“OVIDIUS” UNIVERSITY OF CONSTANŢA

DOCTORAL SCHOOL OF APPLIED SCIENCES

DOCTORAL FIELD: BIOLOGY

DOCTORAL THESIS

SUMMARY

PhD Coordinator:

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Constanța, 2014

“OVIDIUS” UNIVERSITY OF CONSTANŢA

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BIODIVERSITY MANAGEMENT USING GIS TECHNIQUES

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Introduction

The theme of the present doctoral thesis is centred on biodiversity management using techniques typical in Geographic Information System (GIS), starting with the development of a geospatial database, thematic digital cartography and spatial analysis applied in biology, and ending with modelling the predictive distribution of fauna species. The development of GIS tools for applications in conservation biology or ecology produced new means of research that combine interdisciplinary knowledge. Particularly, ecological niche modelling or species distribution modelling used to investigate species range has generated an increasing interest lately.

Since faculty and mainly during the doctoral school, I have been employed in a series of national and transnational projects that were taking place also in natural protected areas, and there I joined the research team as a GIS specialist. Thus I have tested and studied thoroughly the use of GPS devices and GIS field computers in collecting biological data in the field in a more efficient way, as well as the use of GPS and GIS software for mapping and spatial analysis of the field data.

Starting from stating the absence of centralized information regarding the species distribution at a national level, I selected a series of species of amphibians and reptiles to which I applied specific GIS techniques to develop a faunal database, to map the distribution of species occurrences, to perform spatial analysis and the predictive modelling of their distributions.

The doctoral thesis, entitled “The biodiversity management using GIS techniques”, sums up a total of 176 pages, 114 figures, 23 tables, 211 bibliographic references and 2 annexes. It is structured in 5 chapters:

- Chapter 1 – Current state of knowledge;
- Chapter 2 – Goal and objectives of the thesis;
- Chapter 3 – Distribution of amphibian and reptile species in some natural protected areas;
- Chapter 4 – Development and practical application of a geospatial database with the distribution of amphibians and reptiles in Romania;
- Chapter 5 – Modelling the predictive distribution of some amphibian and reptile species.

Personal contributions

1. Goal and objectives of the thesis

The goal of the thesis was to emphasize the utility of GIS techniques in biodiversity management based on study cases that were applied at different scales on a series of reptile and amphibian species.

The objectives were the following:

- Mapping herpetofauna at local and regional scales using data from bibliographic sources, inventories and monitoring programs;
- Development and practical application of a geospatial database with the distribution of herpetofauna in Romania:
    - Summarization of existing distribution data from bibliographic sources, museum collections and unpublished field data in a geospatial database;
    - Practical applications of the database using GIS techniques:
        - Extraction of parameters that characterize the ecological niche of species, and set the altitudinal and bioclimatic range;
        - Mapping species distribution and species richness;
        - Spatial analysis to evaluate the efficiency of the current network of national protected areas in biodiversity conservation;;
- Analyzing and modelling the predictive distribution of several species of reptiles and amphibians in Romania:
    - Summarising the geographic distribution data of *Pelobates fuscus* and *P. syriacus* in Europe;
    - Identifying adequate environmental variables that can contribute in modelling the ecological niche;
    - Running the predictive models of predictive distributions of the two amphibian species that overlap their ranges in Europe.

The study area was diverse and was divided at different spatial scales in order to emphasize particular GIS techniques for each study. Herpetofauna mapping was applied at two different spatial scales in five areas in Romania and part of Bulgaria. The development and applications of the faunal geospatial database was conducted at a national scale in Romania. The analysis and modelling the predictive distribution of *Testudo graeca* was run at the species range in Dobrogea, and of the other two species, *Pelobates fuscus* and *P. Syriacus,* was conducted at continental scale in order to exemplify the complexity of the studies.

2. The distribution of amphibians and reptiles in several natural protected areas

2.1. Materials and methods

2.1.1. Study areas

Mapping herpetofauna, more precisely mapping the distribution of amphibians and reptiles occurrences, was performed at two different scales in five areas in Romania and part of Bulgaria. At local scale, I selected three natural protected areas, the Munții Măcinului National Park (1), the Munții Maramureșului Natural Park (2) and the Retezat National Park (3), and at a regional scale, the Maramureș county (4) and the coastal area between the Midia Cape and Kaliakra Cape (5) that spreads over the two administrative territories of Romania and Bulgaria. (**Fig. 2.1**).

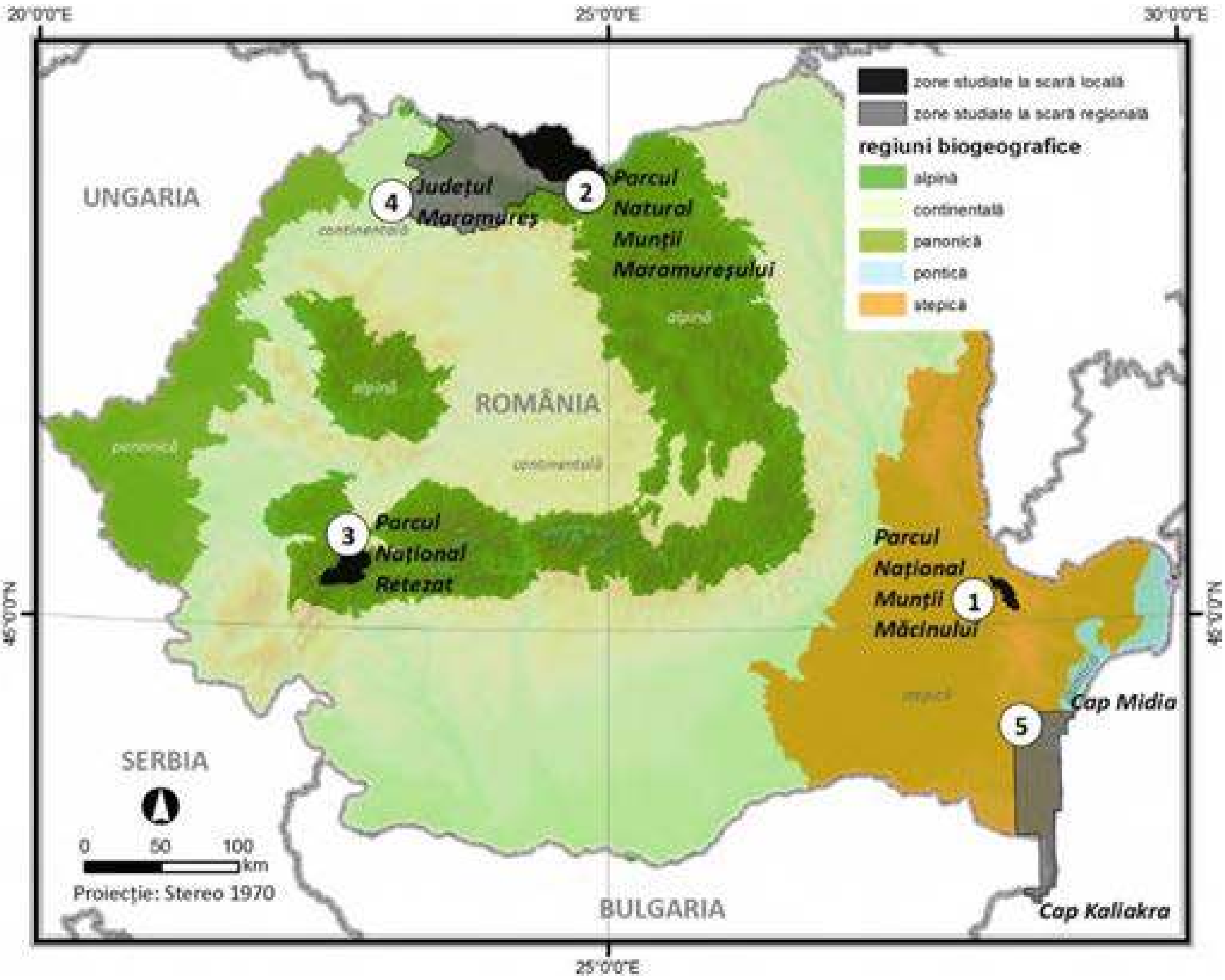


Fig. 2.1 – The five study areas.

2.1.2. Data collection

The taxonomy used in this doctoral thesis refers to the national legislation and did not take into account the recent taxonomic changes for amphibians published by Frost *et al.* (2006).

Mapping the herpetofauna of the National Park of Macin Mountains was based on a series of datasets of occurrences collected by a research team at the Faculty of Natural Sciences, Ovidius University of Constanta, where I activated as a team member in the period 2009-2011. The distribution data was partially published (Cogălniceanu *et al.*, 2007b; Cogălniceanu *et al.*, 2010; Cogălniceanu *et al.*, 2013b). Mapping the herpetofauna of the Natural Park of Maramuresului Mountains (Cogălniceanu *et al.*, 2007a; Cogălniceanu *et al.*, 2008a) included a set of 112 stations, 169 amphibian occurrences and 82 reptile occurrences whose geographical coordinates were collected with a GPS device during an inventory of aquatic habitats and amphibians that was coordinated by professor Cogalniceanu in the period 2004-2006 (Plăiașu *et al.*, 2010; Cogălniceanu *et al.*, 2012). Mapping the herpetofauna of the county of Maramures (Cogălniceanu *et al.*, 2008a) was based on the geographic coordinates collected during the inventory of herpetofauna in the National Park of Maramuresului Mountains (Cogălniceanu *et al.*, 2007a) as well as the data extracted from museum collections and bibliographic sources, all being georeferenced to the UTM 10x10 km grid. Mapping the herpetofauna from the coastal area between Midia Cape and Kaliakra Cape (Cogălniceanu *et al.*, 2008b; Făgăraș *et al.*, 2008) relied on the geographical coordinates collected in the field and occurrence data extracted from bibliographic sources (Lepși, 1926; Lepși, 1927; Lepși, 1929; Beschkov, 1984a; Beschkov, 1984b; Beschkov, 1985; Cogălniceanu *et al.*, 2008b; Székely *et al.*, 2009), all being georeferenced to the UTM 10x10 km grid.

2.1.3. Digital cartography

The maps were created in ArcGIS Desktop (ESRI, 2012b).

2.1.4. Spatial analysis

The spatial analysis was performed in ArcGIS Desktop (ESRI, 2012b).

In the mapping and spatial analysis process of herpetofauna, I used the UTM 5x5 km and UTM 10x10 km biogeographical grids, as well as custom generated grids with cell sizes of 500x500 m. The UTM 5x5 km grid was used to map the herpetofauna between Midia Cape – Kaliakra Cape, and the UTM 10x10 km grid was used to map the herpetofauna in the Maramures County. In the process of mapping the herpetofauna of the National Park of Macin Mountains, a custom grid of 500x500 m was generated using the tool „Create Grid Tool" within the extension „Movement Ecology Tools for ArcGIS – ArcMET" (Wall, 2013).

In order to delineate the study area of Retezat-Judele from the National Park of Retezat, a minimum convex polygon (MCP) was created with the Hawth's Tools (Beyer, 2004). The degree of isolation in the studied water bodies was estimated by calculating the average distance in metres among the water bodies and their nearest three other bodies. The tool used for calculation was „Distance between points tool (within layer)" from within the Hawth's Analysis Tools for ArcGIS (Beyer, 2004).

The number of records and species richness (number of species) in a UTM cell were computed with the „Species Richness" tools found in the Diversity Calculator add-in for ArcGIS by Miller (2013). The morphometric parameters such as slope and aspect were generated from the SRTM 90m Digital Elevation Data (Jarvis *et al.*, 2008) using Slope and Aspect tools from the extension Spatial Analyst Tools (ESRI, 2009a) in ArcGIS Desktop (ESRI, 2009b), which produced individual raster grid with the associated parameter values. Following the formula and reference values to obtain the degree of insolation from the work of Stanciu (1981), the two slope and aspect grids were reclassified using the Raster Calculator tool from the Spatial Analyst tools in ArcGIS (ESRI, 2009a), and then resulted a new grid with the degree of insolation from the composition of the other two grids.

2.2. Results and discussions

2.2.1. Mapping the herpetofauna in the National Park of the Macin Mountains

A number of 23 species, 11 amphibians and 12 reptiles, were identified in the national park and its vicinity, for which a number of 3383 occurrences for reptiles (**Fig. 2.2**) and 690 occurrences for amphibians (**Fig. 2.3)** were recorded with geographic coordinates. The species varied in abundance, density, habitat requirements and detectability. The species richness of the herpetofauna was high (with over 5 species) in the western and south-western sides such as Culmea Pricopanului near peaks such as Sulucu Mare, Sulucu Mic, Cheia and Slatina, as well as the rocky sides from the main ridge of the Macin Mountains in the surroundings of the peaks Stănilă, Cartalu, Ghiunaltu, Căpușa, Călcata, Pietrosu II, Cozluc, Boldea, Archizel, the marshy platter near Nifon, Valea Fagilor and Cetățuia, reaching a maximum of 8 species in Valea Fagilor, Cetățuia, and the peaks Căpușa, Stănilă and Șerparu (**Fig. 2.4**).

The number of herpetofauna records was high especially in the well-inventoried areas such as Cetățuia, the rocky platter under the peaks Țuțuiatu, Sulucu Mare and Ghiunaltu, the large quarry from Greci under the peaks Cartalu, Valea Suluc, and Valea Ditcova, with a maximum density of 341 records mainly for the amphibian species found in the water channels that remained beyond the draining of the Lake Slatina. A number of 750 occurrences of *Testudo graeca* (**Fig. 2.5**) were recorded among which one male individual with an estimated weight of 4.8 kg and a carapace length of 37.5 cm (**Fig. 2.6**) that proved to be the largest individual reported in the wild (Cogălniceanu *et al.*, 2010).

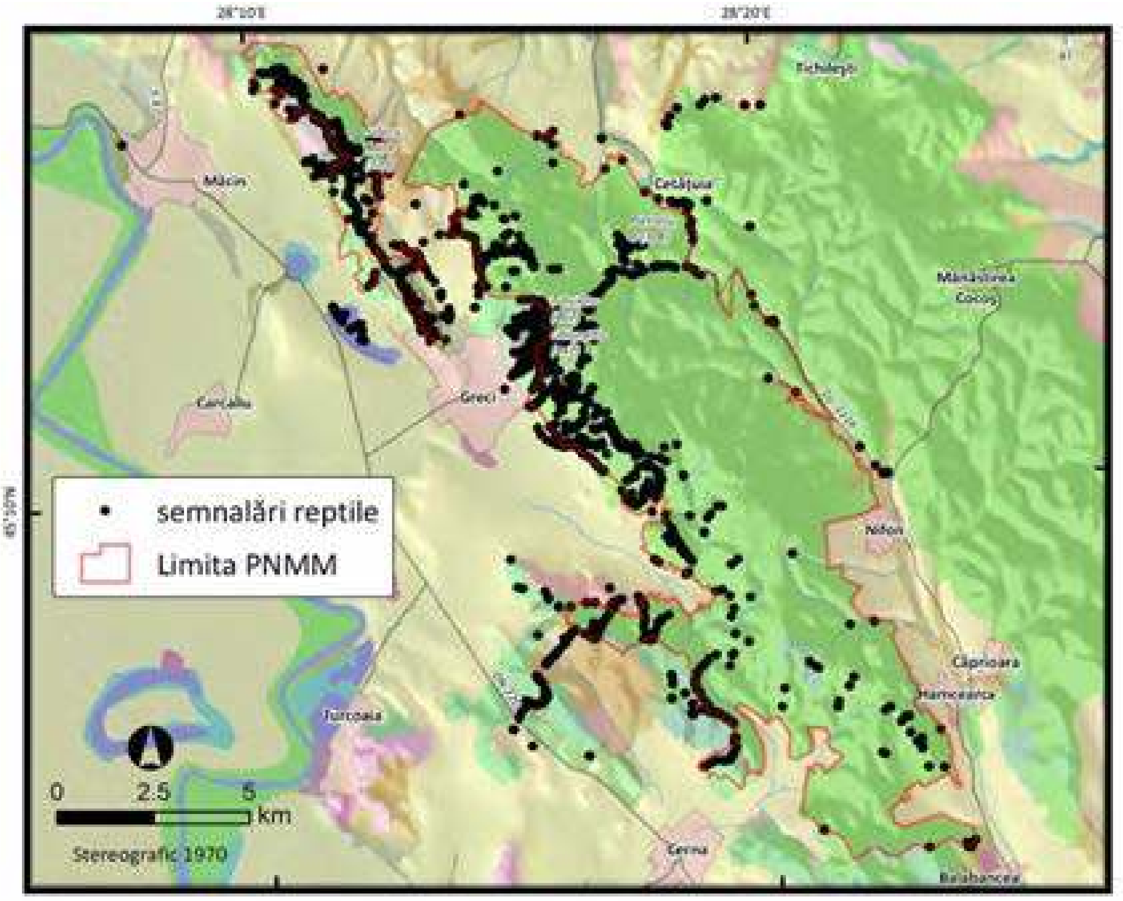


Fig. 2.2 – The distribution of reptile occurrences in the National Park of Macin Mountains.

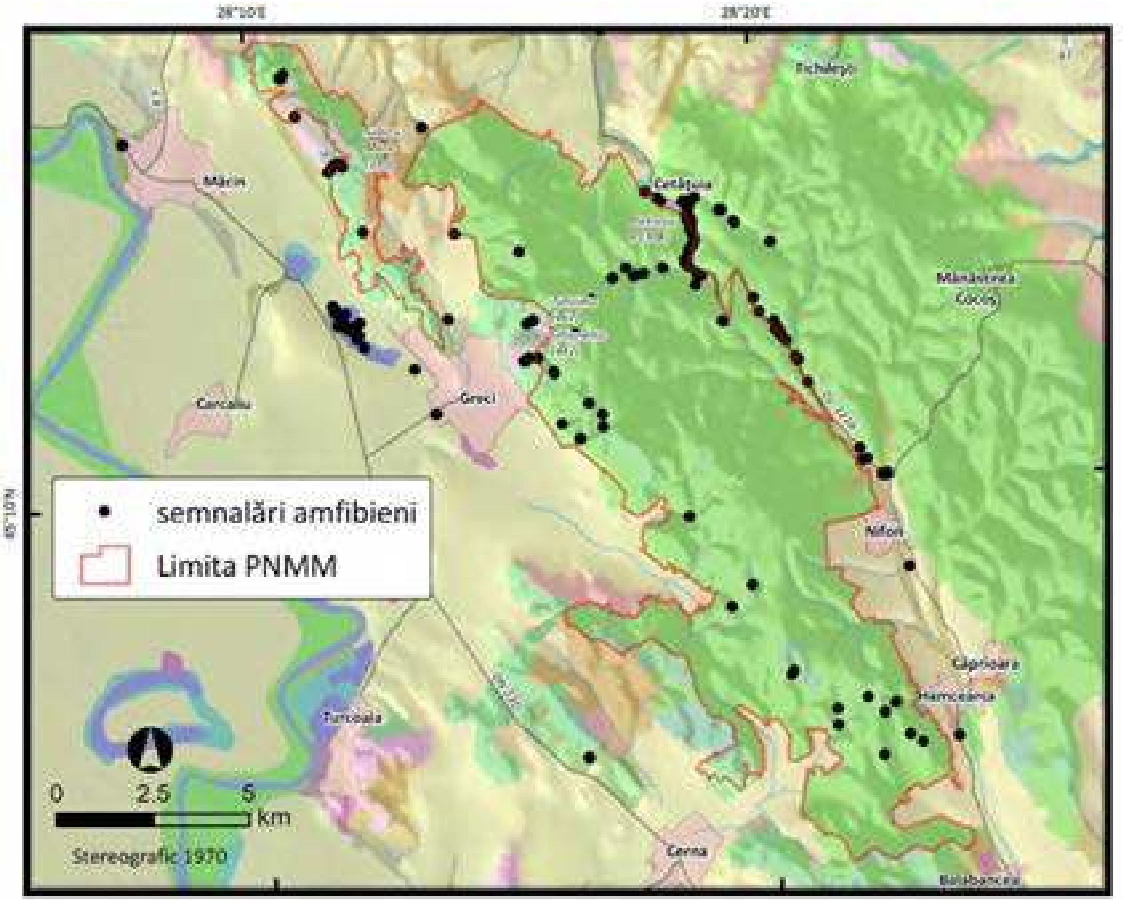


Fig. 2.3 – The distribution of amphibian occurrences in the National Park of Macin Mountains.

