendix 2 - Distribution maps of the amphibians and reptiles in the study area.



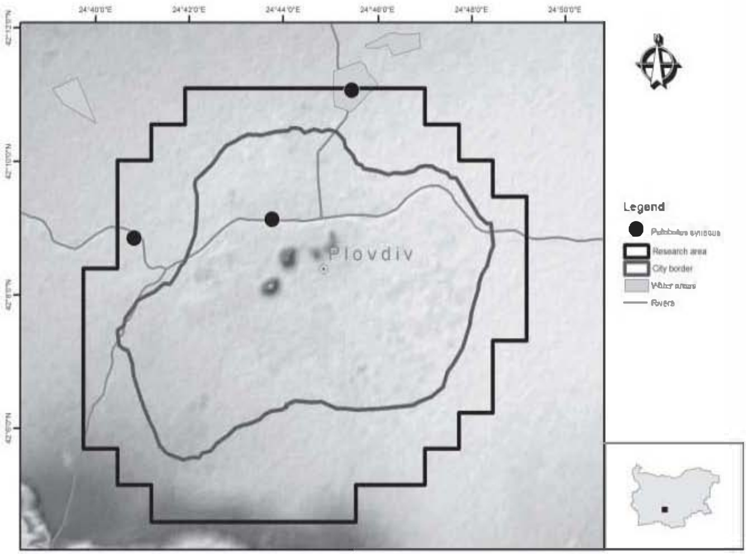
1. Common Toad (*Bufo bufo*) .



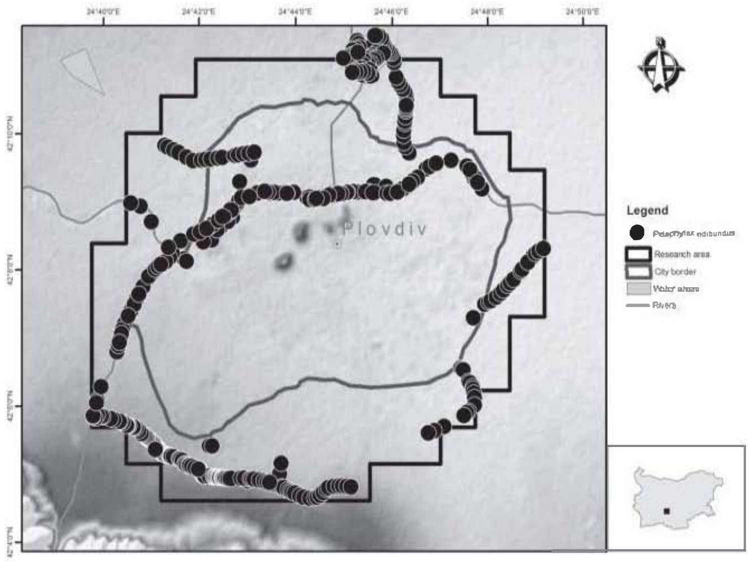
2. Green Toad (*Bufotes viridis* complex).



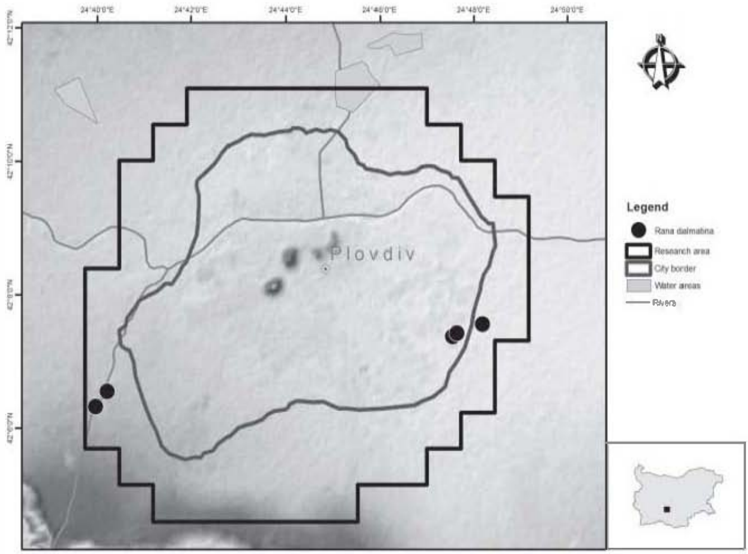
3. Tree Frog (*Hyla arborea* complex)