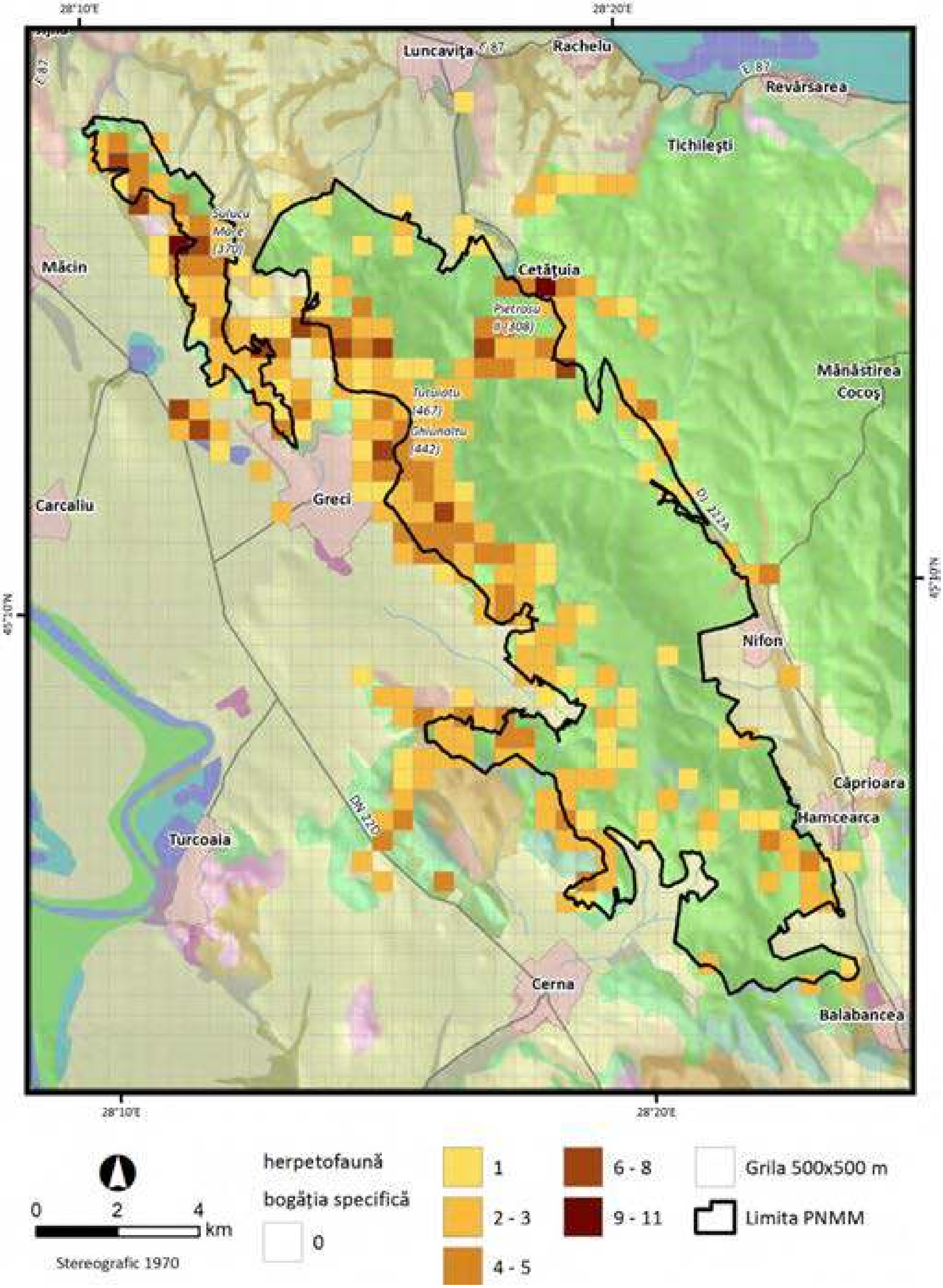


Fig. 2.4 – The species richness of herpetofauna in the National Park of Macin Mountains.

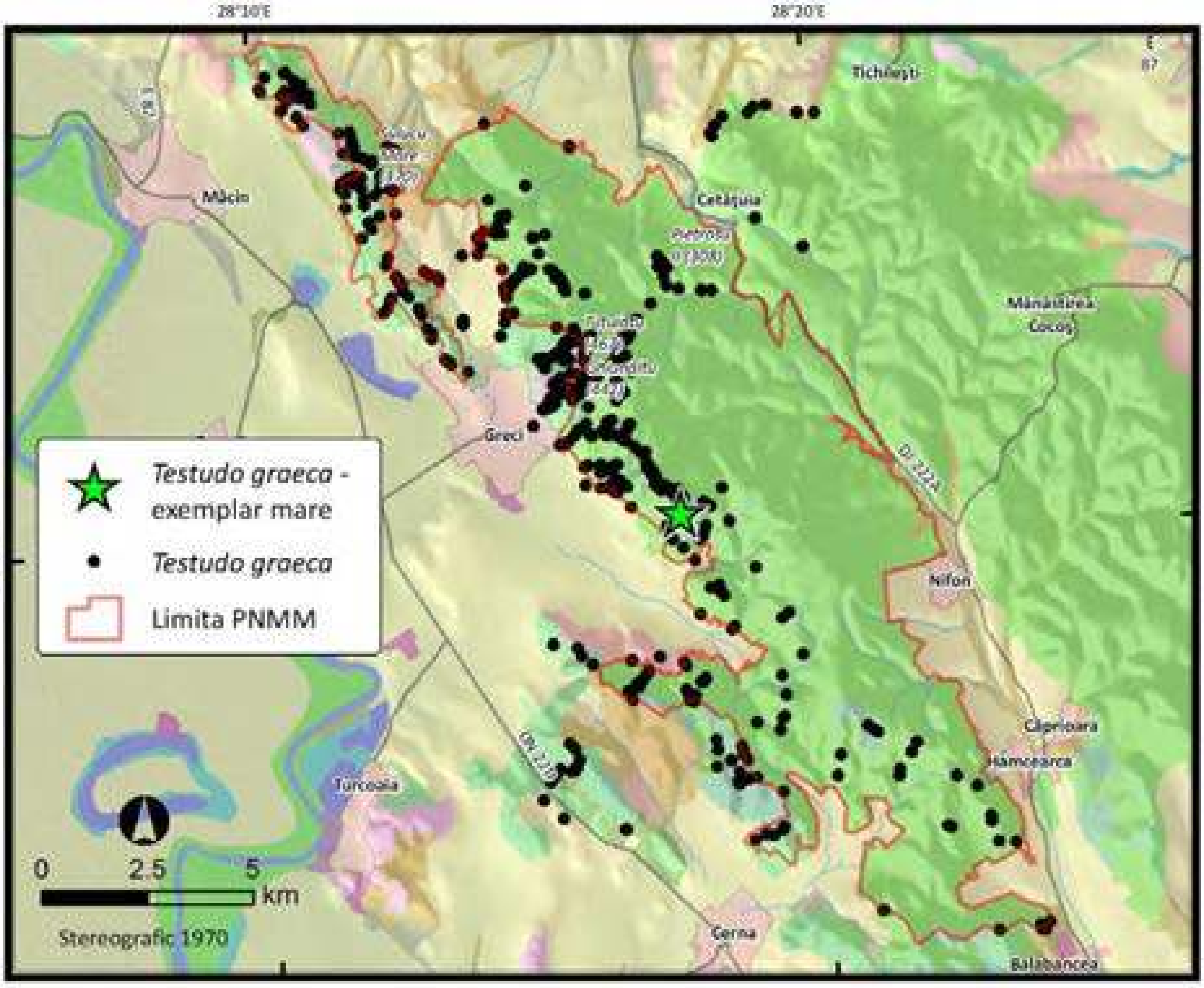


Fig. 2.5 – The location of the male individual of *Testudo graeca* in Macin Mountains.

Fig. 2.6 – The male individual of *Testudo graeca* found on May 15, 2009 (original).

2.2.2. Mapping the amphibians in the National Park of Retezat

The distribution of water bodies inventoried in the area of Zănoaga-Judele Ascuns-Răsucit from the National Park of Retezat

The inventoried aquatic habitats were located at altitudes that varied between 1972 and 2202 m (mean and standard deviation value: 2083± 64 m a.s.l.) (**Fig. 2.7**): 65% (n=26) were permanent and 35% (n=14) were temporary.

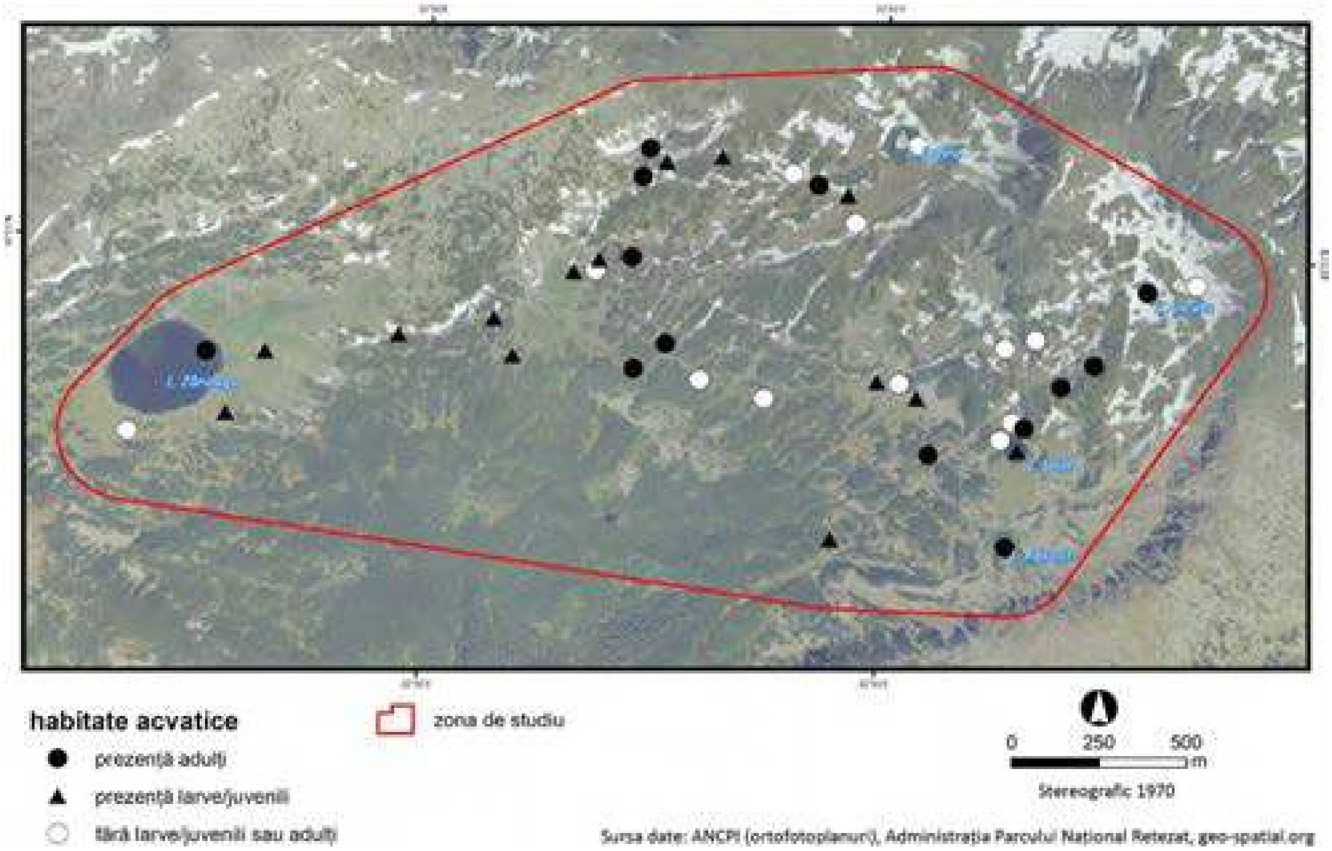


Fig. 2.7 – The distribution of aquatic habitats inventoried in the National Park of Retezat (black circles = presence of adults, black triangle = presence of larvae or juveniles, empty circles = no larvae/juveniles or adults).

The mean distance among every three nearest neighbour aquatic habitats was 198.8 ± 97 m. The small distance of about 200 m among the water bodies situated in the moving distance recorded for *Rana temporaria, Triturus alpestris* și *Bufo bufo* (Kovar *et al.*, 2009). The amphibians were present in 67.5% of the aquatic habitats. *Rana temporaria* was identified in 65% of the aquatic habitats. *Triturus alpestris* was found in 17.5% and *Bufo bufo* in 7.5% of them. *Rana temporaria* presented the broadest altitudinal range and reached at a maximum altitude of 2195 m, while *Bufo bufo* at 2021 m and *Triturus alpestris* at 2095 m.

The amphibians reproduced in 40% of the aquatic habitats where only two species were present in half of the habitats (i.e. *Rana temporaria* and one of every other species). *Rana temporaria* reproduced in only 14 of the aquatic habitats.

2.2.3. Mapping the herpetofauna in the National Park of the Maramureș Mountains

Amphibians and reptiles were identified in 116 sites. A total of 251 occurrences were recorded. The herpetofauna inventory included 13 species of which 7 reptiles (*Lacerta vivipara, Lacerta agilis, Anguis fragilis, Natrix natrix, Elaphe longissima, Coronella austriaca* și *Vipera berus*) and 6 amphibians (*Salamandra salamandra, Triturus montandoni, Triturus alpestris, Bombina variegata, Bufo bufo* și *Rana temporaria*) (**Fig. 2.8**). The most abundant species were *Bombina variegata, Triturus montandoni, Rana temporaria* și *Lacerta vivipara*. Other two species (*Bufo viridis* și *Rana dalmatina*) were reported in the park but their presence was not confirmed during the field trips. Except for a few alpine lakes and ponds with high species richness in amphibians, all other inventoried water bodies were represented by a number of 1 to 3 species of amphibians.

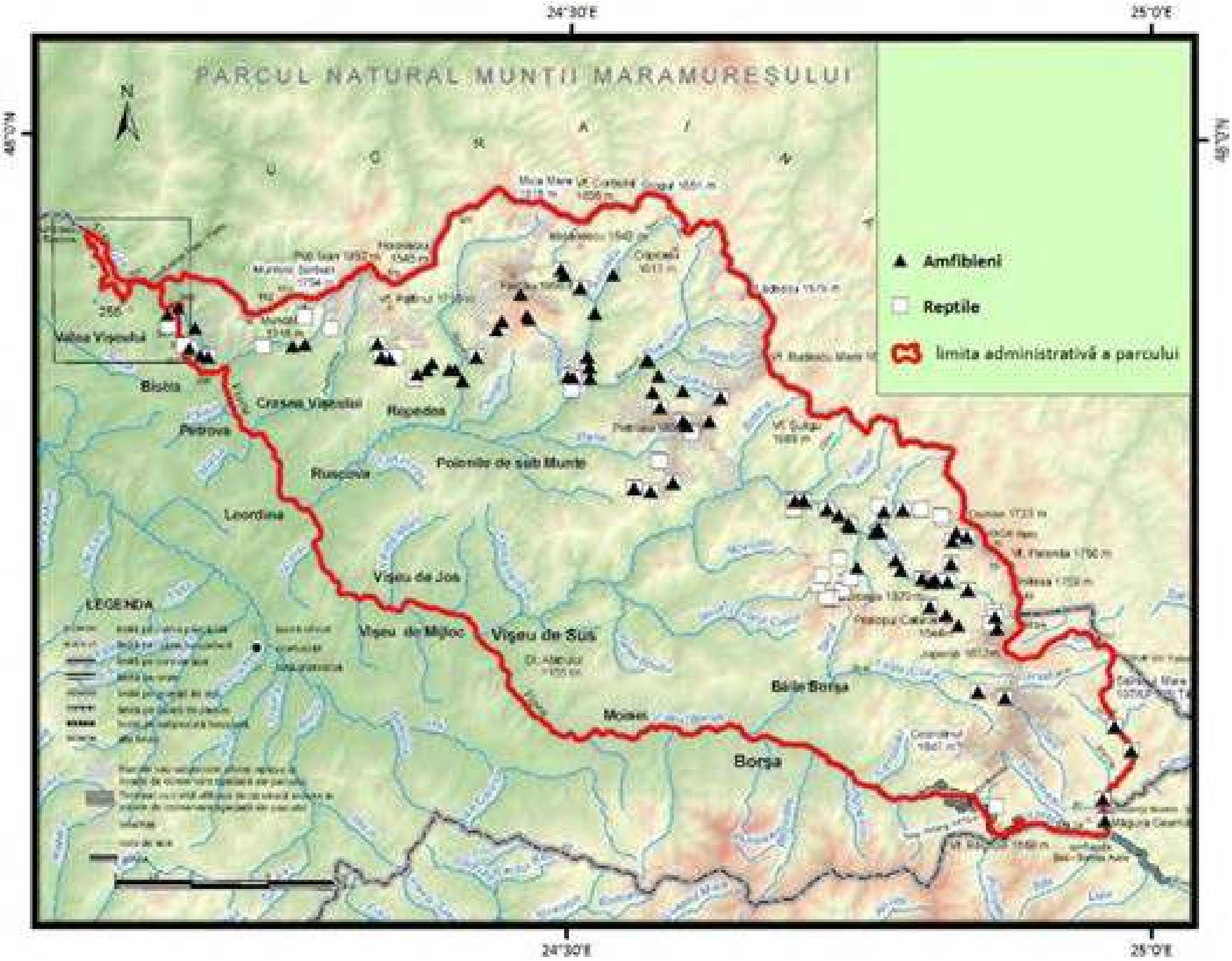


Fig. 2.8 – The spatial distribution of occurrences of amphibian and reptile species (black triangle – amphibians, white squares – reptiles, red polygon – the administrative limit of the park).

2.2.4. Mapping the herpetofauna of the Maramureș County

The distribution records of amphibian and reptile species were available only for 50.96% of the area of the Maramureș County and 42.10% of the area of the National Park of the Maramureșului Mountains. A total of 14 amphibian and 11 reptile species were identified in the Maramureș County. The distribution records were aggregated to a total number of 102 UTM 10x10 km grid cells.

The species with the widest distribution were *Bombina variegata* and *Rana temporaria* among amphibians, and *Lacerta agilis* and *Natrix natrix* among reptiles. Out of a total of 1133 records from the database (841 from bibliographic sources, 4 from museum collections and 288 from field trips), 90.64% of them were recorded after year 1990 and only 9.36% were records before 1990. There were only 47 records from the National Park of the Maramureșului Mountains before the inventory conducted in 2007, and only 24 occurrences were recorded after 1990.

The inventory conducted in the National Park of Maramureșului Mountains in 2007 set off 8 new cells records on the UTM 10x10 km grid (**Fig. 2.9**).

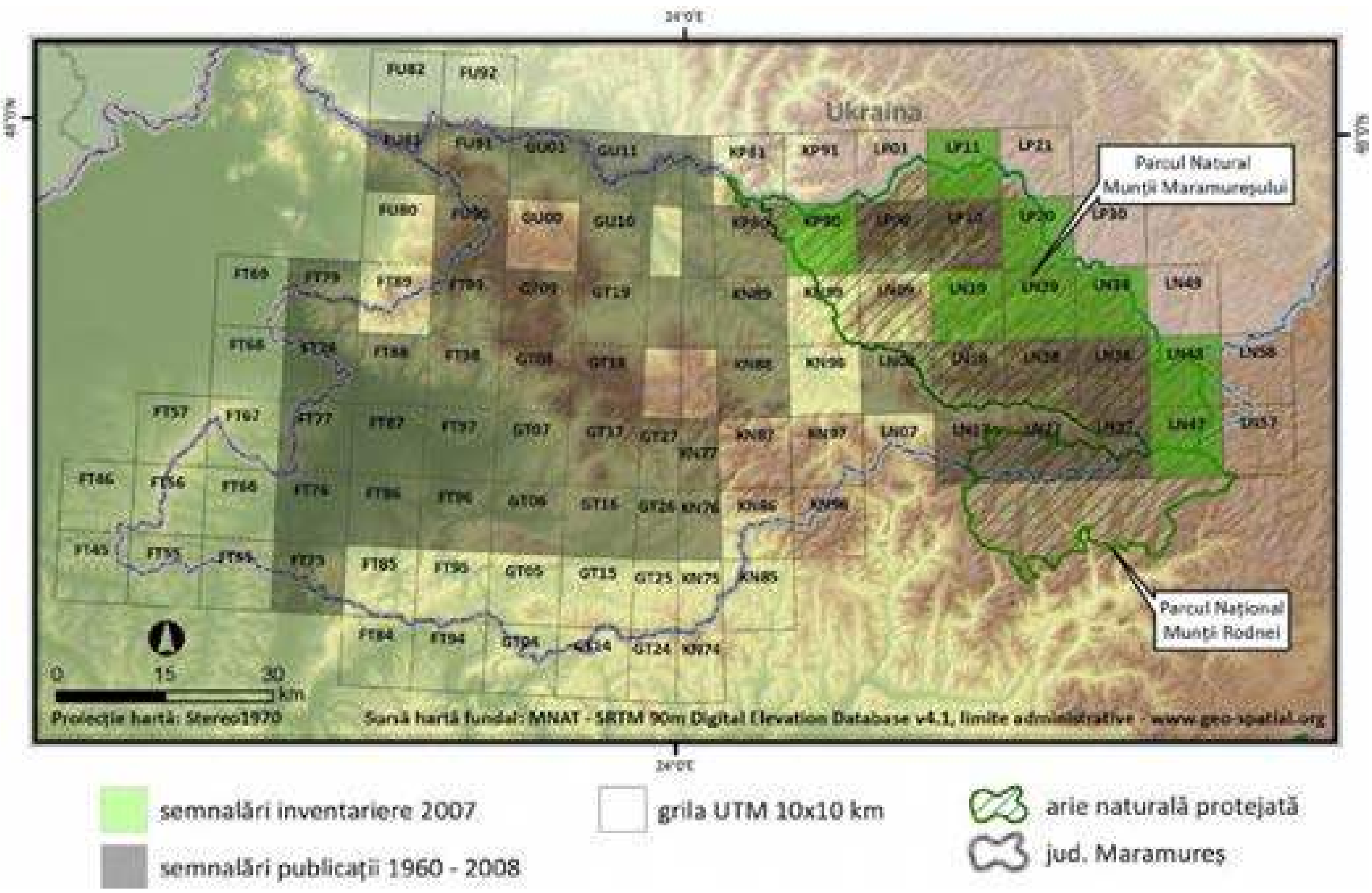


Fig. 2.9 – The spatial distribution of occurrences for amphibians and reptile species in the Maramureș County (green squares – records in 2007, grey squares – records from published sources in 1960-2008), empty squares – UTM 10x10 grid).

The distribution maps for the most common species such as *Rana temporaria, Triturus alpestris, T. montandoni, Lacerta vivipara, Anguis fragilis* and *Bombina variegata* include both published data and museum collections georeferenced to the UTM 10x10 km grid as well as GPS records represented as point data at high resolution scale.

The analysis of new distribution data (records after 1990) indicated that the three reptile species (*Emys orbicularis, Natrix tessellata* și *Podarcis muralis*) were not previously reported in the Maramureş County. A fair increase in the number of records belonged to *Triturus montandoni, Rana dalmatina, Rana esculenta* and *Lacerta agilis*.

2.2.5. Mapping the herpetofauna in the coastal area between Midia Cape and Kaliakra Cape

The herpetofauna of Romania and Bulgaria varies both in terms of species composition and percentage of protected species.The conservation status of amphibians and reptiles differs between the two countries. While in Romania all herpetofauna species, except for *Natrix natrix*, are included in the Law 49/2011, only 2/3 is included in the annexes of the Law 77/2002 in Bulgaria.

The species richness of reptiles and amphibians in the coastal area between Midia Cape and Kaliakra Cape (**Fig. 2.10**) showed that the Romanian part registered more UTM 5x5 km grid cells with a species richness higher than 7 species of reptiles and amphibians particularly due to a greater research effort.

The spatial distribution of amphibian and reptile species showed coverage of over 50% of all 107 UTM grid cells of the study area, and a number of over 20 records in the coastal areas of Năvodari, Constanța, Mangalia, Cap Kaliakra, Rusalka or wooded areas such as the Hagieni Forest.

The spatial and temporal distribution of herpetofauna records displayed an effort in inventorying and publishing distribution data particularly after 1990, and only six UTM grid cells contained records before 1990. The spatial and temporal distribution of amphibians in relation to reptiles showed the inventory effort for reptiles closer to the coastal area while the amphibians were researched and identified inland.

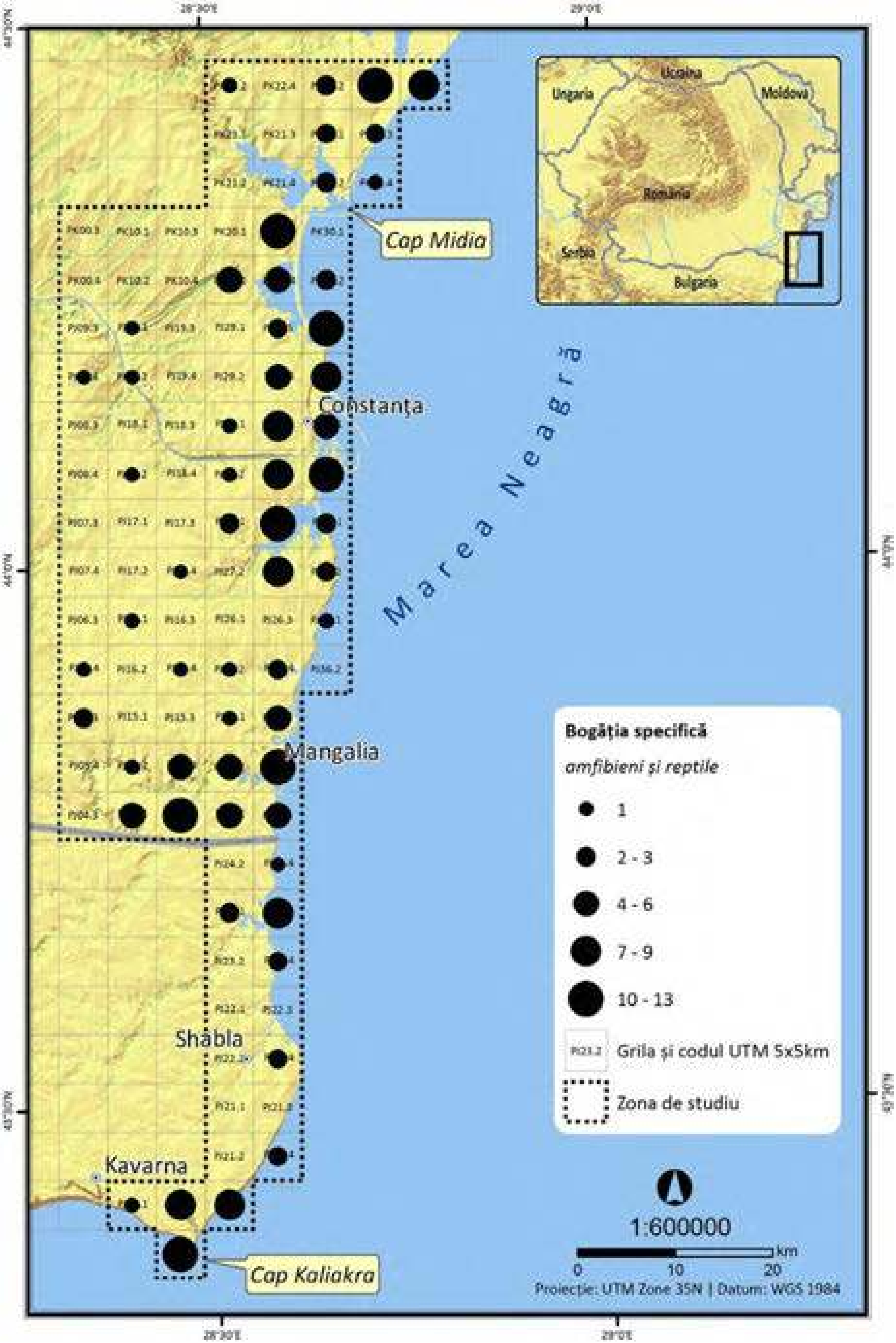


Fig. 2.10 – The spatial distribution of amphibian and reptile species richness in the studied coastal area.

2.3. Conclusions

The thematic digital cartography of the species range distribution is an efficient and useful tool for biologists. Digital mapping using desktop GIS applications evolves towards Web GIS mapping facilitating control over the distribution data and continuous update of distribution maps for any species, the creation of maps in shorter times compared to classical cartography, as well as the possibility of analysing dynamics in time and space of distribution records and species richness. The acquired results exemplified only a few aspects from a wide area of potential applications.

3. The development and practical applications of a geospatial database of amphibians and reptiles from Romania

3.1. Materials and methods

3.1.1. Study area

The territory of Romania is covered by 9977 UTM 5x5 km grid cells **(Fig. 3.1)** wherein the distribution records of native species of reptiles and amphibians from Romania were georeferenced.

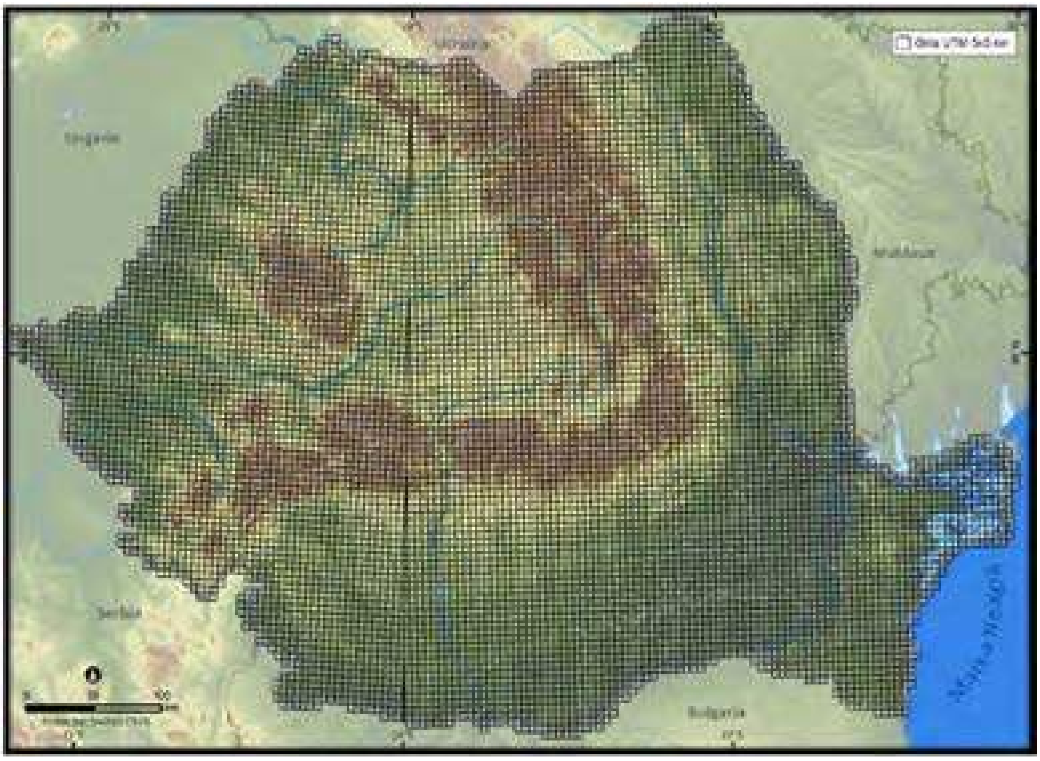


Fig. 3.1 – The UTM 5x5 km grid covering Romania.

Out of 42 species of amphibians and reptiles, 41 (97,6%) are protected by the European Union's Habitats Directive, undertaken by the Romanian Law 49/2011. Thus, 19 species of amphibians are present in Romania, among which 9 reach the limit of their range on the territory of Romania. The diversity of reptiles is surprisingly high for a country with a temperate to continental climate. Among the 23 species of reptiles, 12 reach the limit of their range (*Testudo hermanni, T. graeca, Ablepharus kitaibellii, Lacerta trilineata, Podarcis taurica, P. muralis, Eremias arguta, Lacerta praticola, Eryx jaculus, Coluber caspius, Elaphe quatuorlineata, Vipera ammodytes*) while other two species are closer to the range limit (*Elaphe longissima, Vipera ursinii*) (Gasc *et al.*, 1997).

There are five biogeographical regions in Romania (i.e. alpine, continental, panonic, stepic and pontic) out of the eleven acknowledged by the European Union (Cogălniceanu & Cogălniceanu, 2010; Iojă *et al.*, 2010; Evans, 2012).

3.1.2. Data collection

The purpose of developing the geospatial database with the herpetofauna of Romania was to extract all existing records for a spatio-temporal analysis at regional and national level. The personal contributions to the development of the geospatial database consisted of going through step by step management of data from the initial data gathering in Microsoft Excel to the final data import in a GIS environment and the spatio-temporal analysis of herpetofauna distribution data.

For that purpose I used distribution data of amphibian and reptile species present in Romania, the data being extracted from four major sources: scientific publications, museum collections, personal communications for specialists and own unpublished data derived from field research. The publications used to extract the distribution data may be consulted in the annexes of the published articles (Cogălniceanu *et al.*, 2013a; Cogălniceanu *et al.*, 2013b).

The taxonomic nomenclature used in my doctoral thesis stands on the references in our current legislation and does not take into account the recent taxonomic amendments in amphibian nomenclature by Frost *et al.* (2006) or reptiles (Speybroeck *et al.*, 2010).

3.1.3. The development of the geospatial database of amphibians and reptiles of Romania

The data pulled from all four sources comprised the species or taxon name, spatial references (locality or toponym name, county, UTM code and geopgrahical coordinates), date of observation or collection, author citation and the year of publication where applicable.

In order to spatialize the data, it was necessary to import the Excel tabular data into an Access database, then georeference them in the ArcMap application found within ArcGIS Desktop suite, and store the data into an ESRI file geodatabase **(Fig. 3.2)**.

The import of the Access database in ArcGIS was done by establishing an OLE DB connection in ArcGIS (ESRI, 2012a) and add the Access database tables in the ArcMap map project.

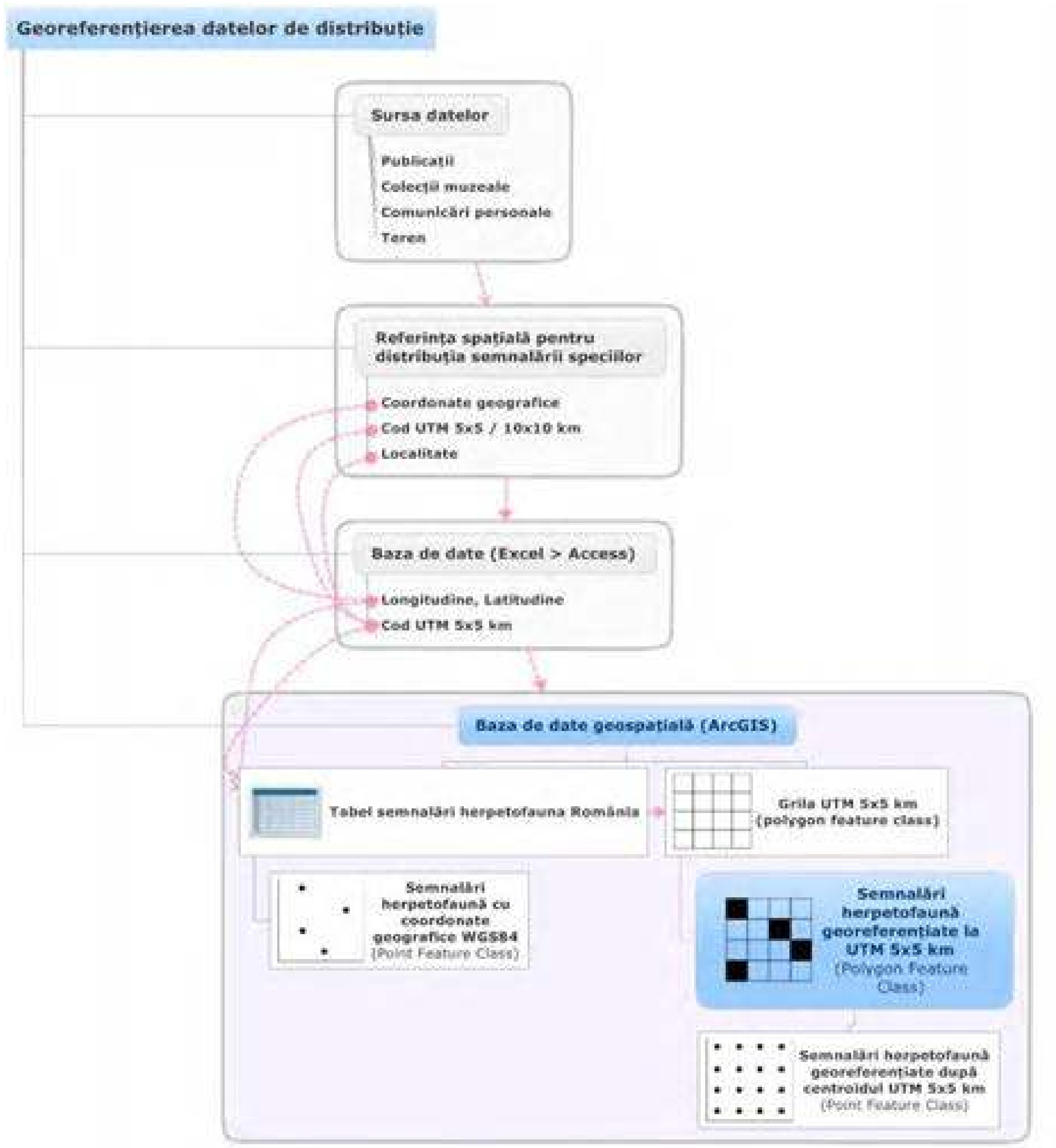


Fig. 3.2 – The process flow diagram of georeferencing the distribution data.