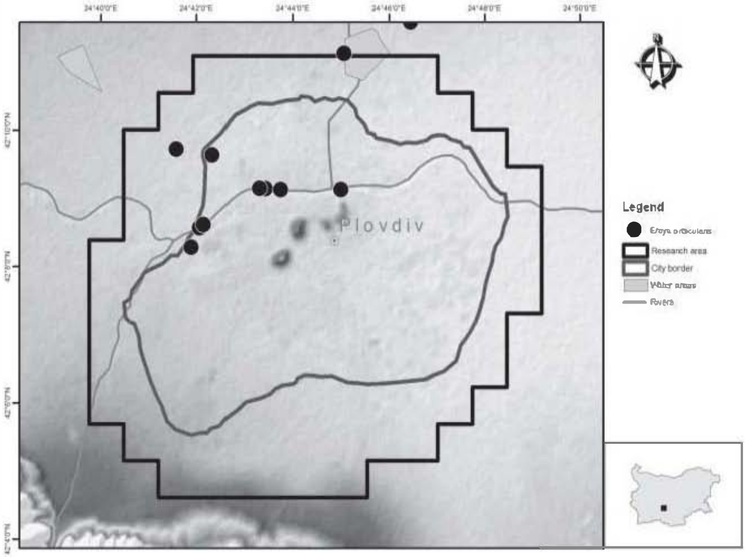
4. Syrian Spadefoot Toad (*Pelobates syriacus*).



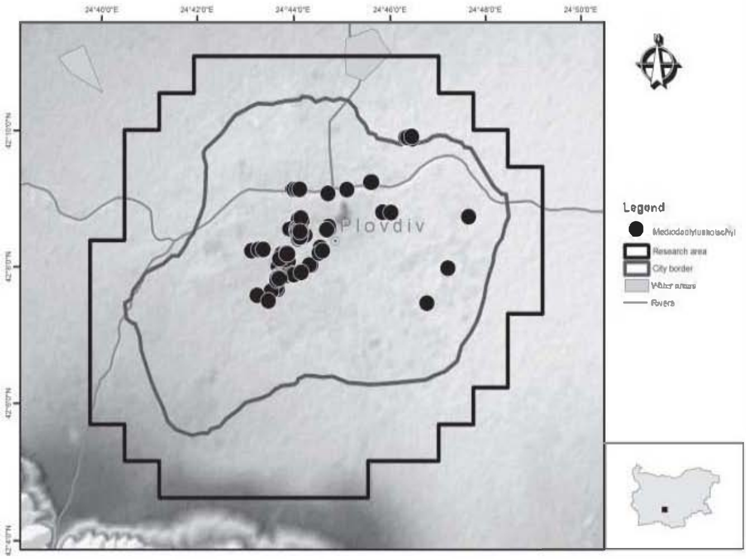
5. Marsh Frog (*Pelophylax ridibundus*).



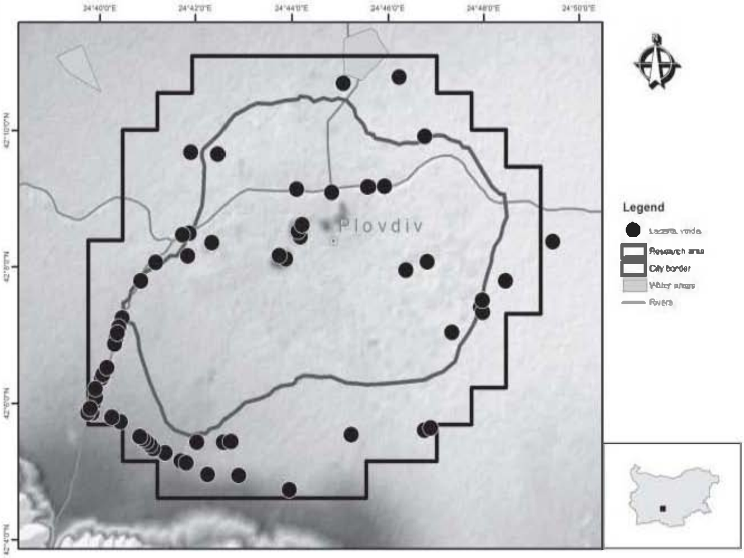
6. Agile Frog (*Rana dalmatina*).