In the first phase, the data georeferencing was conducted through the aggregation of all occurrences to the UTM 5x5 km grid and store them in a polygon feature class projected in the Stereo 1970 national projection. The records that contained the geographical coordinates in the longitude and latitude fields were georeferenced to a point feature class in a WGS84 coordinate system, and then projected to Stereo 1970. For cartographical reasons, I created a third point feature class that represented the records georeferenced to the centroid of the UTM 5x5 km grid cells.

3.1.4. **The digital cartography and the spatial analysis of data into GIS**

The spatial distribution of records were mapped in ArcMap of the ArcGIS Desktop 10.1 suite (ESRI, 2012b). The GIS basemap layers used were the SRTM DEM (Jarvis *et al.*, 2008), the hydrography network with the large European rivers and lakes (European Environment Agency, 2009), the Romanian boundary, the county administrative boundaries (geo-spatial.org, 2007), the boundaries of the Nature 2000 ROSCI protected areas and the biogeographical regions (Ministerul Mediului și Schimbărilor Climatice, 2013), the neighbour country boundaries (ESRI, 2010). All GIS layers and maps were drawn in the national projection Stereo 1970.

For mapping the distribution of records, I used the point feature class georeferenced to centroids of the UTM 5x5 km grid from the geospatial database, then filtered by the name of abundant species at national level such as *Bombina variegata, B. bombina*, abundant species at regional level such as *Triturus montandoni* and rare species such as *Testudo graeca, Coluber caspius, Elaphe longissima, Pelobates fuscus* and *P. syriacus.* The distribution of records for each species was symbolized differently according to two unique values in the field **Vechime (Age)**.

The distribution of records for each of the two classes of amphibians and reptiles was represented by filtering the name of amphibians or reptiles. The distribution of records that were spatially based on GPS coordinates was represented by using the point feature class with the herpetofauna occurrences georeferenced to the geographical coordinates.

The geographical distribution of records in terms of biogeographical regions was possible by using specific GIS techniques in the ArcGIS Desktop suite. I used the selection by location tool with the target layer set to the herpetofauna records georeferenced to the UTM 5x5 km grid, and the source layer set to the biogeographical regions feature class, while the spatial selection method was an intersection of the two with a distance filter of 2500 m.

In the table of attributes of the target layer I added the following new fields, RBAlpin, RB Continental, RBPanonic, RBPontic, RBStepic for every biogeographical region and used the field calculator tool in ArcGIS to populate each field with the value “1” for all records that are contained in each biogeographical region and value “0” for those outside the selected biogeographical region. I created a GIS layer for the records within each biogeographical region and symbolized them differently.

The species richness and the number of records in each UTM 10x10 km grid cell were calculated using the Diversity Calculator tool (Miller, 2013) where I set the layer with the herpetofauna records, the field name of the species name, and the layer with the UTM 10x10 km grid polybon.

3.2. Results and discussions

3.2.1. The description of the geospatial database with the amphibians and reptiles of Romania

The ESRI file geodatabase contains two feature classes with 43790 records of herpetofauna occurrences georeferenced to the UTM 5x5 km grid with (1) a polygon feature class that resulted from the data aggregation to the UTM 5x5 km grid, (2) a point feature class that resulted from the generating the centroids of the UTM 5x5 km grid cells used for cartographical purposes, and (3) a point feature class with 8949 herpetofauna records at a fine spatial scale of 3-50m that resulted from the longitude and latitude fields from the database.

Out of the 9977 UTM 5x5 km grid cells that cover the whole territory of Romania, only 3429 cells contain reptile and amphibian records (34,3%). Over 70% of the records were extracted from scientific publications and 25% of the records represented field data.

The most notable species by the number of records from the database are *Bombina variegata, Rana ridibunda, R. esculenta, Bufo bufo, Triturus vulgaris*, *R. dalmatina, Lacerta viridis, L. agilis* and *Natrix natrix* with over 2000 records in the database, while the fewest records of under 500 are found at *Pelobates syriacus, R. lessonae, Triturus dobrogicus*, *Rana arvalis, Eryx jaculus, Elaphe quatorlineata, Vipera ursinii, Eremias arguta, Lacerta praticola, L. trilineata, Vipera ammodytes*, *Ablepharus kitaibelii, Coluber caspius* and *E. longissima.*

The records related to the area of the biogeographical regions indicate a major weight in the pontic region, mostly due to a smaller area of the region but also to a higher effort in inventorying. The panonic region asserts through the high number records mainly to the northern side. The southern side of the continental region is instead highly under inventoried compared to the rest of the region, as the stepic region is very well inventoried in Tulcea and Constanta counties, but extremely little in counties such as Ialomita, Calarasi and Braila **(Fig. 3.3).**

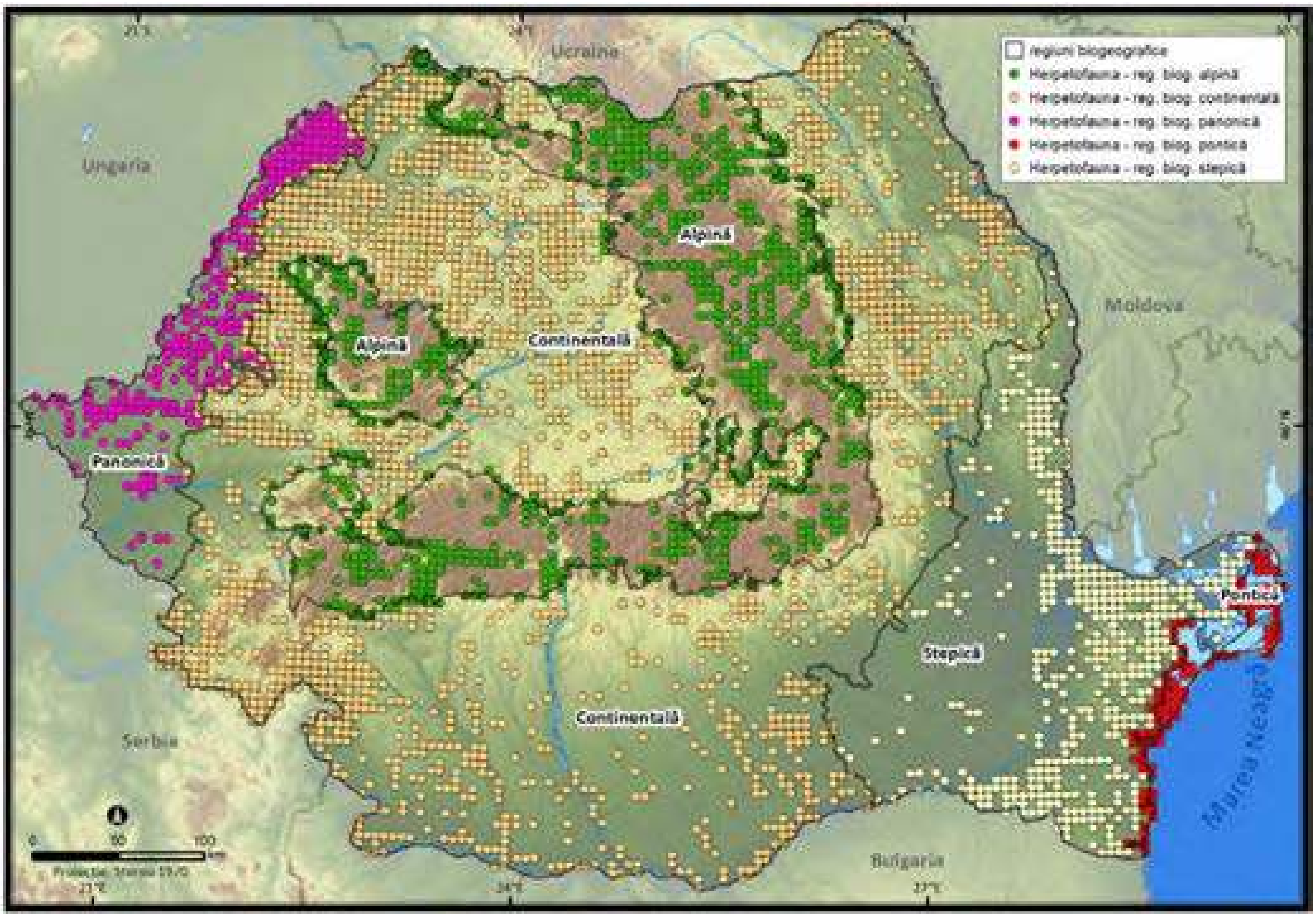


Fig. 3.3 – The distribution of herpetofauna records on biogeographical regions based on the UTM 5x5 km grid.

A higher spatial distribution of records was registered in counties such as Tulcea, Constanța, Bihor, Sălaj, Arad, Hunedoara, Cluj şi Satu-Mare while other counties such as Olt, Ialomița, Călărași or Vrancea present a narrower distribution of records **(Fig. 3.4)**.

A high species richness of the herpetofauna is found mainly in the stepic and pontic regions, but also in the western part of the continental region as well as in the panonic region. The lack of important natural protected areas, the effects of intense agricultural activities and a weak efforet of inventory was identified in the southern parts of Romania, specifically in Muntenia region **(Fig. 3.5)**.

Out of the total records from the database, approximately 10% of the records are old, namely those recorded before 1990, the rest of the records dating after 1990 **(Fig. 3.6)**. The age of the records may be noticed in regions such as Oltenia but also in Muntenia, and quite a few in Crisana.

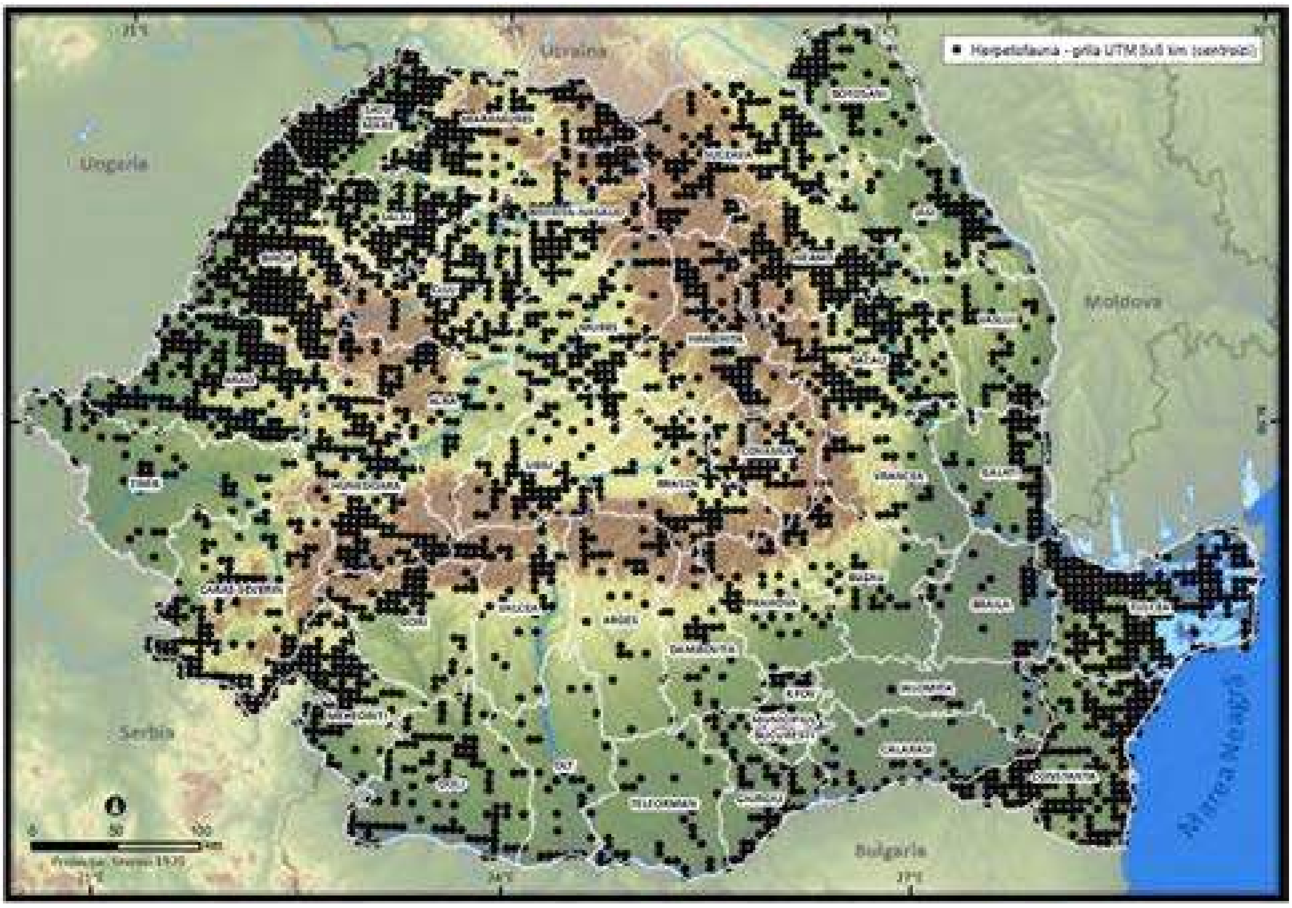


Fig. 3.4 – The distribution of records by counties aggregated to the UTM 5x5 km (centroids).

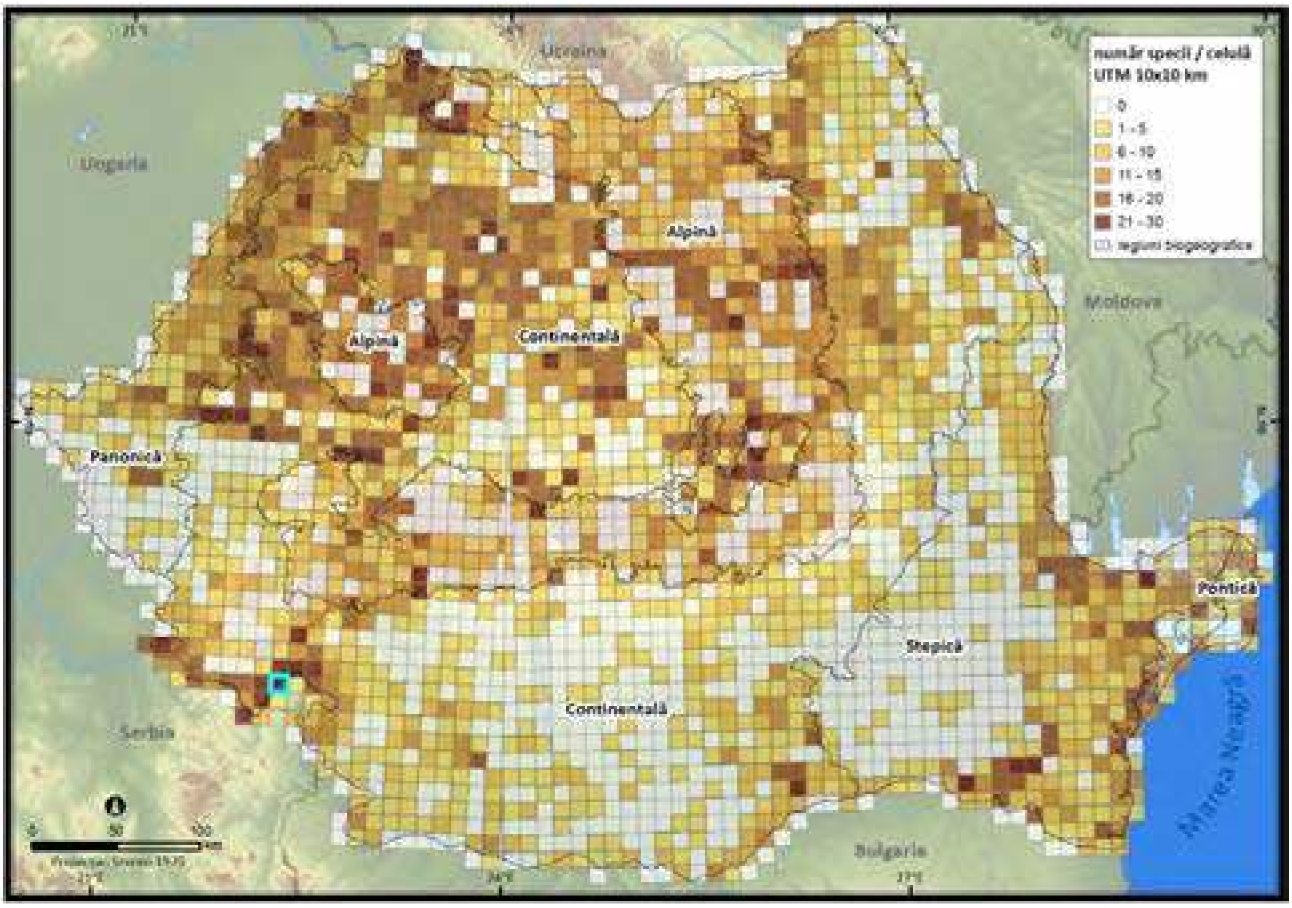


Fig. 3.5 – The species richness of herpetofauna based on the UTM 10x10 km grid with an emphasis on the biogeographical regions.

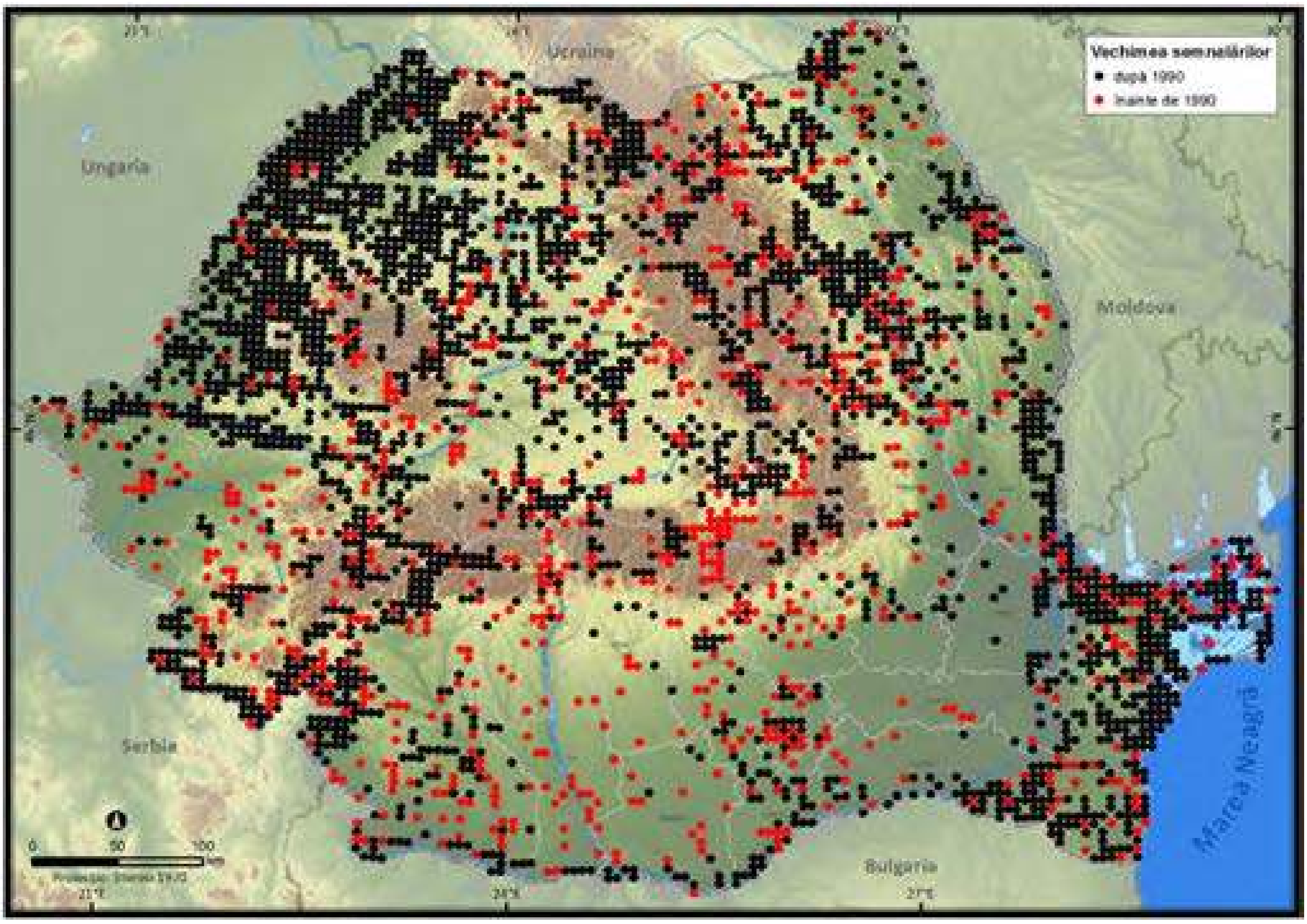


Fig. 3.6 – The age of the herpetofauna records in Romania.

3.2.2. The spatial distribution of several species of amphibians and reptiles at national level

The distribution of the species *B. bombina* on an altitudinal range of up to 400 m (Cogălniceanu *et al.*, 2000) is quite noticeable in **Fig. 3.7**, that species missing in the higher areas of the Carpathian chain. The distribution of the species *B. variegata* for choice in the Carpathian Mountains and to the north with an altitudinal range of 150-2000 m (**Fig. 3.8**) may be due to the climatic shifts and would explain its retreat to more humid and colder areas compared to the south of the country. The distribution of the Carpathian newt (*Triturus montandoni*), a species endemic to the Carpathian Mountains, which occupies an altitudinal range of 200-2000 m, is well highlighted. (**Fig. 3.9**). The spur-thighed tortoise (*Testudo graeca ibera*) is a species endemic to Dobrogea, being isolated to the rest of the country by a natural barrier which is the Danube (**Fig. 3.10**). Although it is a species quite common in Dobrogea, the distribution of *Coluber caspius* is limited in the rest of the country, still mainly observed along Danube and some of its tributaries (**Fig. 3.11**). The distribution of *Elaphe longissima* (**Fig. 3.12**) is relatively limited spatially in central and western part of Romania, with a few other records in some protected areas in Dobrogea and the Iron Gates.

The range of the two spadefoot toads, *Pelobates fuscus* (**Fig. 3.13**) and *Pelobates syriacus* (**Fig. 3.14**) overlaps in the southern side of Romania, mainly in Dobrogea region.

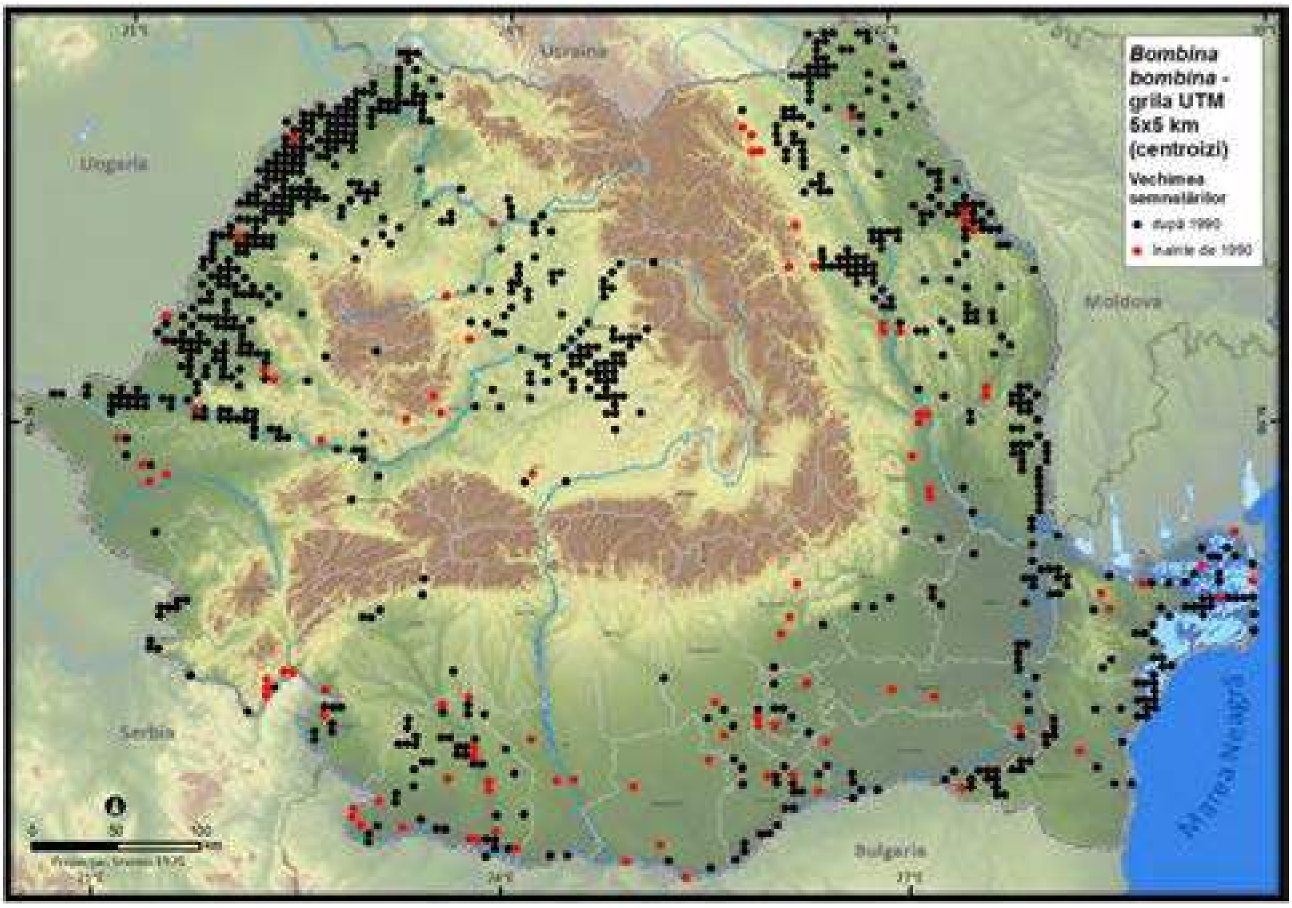


Fig. 3.7 – The spatio-temporal distribution of *Bombina bombina* records.

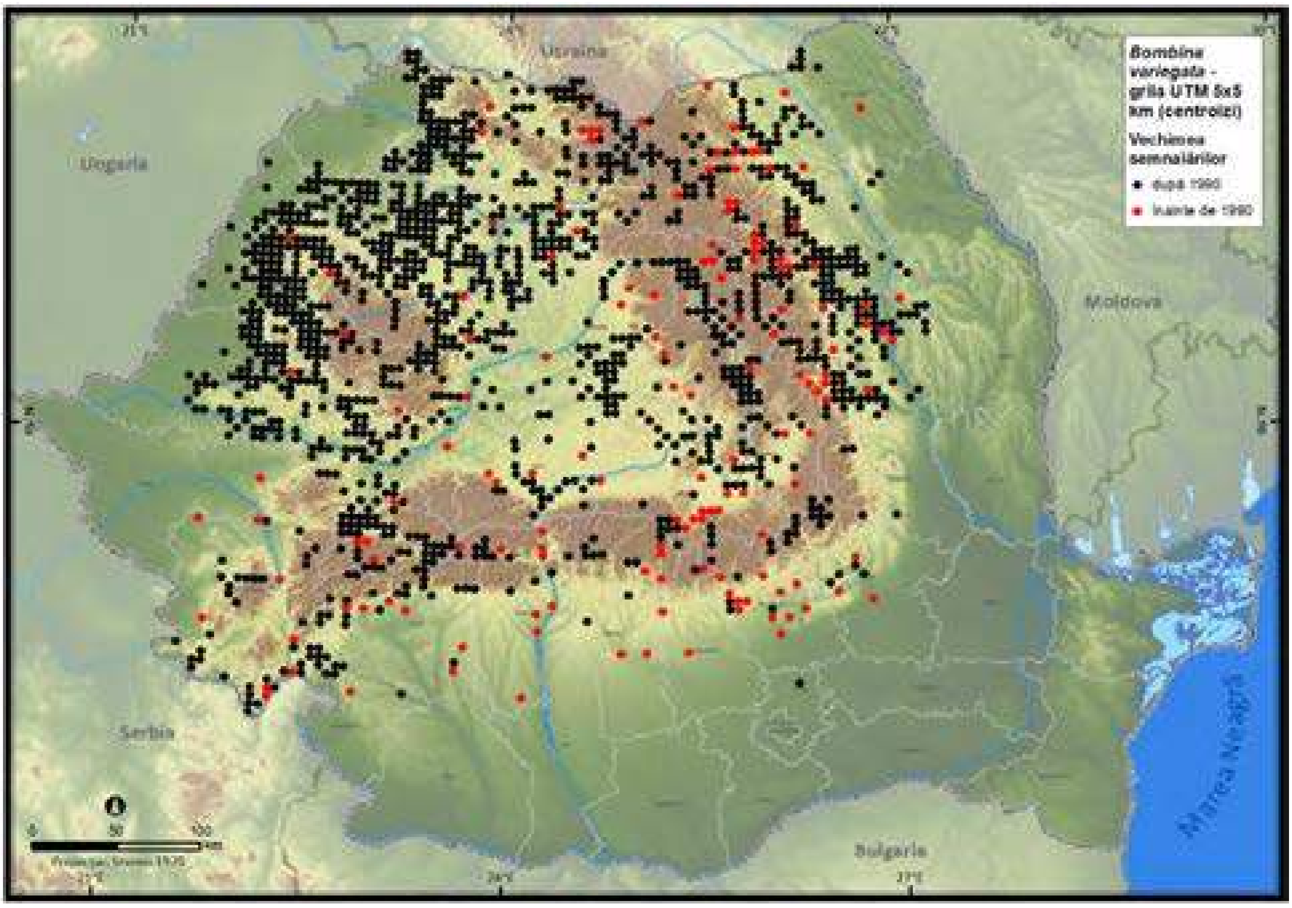


Fig. 3.8 – The spatio-temporal distribution of *Bombina variegata* records.

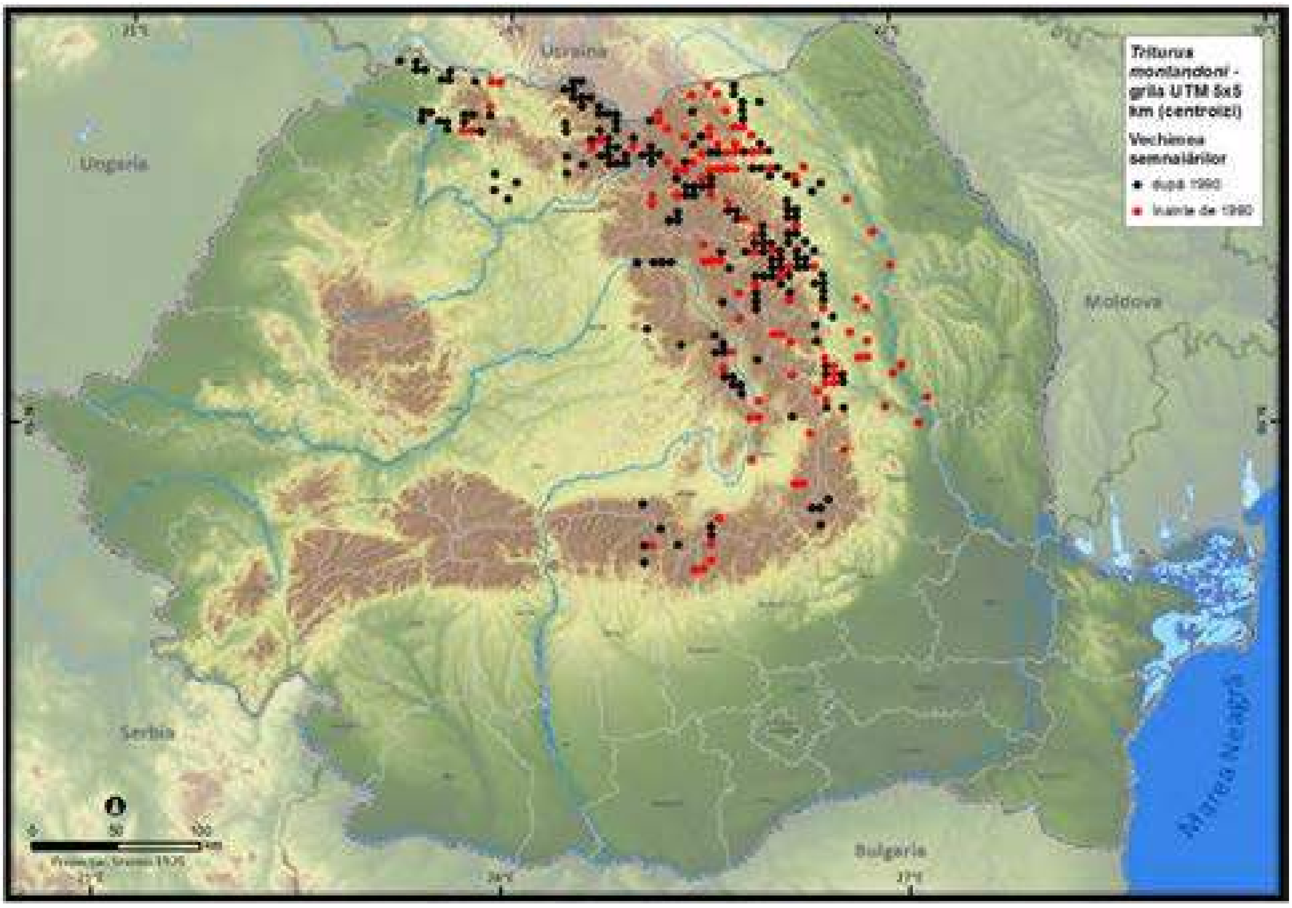


Fig. 3.9 – The spatio-temporal distribution of *Triturus montandoni* records.

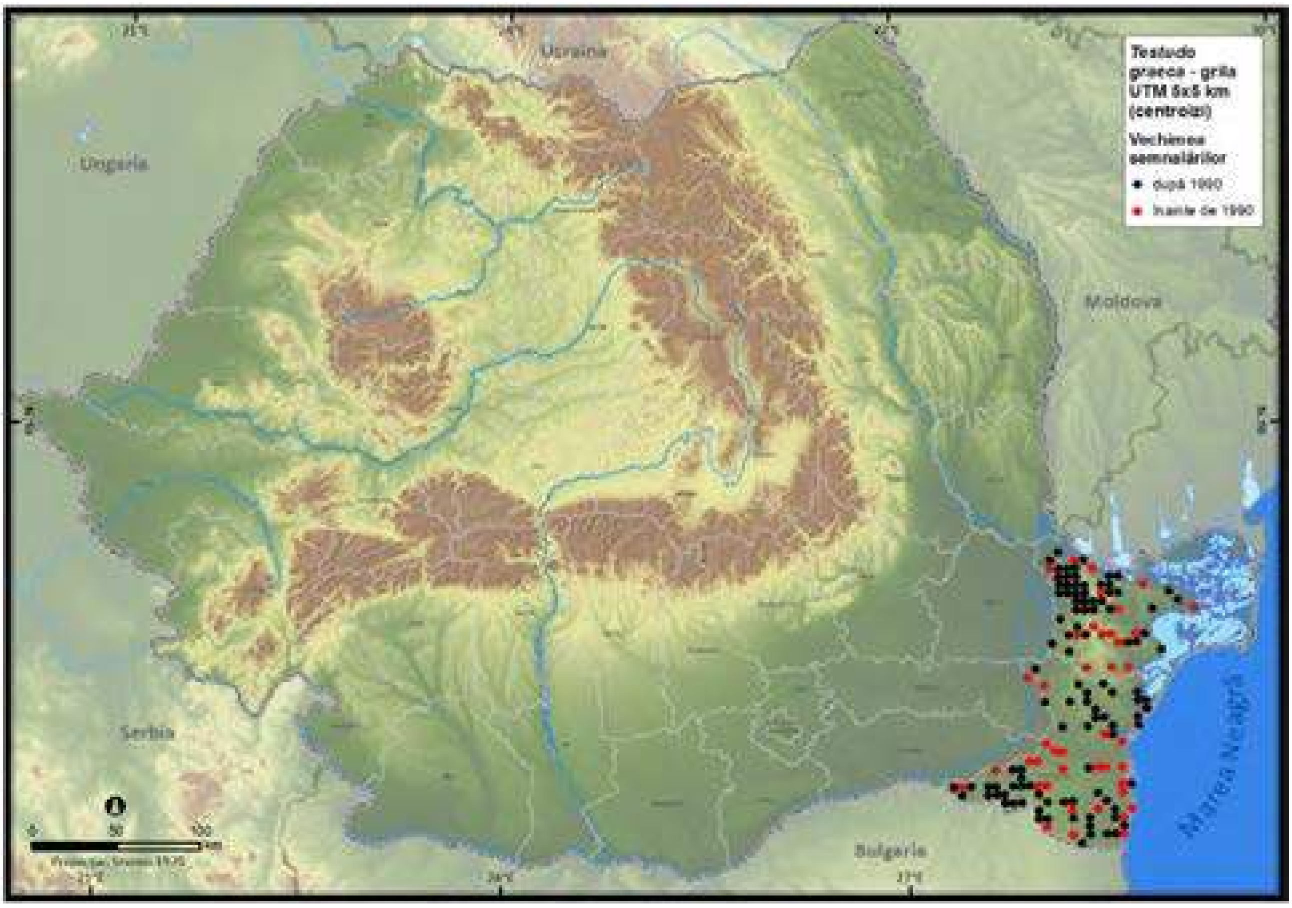


Fig. 3.10 – The spatio-temporal distribution of *Testudo graeca* records.