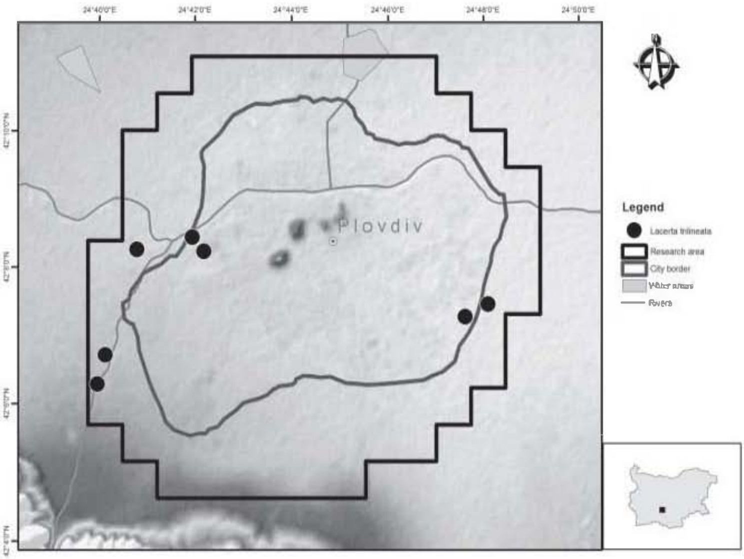
7. European Pond Turtle (*Emys orbicularis*).



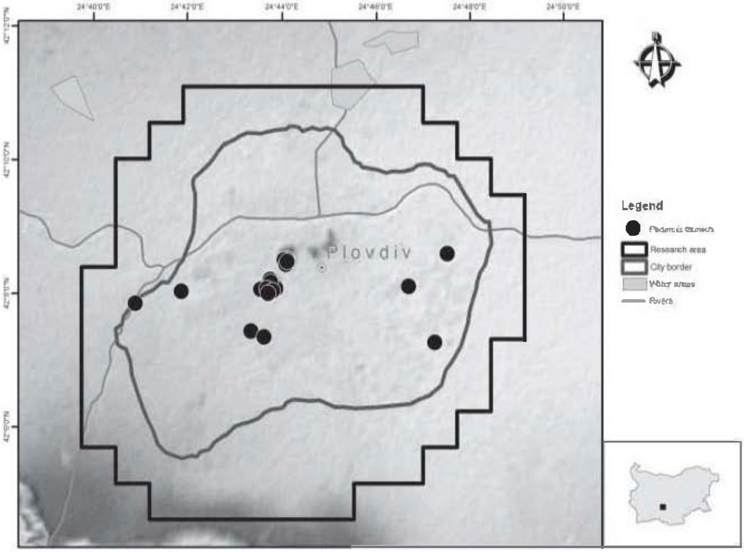
8. Kotschy's Gecko (*Mediodactylus kotschyi*).