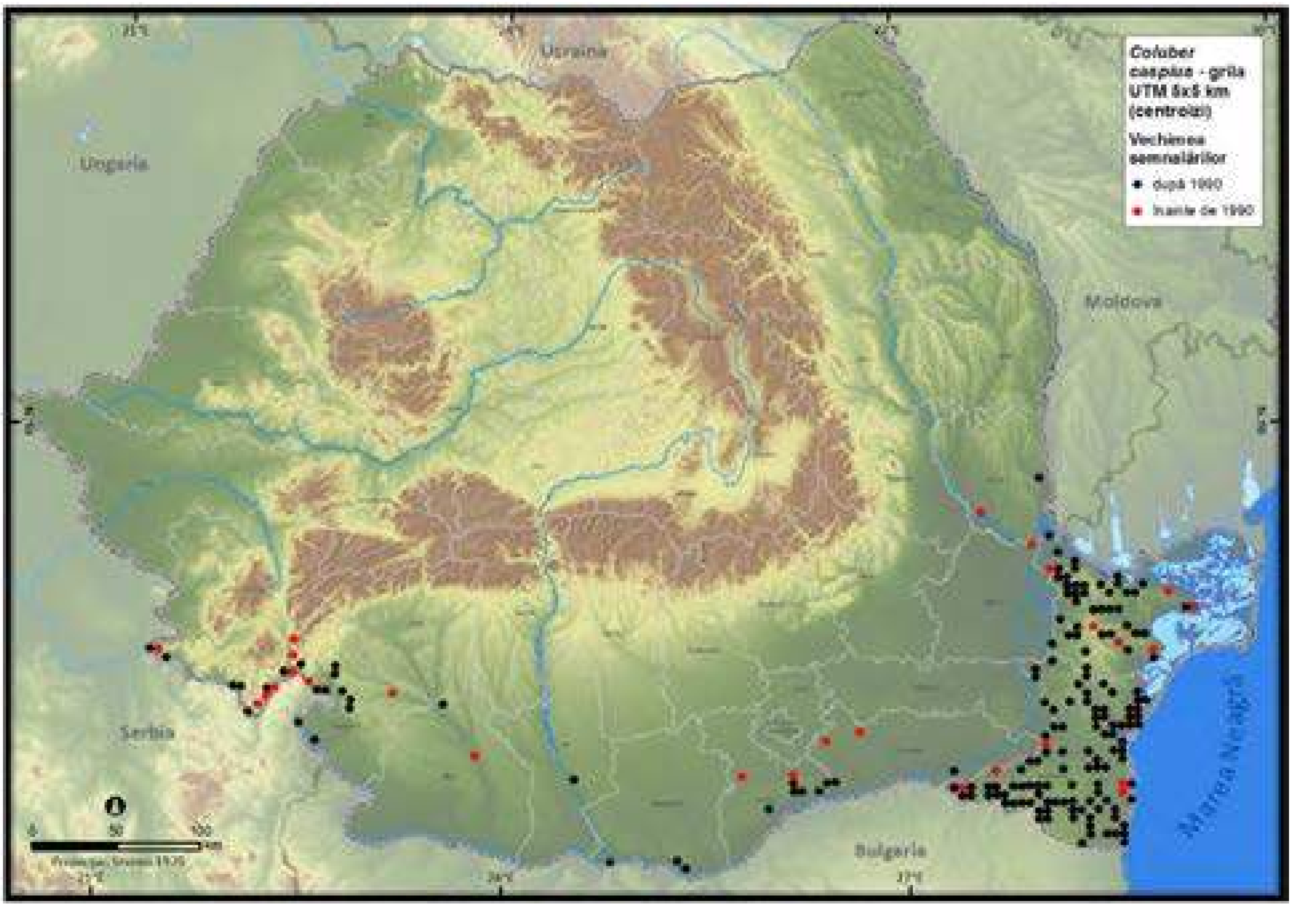


Fig. 3.11 – The spatio-temporal distribution of *Coluber caspius* records.

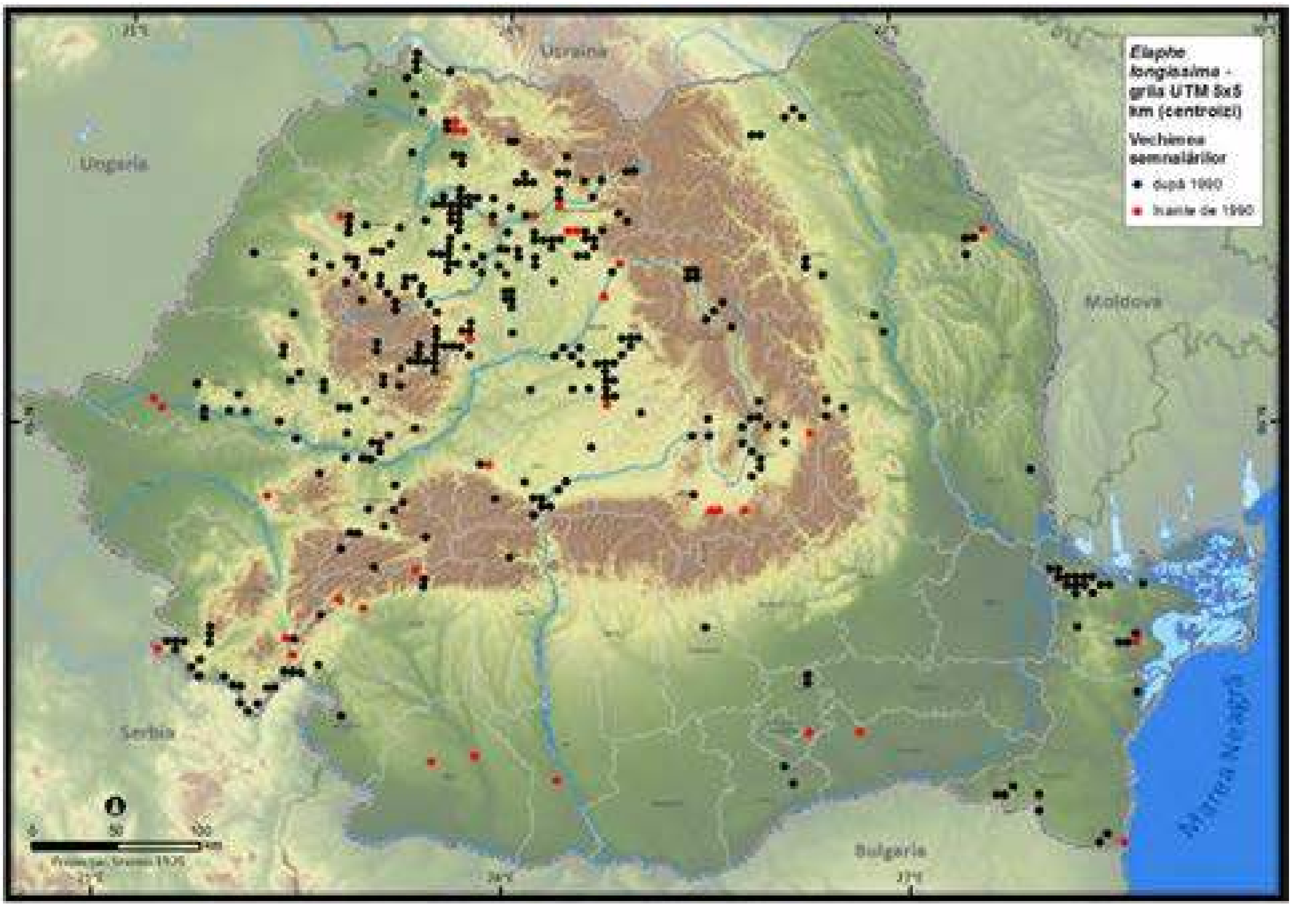


Fig. 3.12 – The spatio-temporal distribution of *Elaphe longissima* records.

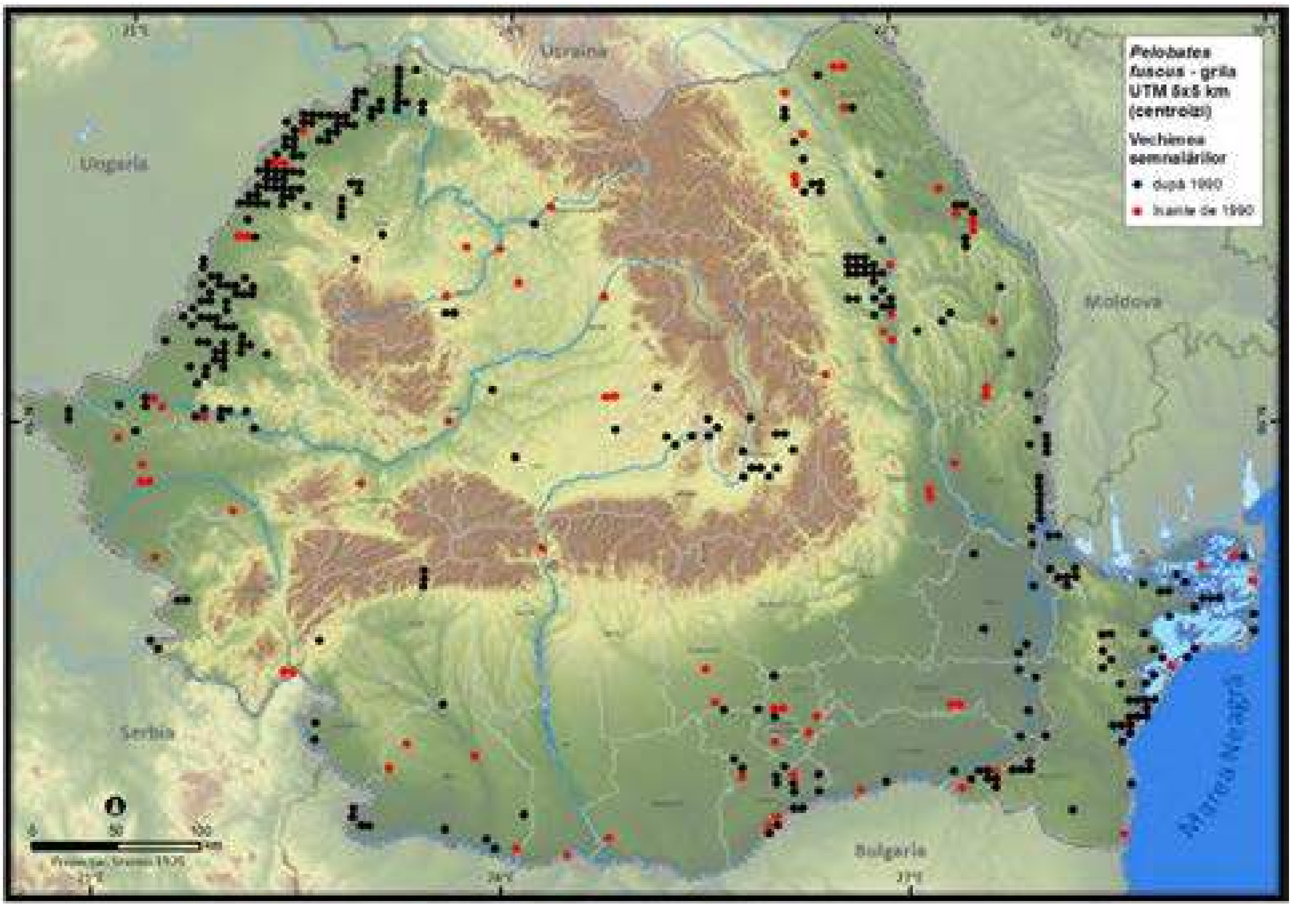


Fig. 3.13 – The spatio-temporal distribution of *Pelobates fuscus* records.

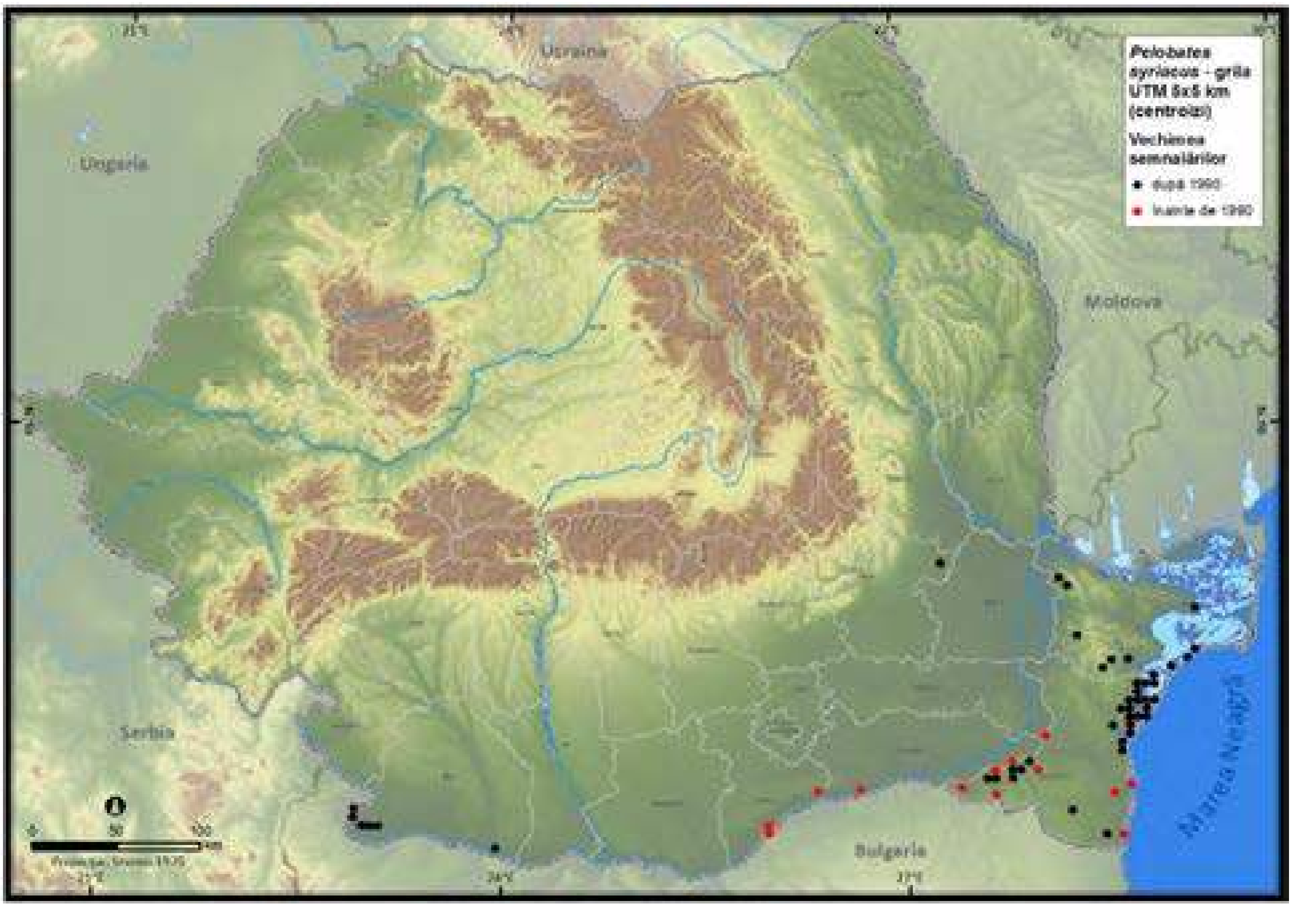


Fig. 3.14 – The spatio-temporal distribution of *Pelobates syriacus* records.

3.3. Conclusions

The process of developing a faunistic database is rather complex and assumes the summarization of a large number of records from scientific publications as well as from unpublished data from various experts or organizations that carry out faunistic studies in different regions or natural protected areas.

The summarization of data collected into a Geographical Information System (GIS) allows an efficient management and practical applications for further spatial analyses and necessary reports in evaluating the species distribution and state of conservation. The presented techniques have a longer learning curve, but once mastered allow an efficient management of spatial information.

A preliminary analysis of depicting the herpetofauna distribution in the Nature 2000 network of protected areas in Romania indicate their insufficient inventory within the protected areas, the majority of occurrences being outside the protected areas.

4. The predictive distribution modelling of several species of reptiles and amphibians

4.1. Materials and methods

4.1.1. Study area

The study area for *Testudo graeca* includes the northern limit of its range, located in Dobrogea, on the territory of Romania. Dobrogea, the most eastern region of Romania, extends from the Danube in the west, north-west and north, to the Black Sea in the east and the country border with Bulgaria in the south. Dobrogea is renowned for the Macin Mountains, the oldest mountain range, and the Danube Delta, the most recent European territory, alongside with the continental shelf. Their geographic presence permitted the growth of distinct flora and fauna in Dobrogea that wonders us with a variety of elements of different origins (Skolka, 1999a; Skolka, 1999b; Skolka, 2001; Skolka, 2003; Skolka *et al.*, 2005; Cogălniceanu *et al.*, 2008b; Făgăraș *et al.*, 2008) .

The study area for *Pelobates fuscus* extends over the range of this species according to IUCN (Agasyan *et al.*, 2009a), from the eastern side of Holland, east of Belgium and France, Germany, Denmark, Sweden (the northern limit) and Central and Eastern Europe to the western Siberia (Russia) and the north-west of Kazakhstan. The study area for *P. syriacus* extends over the range of this species according to IUCN (Agasyan *et al.*, 2009b), from south-east Balkans, east to south-east of Transcaucasus and northern Iran, to the south in Levant.

4.1.2. The species

Testudo graeca (Linnaeus, 1758) (**Fig. 4.1**) is one of the 5 mediterranean spur-thighed tortoises in addition to *T. hermanni*, *T. horsfieldii, T. kleinmanni* and *T. marginata. T. graeca* reaches the northern limit of its range in Romania, in the Dobrogea region, a limit that touches the Danube that becomes the northern boundary of this species distribution. This species is well represented by large populations in the Macin Mountains (Cogălniceanu *et al.*, 2007b), situated in the northern part of Dobrogea.

Fig. 4.1 – A juvenile individual of *T. graeca* in the National park of the Macin Mountains (original).

Pelobates fucus (Laurenti, 1768), a species knows as the spadefoot toad, is a nocturnal species, except for the breeding period. It is prevailingly present in sandy and clay soils where it can bury easily (Cogălniceanu *et al.*, 2000) (**Fig. 4.2**).

Fig. 4.2 – An adult individual of *Pelobates fuscus* (Photo: Szekely Paul).

Pelobates syriacus (Boettger, 1889), a species known as the eastern spadefoot or the Syrian spadefoot, is like *P. syriacus,* a nocturnal species that stays buried by day, sometimes deep underground (Cogălniceanu *et al.*, 2000) (**Fig. 4.3**).

Fig. 4.3 – An adult individual of *Pelobates syriacus* (Photo: Szekely Paul).

4.1.3. **The modelling process**

The Maxent algorithm (Phillips *et al.*, 2006; Elith *et al.*, 2011) was used for the predictive modelling of the predictive distribution of the three species using the Maximum Enthropy Species Distribution Modeling (Maxent) application, version 3.3.3k, available online at http://www.cs.princeton.edu/~schapire/maxent.

Modelling the predictive distribution of the three species was conducted at a spatial resolution of about 1 km for *Testudo graeca* at a regional scale and about 10 km for the two species of *Pelobates* at continental scale. The distribution data resolution of the species *Testudo graeca* was of maximum 1 km and the environmental variables of 30 arc seconds or 0.00833 degrees (~ 1km). The species distribution resolution of the species *Pelobates fuscus* and *P. syriacus* varied between 1 and 10 km and the environmental variables resolution was of 5 arc minutes or 0.08333 degrees (~ 10 km) (Hijmans *et al.*, 2005).

4.1.4. **The species distribution data collection and analysis**

For *Testudo graeca*, I used a dataset of 1058 de records with high-resolution geographical coordinates (under 30 m horizontal error) that were collected with GPS receivers by the research team at Ovidius University of Constanta and collaborators, and 145 records at a coarser resolution of UTM 5x5 km (Cogălniceanu *et al.*, 2007b; Cogălniceanu *et al.*, 2013a). A part of the field data was collected by me (n=75) in the Macin Mountains National Park in the period 2009-2010, by using a Trimble Nomad field calculator with GPS, and the rest of the records were collected from various areas in Dobrogea region in the period 2006-2012.

For *Pelobates fuscus* and *P. syriacus,* I gathered 8818, respectively 509 distribution records with different spatial resolutions from scientific publications, personal communications (i.e. http://nhm-wien.ac.at) or database portals (i.e. http://data.gbif.org) that contained geographical coordinates from Romania, Bulgaria and Eastern Europe (Borkin *et al.*, 2003; Székely *et al.*, 2009; Cogălniceanu *et al.*, 2013b), localities or toponyms from the Balkans and neighbour areas, including Romania (Džukić *et al.*, 2008; Cogălniceanu *et al.*, 2013b), UTM 5x5 km coordonates from the Eastern Rhodopes of Bulgaria and Greece (Petrov, 2004), and Dobrogea (Székely *et al.*, 2009), UTM 10x10 km coordonates from Hungary (Schäffer & Purger, 2005), România (Cogălniceanu *et al.*, 2013b) and Bulgaria (Beschkov, 1961; Beschkov & Beron, 1964; Beschkov, 1972; Stojanov, 1997; Stoev, 2000; Undjian, 2000; Naumov, 2005; Mollov *et al.*, 2007).

The origins of the distribution data differed according to the listing of geographical reference inside the scientific publications, museum collections, personal communications or the datasets received from various collaborators. The georeferencing process of the distribution data was conducted in ArcGIS Desktop (ESRI, 2012b). 1058 records of *Testudo graeca* and 9327 records of the two species of *Pelobates* were initially summarized in an Excel worksheet, and then imported into an ESRI file geodatabase with WGS84 coordinate system.

The name of the species, longitudine and latitude of occurrences for each of the three species were then exported for the modelling process in a CSV filetype by using the XTools Pro extension in ArcGIS (www.xtoolspro.com). The distribution data of *Testudo graeca* were inspected for errors and duplicates, and those with a geographical positioning greater than 1 km were discarded. ENMTools 1.4.3 (Warren *et al.*, 2010) discarded automatically the duplicates from the CSV file using the Grid cell functionality. 84.5% of the records were eliminated, the majority being concentrated in the Macin Mountains, thus leaving only 164 records for *Testudo graeca*. The distribution data of the two species of *Pelobates* were inspected for errors and duplicates, and discarded all records with a geographical positioning error greater than 10 km. ENMTools 1.4.3 (Warren *et al.*, 2010) automatically discarded all duplicates from the CSV file. Thus, 38% of the records were discarded, leaving only 5482 records for *Pelobates fuscus* and 375 records for *P. syriacus*.

4.1.5. **The environmental variables collection, processing and selection**

I collected a set of 24 environmental variables from various sources in order to use them in the predictive distribution modelling of the three species (**Table 4.1**). The variables that served to predict the predictive distribution of species niches were used to describe the climatic, terrain, land cover and soil conditions.

Table 4.1 – The environmental variables selected for modelling the species.

Code	**Environmental variable**	**Original resolution**	**Data source**
alt panta	Altitude Slope	1 km	SRTM v4.1(Jarvis *et al.*, 2008)
clc2006	CLC2006 land cover use *	vector	CLC2006 (European Environment Agency, 2012)
globcover	GlobCover land cover use **	5 arc min (~ 10 km)	GlobCover 2009 (European Space Agency & Universite Catholique de Louvain, 2010)
sol	Soils **	vector	Digital Map Soil of the World v3.6 (FAO-UN, 2007)
bio1	Annual Mean Temperature	30 arc secondsfor *Testudo graeca* / 5 arc minutes (~ 10 km) for *Pelobates fuscus* and *P. syriacus*	WorldClim - Global Climate Data (Hijmans *et al.*, 2005)
bio2	Mean Diurnal Range		
bio3	Isothermality		
bio4	Temperature Seasonality		
bio5	Max Temperature of Warmest Month		
bio6	Min Temperature of Coldest Month		
bio7	Temperature Annual Range		
bio8	Mean Temperature of Wettest Quarter		
bio9	Mean Temperature of Driest Quarter		
bio10	Mean Temperature of Warmest Quarter		
bio11	Mean Temperature of Coldest Quarter		
bio12	Annual Precipitation		
bio13	Precipitation of Wettest Month		
bio14	Precipitation of Driest Month		
bio15	Precipitation Seasonality (Coefficient of Variation)		
bio16	Precipitation of Wettest Quarter		
bio17	Precipitation of Driest Quarter		
bio18	Precipitation of Warmest Quarter		
bio19	Precipitation of Coldest Quarter		

* Variables selected only for *Testudo graeca*

** Variables selected only for *Pelobates fuscus* and *P. syriacus*

The 19 bioclimatic variables are part of the WorldClim climate data, a dataset of climatic layers at global scale with a resolution from 30 arc seconds to 5 arc minutes, generated through a thin-plate smoothing spline interpolation of data from global meterogological stations for the period 1950-2000 (Hijmans *et al.*, 2005).

All variables were converted in ESRI ASCII raster layers and projected in the GCS_WGS84 coordinate system with a spatial resolution of 30 arc seconds or 0.00833 degrees (~ 1 km) for *Testudo graeca* and 5 arc minutes or 0.08333 degrees (~ 10 km) for *Pelobates fuscus* and *P. syriacus,* using the ArcGIS Desktop geoprocessing tools such as **Project**, **Resample**, **Clip**, **Raster to ASCII** (ESRI, 2012b). Getting the minimum and maximum values for each bioclimatic variable was possible using **Extract Multi Values to Points** tool that extracted and recorded the values of the variables raster cells that intersected with the species distribution point data.

4.1.6. Running Maxent application

Maxent application was run from command prompt with the file maxent.bat that was altered to allow Java application to benefit from up to 12 GB RAM, so that the modelling process time could be shortened. The default settings of the Maxent application were changed according to the MaxEnt tutorial elaborated by Young *et al.* (2011) to run the predictive modelling of the species distributions.

For modelling the species *Testudo graeca*, I used the following combinations of datasets for six different modelling scenarios (**Table 4.2**).

Table 4.2 – The scheme of scenarios for the predictive modelling of *Testudo graeca.*

Model	**Spatial resolution**	**Environmental variables**
A	< 100 m	bio1, bio2, bio3, bio4, bio5, bio6, bio7, bio8, bio9, bio10, bio11, bio12, bio13, bio14, bio15, bio16, bio17, bio18, bio19
B	< 100 m	bio1, bio2, bio3, bio4, bio5, bio6, bio7, bio8, bio9, bio10, bio11, bio12, bio13, bio14, bio15, bio16, bio17, bio18, bio19, clc2006
C	< 100 m	bio4, bio9, bio11, bio15, bio19
D	5 km	bio1, bio2, bio3, bio4, bio5, bio6, bio7, bio8, bio9, bio10, bio11, bio12, bio13, bio14, bio15, bio16, bio17, bio18, bio19
E	5 km	bio1, bio2, bio3, bio4, bio5, bio6, bio7, bio8, bio9, bio10, bio11, bio12, bio13, bio14, bio15, bio16, bio17, bio18, bio19, clc2006
F	5 km	bio4, bio9, bio11, bio15, bio19

For modelling the species *Pelobates fuscus* and *P. syriacus*, I used the following combinations of datasets for two different modelling scenarios (**Table 4.3**):

Table 4.3 – The scheme of scenarios for the predictive modelling of *Pelobates fuscus* and *P. syriacus*.

Model	**Spatial resolution**	**Environmental variables**
A	10 km	bio1, bio2, bio3, bio4, bio5, bio6, bio7, bio8, bio9, bio10, bio11, bio12, bio13, bio14, bio15, bio16, bio17, bio18, bio19, alt, panta, soluri, globcover
B	10 km	bio5, bio6, bio7, bio9, bio11, alt, panta, soluri, globcover

The 19 bioclimatic variables (bio1 – bio19), altitude and slope are continuous data, while the clc2006, soils and globcover variables are categorical data. In Maxent application, the species distribution data are loaded from a CSV file in the **Samples** section, and the environmental variables from **Environmental layers** section. It is highly important that the type of data, continuous or categorical, is selected.

4.1.7. **Processing and interpreting the modelling data resulted from Maxent into GIS**

The raw data resulted after running Maxent application were further processed in ArcGIS Desktop in order to obtain the final prediction maps and the area calculations of optimal prediction. Maxent generates a series of rasters with continuous values from 0 to 1 in ASCII (.asc) format with minimum, maximum, average, median and standard deviation values that represent the prediction level of habitat suitability. In order to display the prediction results through a discrete classification, with two values of favourable or unfavourable/inadequate habitat, I chose the value **10 percentile training presence logistic threshold** found in maxentResults.csv file to serve as a threshold value for the favourable habitat.

In ArcCatalog application within ArcGIS Desktop, I imported and processed the .asc rasters with averaged values, set the **Spatial reference** of each raster to GCS_WGS_1984, and generated the histograms with **Calculate Statistics** tool in order to symbolize the rasters according to a classification system of values and colours that resembled the results from Maxent application. Next, I converted the ASCII rasters to a file geodatabase raster (FGDBR) using **ASCII to Raster (Conversion)** tool with the option Data Output Type set to Float in order to keep the raster values with two decimals in the range 0 to 1, then I reclassified the rasters with the **Reclassify (Spatial Analyst)** tool according to the two classes of values split by the threshold value of each raster resulted in Maxent. In order to display and summarize the favourable/unfavourable areas for *Testudo graeca*, I reprojected the rasters from the initial WGS84 coordinate system to the Romanian national projection Stereo 70, using **Project Raster (Data Management)** tool in ArcGIS.

4.2. Results and discussions

4.2.1. The predictive distribution of *Testudo graeca* at regional level

The best prediction was given by the model C with the value AUC = 0,969 (Area Under Curve), based on *Testudo graeca* samples with high resolution GPS coordinates, a selection of bioclimatic variables with the highest contribution from model A and the CLC2006 land cover use (**Table 4.4**).

Table 4.4 – The comparative results of the six modelling scenarios for *Testudo graeca*.

Model	AUC	Threshold 10 %*	Top 5 variables	% contribution
A	0,946	0,1049	bio9	35,7
			bio4	14,2
			bio1	9,8
			bio19	9,2
			bio15	6,2
B	0,957	0,1188	bio9	34,2
			clc2006	19,8
			bio4	15,6
			bio19	12,5
			bio15	5,2
C	0,969	0,1169	bio9	39,8
			clc2006	17,6
			bio4	16,8
			bio19	14,5
			bio15	8,9
D	0,763	0,3722	bio19	43,1
			bio8	14,7
			bio14	9
			bio3	9
			bio18	3,5
E	0,762	0,3393	bio19	43,2
			bio8	7,8

Model	AUC	Threshold 10 %*	Top 5 variables	% contribution
			clc2006	7,7
			bio16	6,8
			bio14	6,7
F	0,764	0,3646	bio19	62,5
			bio15	17,5
			bio11	7
			clc2006	5,7
			bio9	3,9

* 10 % = 10 percentile training presence logistic threshold

For Dobrogea, the modelling scenarios emphasized the importance of two variables with a weight of over 34% in the models prediction, namely the mean temperature of the driest quarter (bio9) and the precipitation of the coldest quarter (bio19) that may act as two bioclimatic limiting factors for the survival of this species.

The precipitations and the extreme temperatures are other two important factors that need to be accounted for *Testudo graeca* as it also results from the studies of Anadón *et al.* (2006a) in Spain. Concurrently , this species is known to inhabit simplified structures of vegetation, including in its vital area shrubs and small non-irrigated fields (Anadón *et al.*, 2006b).

The predictive distribution maps emphasize the bioclimatic and habitat space in which the species *Testudo graeca* would find favourable conditions of subsistence. The predictive modelling scenarios are grouped in pair based on the similitude of environmental variables used and the difference in the training dataset with the species samples, namely the models A, B and C having high resolution GPS samples, while the models D, E and F are trained with sample at a resolution of UTM 5x5 km.

The use of species presence occurrences at a lower resolution, such as the occurrences georeferenced to the UTM 5x5 km grid, determine an exaggerated prediction compared to the model with high resolution GPS samples (**Fig. 4.4**).

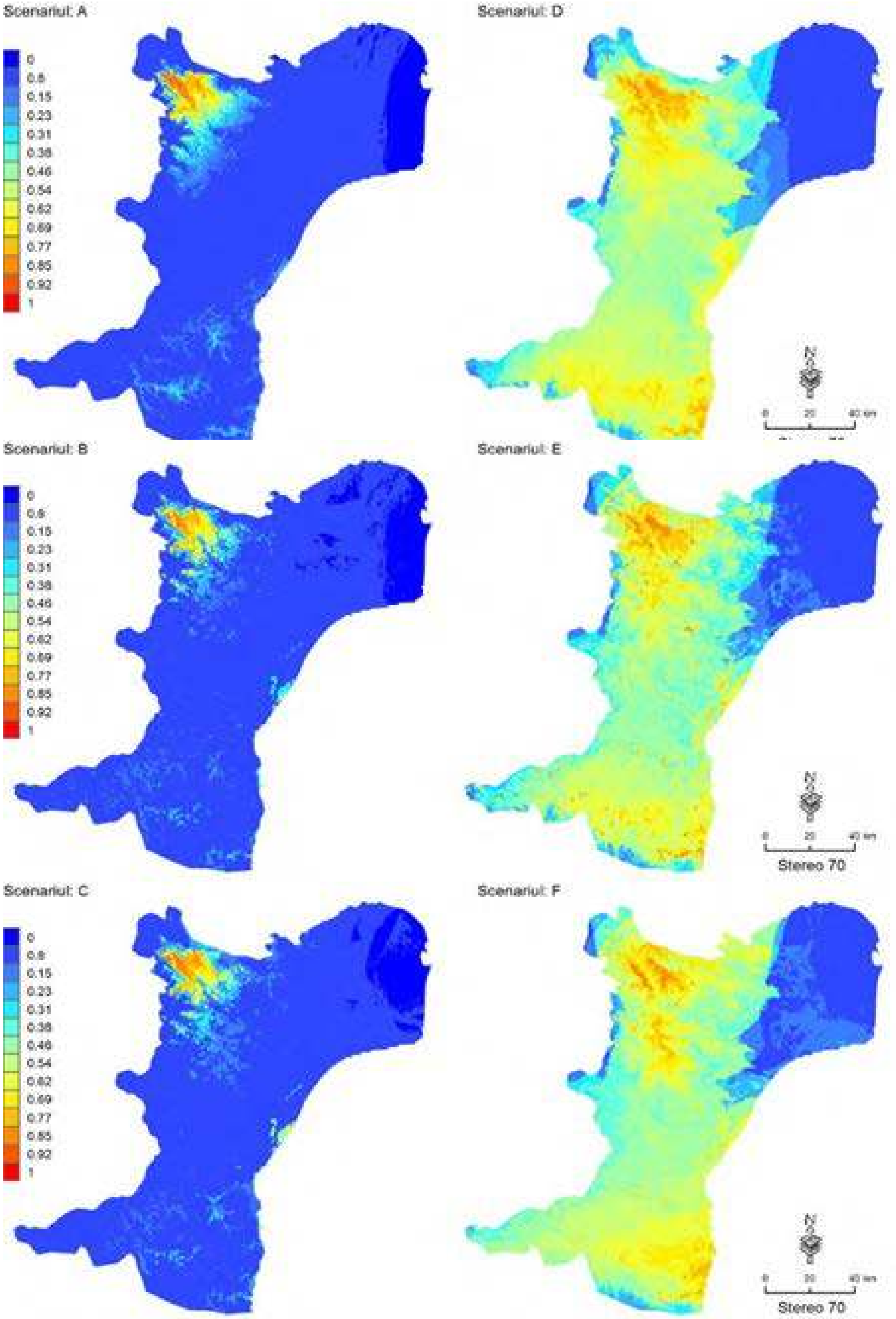
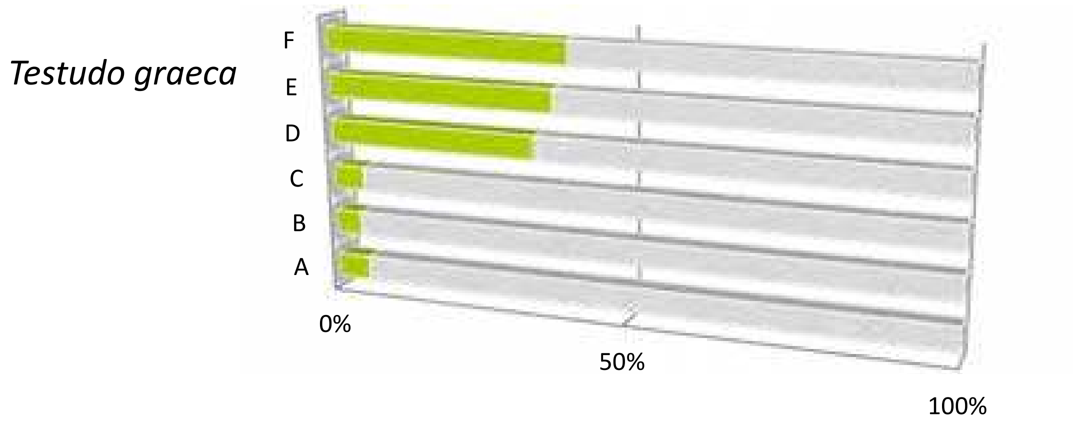


Fig. 4.4 – Model scenarios A - F of predictive modelling of *Testudo graeca* in Maxent.