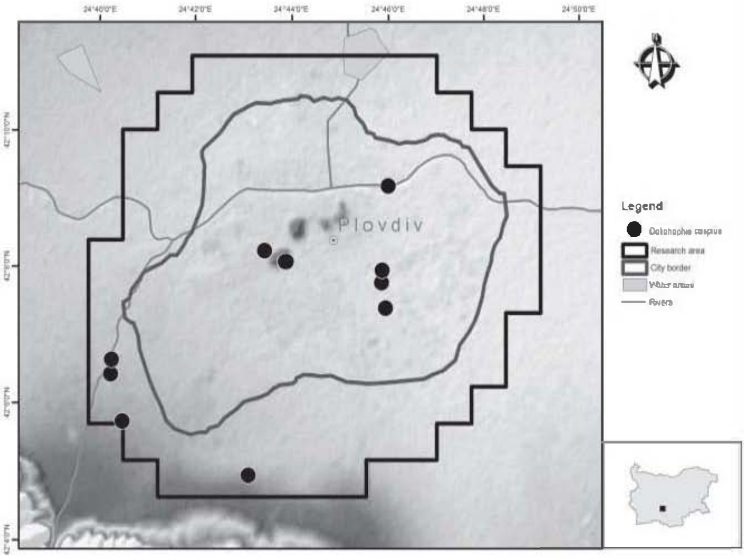
9. Green Lizard (*Lacerta viridis*).



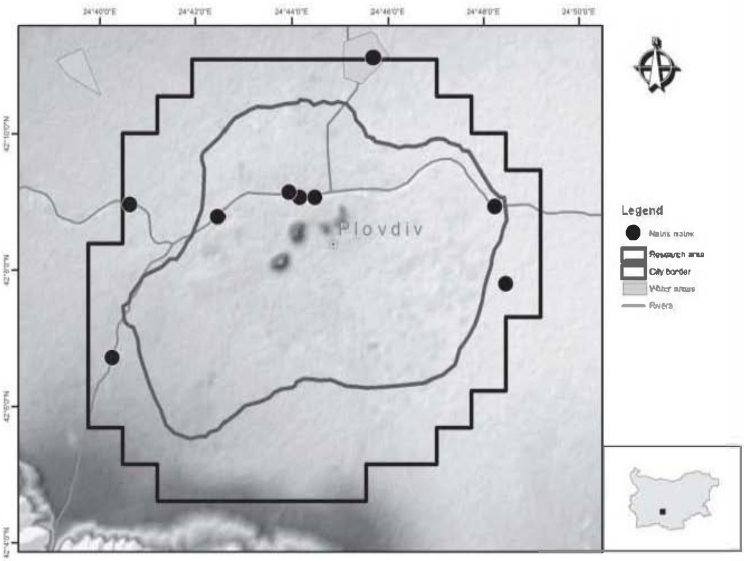
10. Balkan Green Lizard (*Lacerta trilineata*).



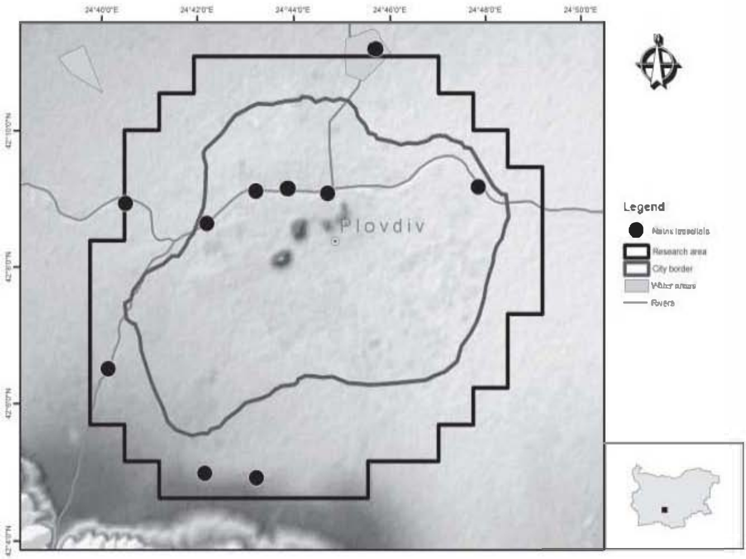
11. Balkan Wall Lizard (*Podarcis tauricus*).



12. Caspian Whip Snake (*Dolichophis caspius*).



13. Grass snake (*Natrix natrix*).



14. Dice snake (*Natrix tessellata*).