Taking into consideration the influence of presence occurrences onto the exaggeration of the predictive modelling of the species *Testudo graeca,* the greatest weight in favourable habitats was given by model scenario A with 5.59% when using high resolution occurrences and only the 19 bioclimatic variables, while the model scenario F with 40.8% when using occurrences georeferenced to the UTM 5x5 km grid and a selction of variables with higher contribution percentage in the previous models (**Fig. 4.5**).



	A	B	C	D	E	F
Habitat favorabil	5.59%	4.45%	5.33%	35.08%	38.39%	40.80%
Habitat nefavorabil	94.41%	95.55%	94.67%	64.92%	61.61%	59.20%

Fig. 4.5 – The percentage of areas occupied by favourable and unfavourable habitats predicted by Maxent.

The rasters resulted in the Maxent modelling were reclassified in two classes of values with favourable and unfavourable habitats according to the threshold value “10 percentile minimum training presence logistic threshhold”, in order to make the prediction more visible by overlaying the samples data collected from scientific publications and georeferenced to the UTM 5x5 km grid (**Fig. 4.6**).

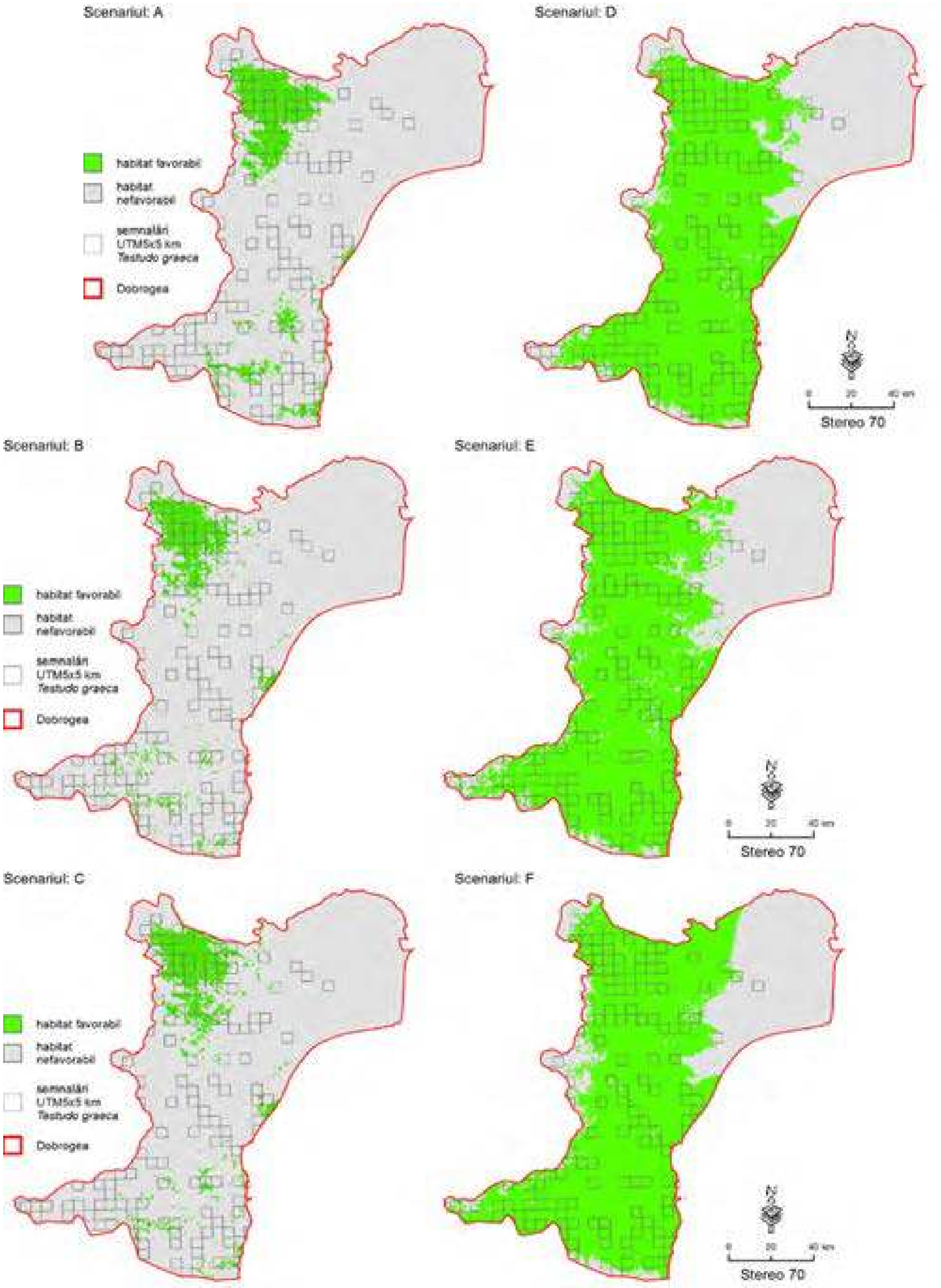


Fig. 4.6 – Favouable and unfavourable habitats for *Testudo graeca* predicted in the model scenarios A- F (green = favourable habitat, grey = unfavourable, empty squares = UTM5x5km samples.

4.2.2. The predictive distribution of *Pelobates fuscus* and *P. syriacus* at their species range level.

The predictive distribution of *Pelobates fuscus*

Following up the predictive distribution modelling of *Pelobates fuscus*, Maxent application recorded in the species distribution samples the annual mean temperature range (bio1) of 0.7°C – 13.6°C, the maximum temperature of the warmest month (bio5) in the range 18.3°C - 33°C, the minimum temperature of coldest month (bio6) in the range -22.7°C – 1.8°C, the temperature annual range (bio7) in the range 20.6°C – 28.9°C, the precipitation of driest month (bio14) in the range 9 mm – 90 mm and the precipitation of warmest quarter (bio18) in the range 40 mm – 451 mm.

The best prediction was given by model A with an AUC = 0,803 (Area Under Curve), which used a set of 19 bioclimatic variables and other environmental variables (**Table 4.5**).

Table 4.5 – The comparative results of the two modelling scenarios for *Pelobates fuscus*.

Model	AUC	Threshold 10 %*	Top 5 variables	% contribution
A	0,803	0,3576	bio9	30,5
			bio14	23,3
			bio8	9,7
			bio7	8,3
			bio18	6,3
B	0,795	0,3625	bio9	54
			bio7	10,5
			alt	8,6
			bio6	8,1
			bio5	8,1

* 10 % = 10 percentile training presence logistic threshold

The prediction maps of the modelling scenarios A and B presented the environmental conditions predicted for *Pelobates fuscus* and cross the species range limit established by IUCN (Agasyan *et al.*, 2009a), mainly in the interior of the Carpathian chain in Romania and in the Balkans region. The custom selection of a set of variables in the model B (bio5, bio6, bio7, bio9, bio11, alt, panta, soluri, globcover) predicted an extended distribution in several countries such as France and Romania (**Fig. 4.7).**

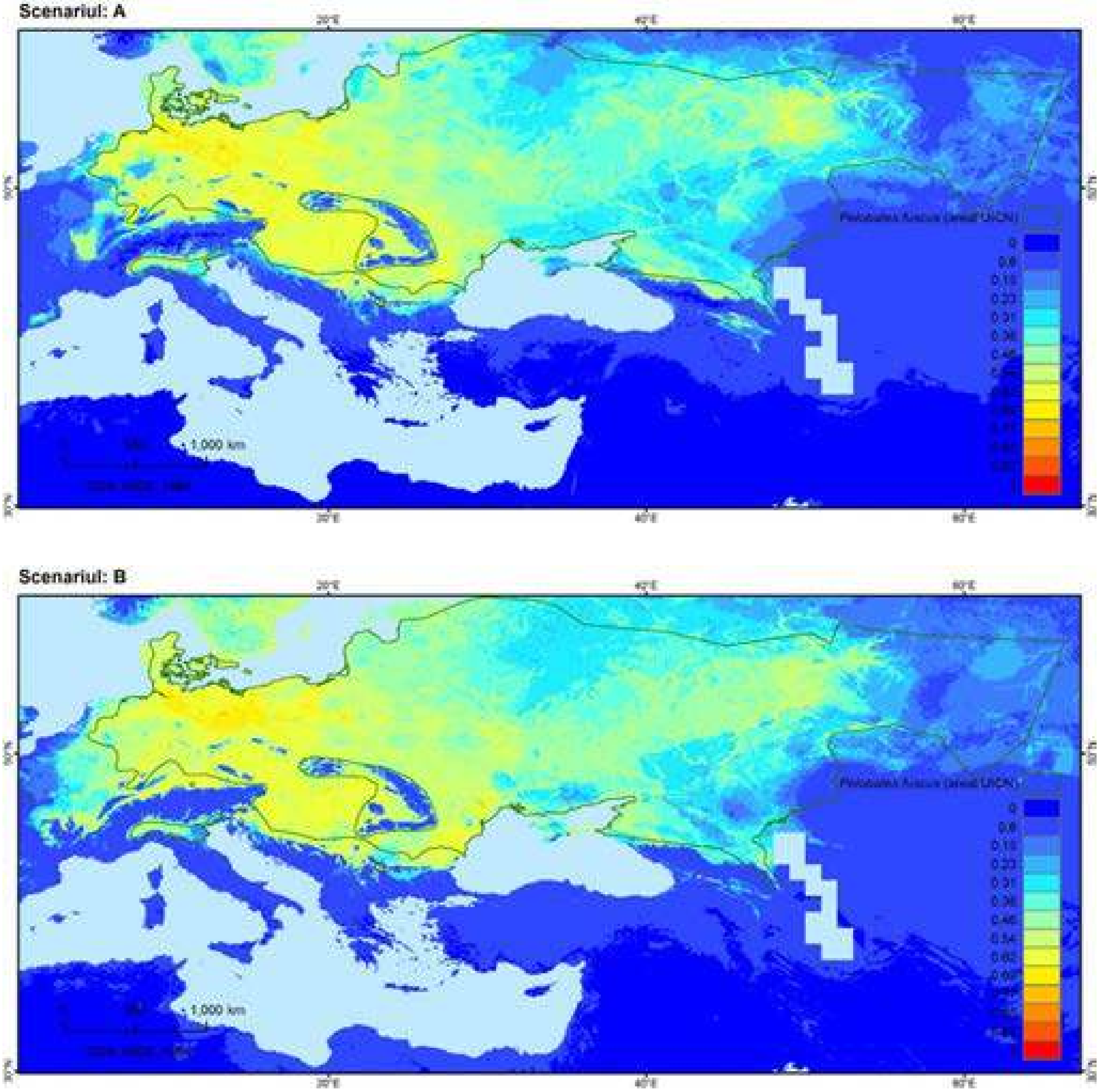


Fig. 4.7 – Scenarios A and B of predictive modelling for *Pelobates fuscus* in Maxent. The green line delineates the species range limit according to IUCN.

Taking into consideration the influence of presence occurrences upon the exaggeration of the predictive modelling of *Pelobates fuscus,* the greatest weight in favourable habitats was given by scenario B with 22.34% where I used a set of variables selected upon personal considerations (**Fig. 4.8 – 4.9**).

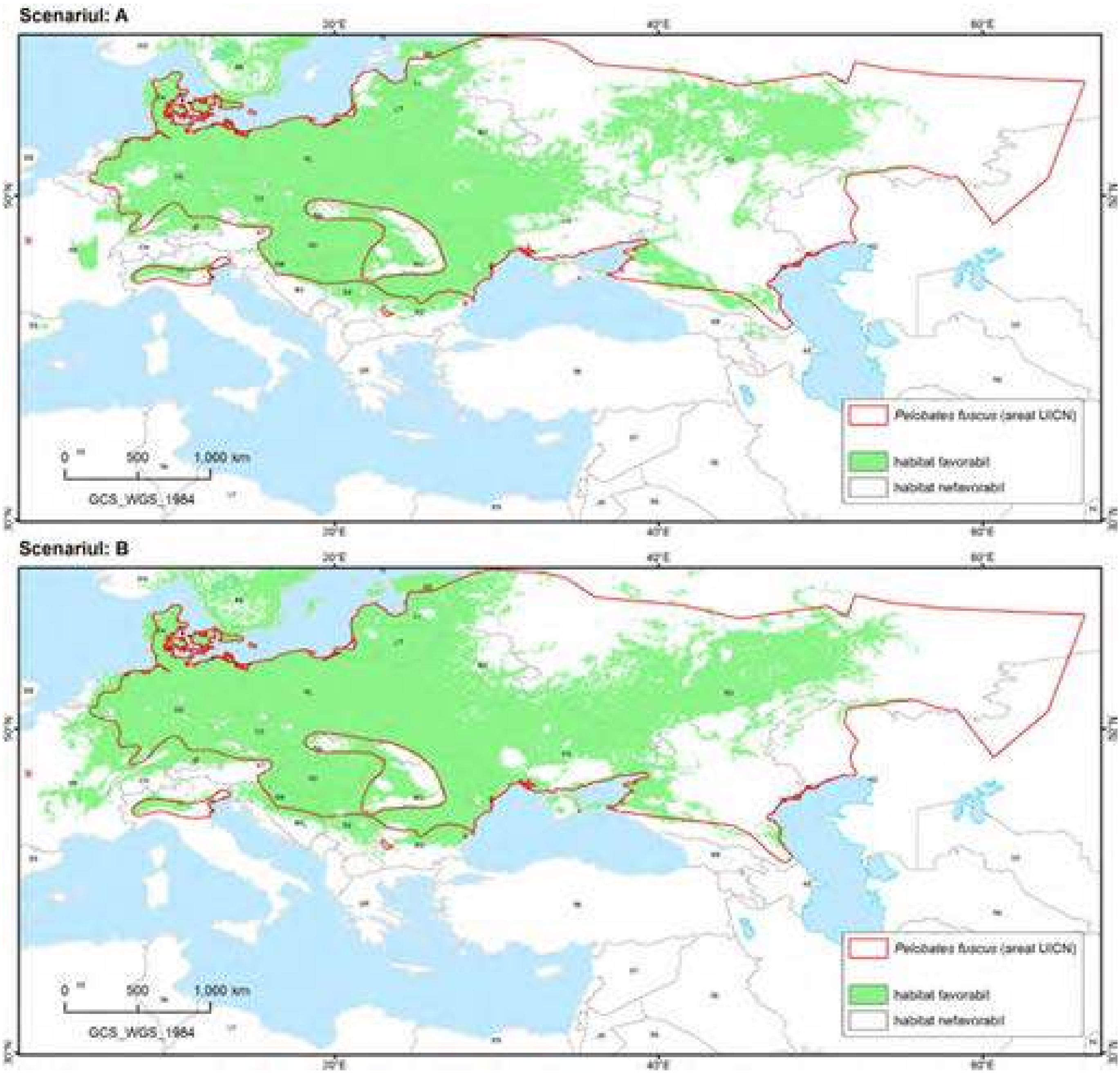
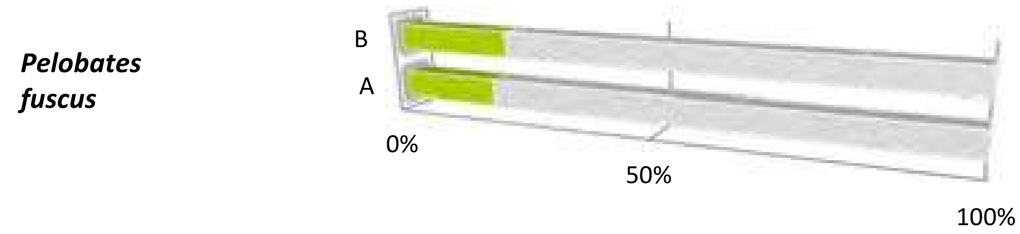


Fig. 4.8 – The favourable and unfavourable habitats for *Pelobates fuscus*. The green line delineates the species range limit according to IUCN.



	A	B
Habitat favorabil	19.09%	22.34%
Habitat nefavorabil	80.91%	77.66%

Fig. 4.9 – The percentage of favourable and unfavourable habitats predicted for *Pelobates fuscus* in Maxent.

The predictive distribution of *Pelobates syriacus*

Following up the predictive distribution modelling of *Pelobates syriacus*, Maxent application recorded in the species distribution samples the annual mean temperature range (bio1) of 2.4°C – 21.9°C, the maximum temperature of the warmest month (bio5) in the range 20.2°C – 42.1°C, the minimum temperature of coldest month (bio6) in the range –13.5°C – 9.2°C, the temperature annual range (bio7) in the range 21.9°C – 43.3°C, the precipitation of driest month (bio14) in the range 0 mm – 53 mm and the precipitation of warmest quarter (bio18) in the range 0 mm – 284 mm.

The best prediction was given by model A with an AUC = 0,968 (Area Under Curve), which used a set of bioclimatic variables selected according to the extreme limits that would climatically affect the survival of this species (**Table 4.6**).

Table 4.6 – The comparative results of the two modelling scenarios for *Pelobates syriacus*.

Model	**AUC**	**Threshold 10 %***	**Top 5 variables**	**% contribution**
A	0,969	0,3377	bio7	19
			bio12	14
			bio5	12,7
			bio1	11,8
			bio17	7,3
B	0,960	0,2756	bio7	28,3
			bio5	22,7
			globcover	14,6
			soluri	13
			bio11	10,7

* 10 % = 10 percentile training presence logistic threshold

The prediction maps of the modelling scenarios A and B presented the environmental conditions predicted for *Pelobates syriacus* and cross the species range limit established by IUCN (Agasyan *et al.*, 2009b), mainly in the Balkans region and Turkey. The custom selection of a set of variables in the model B (bio5, bio6, bio7, bio9, bio11, alt, panta, soluri, globcover) predicted an extended distribution in several countries such as Romania, Turkey, Georgia and Greece (**Fig. 4.10).**

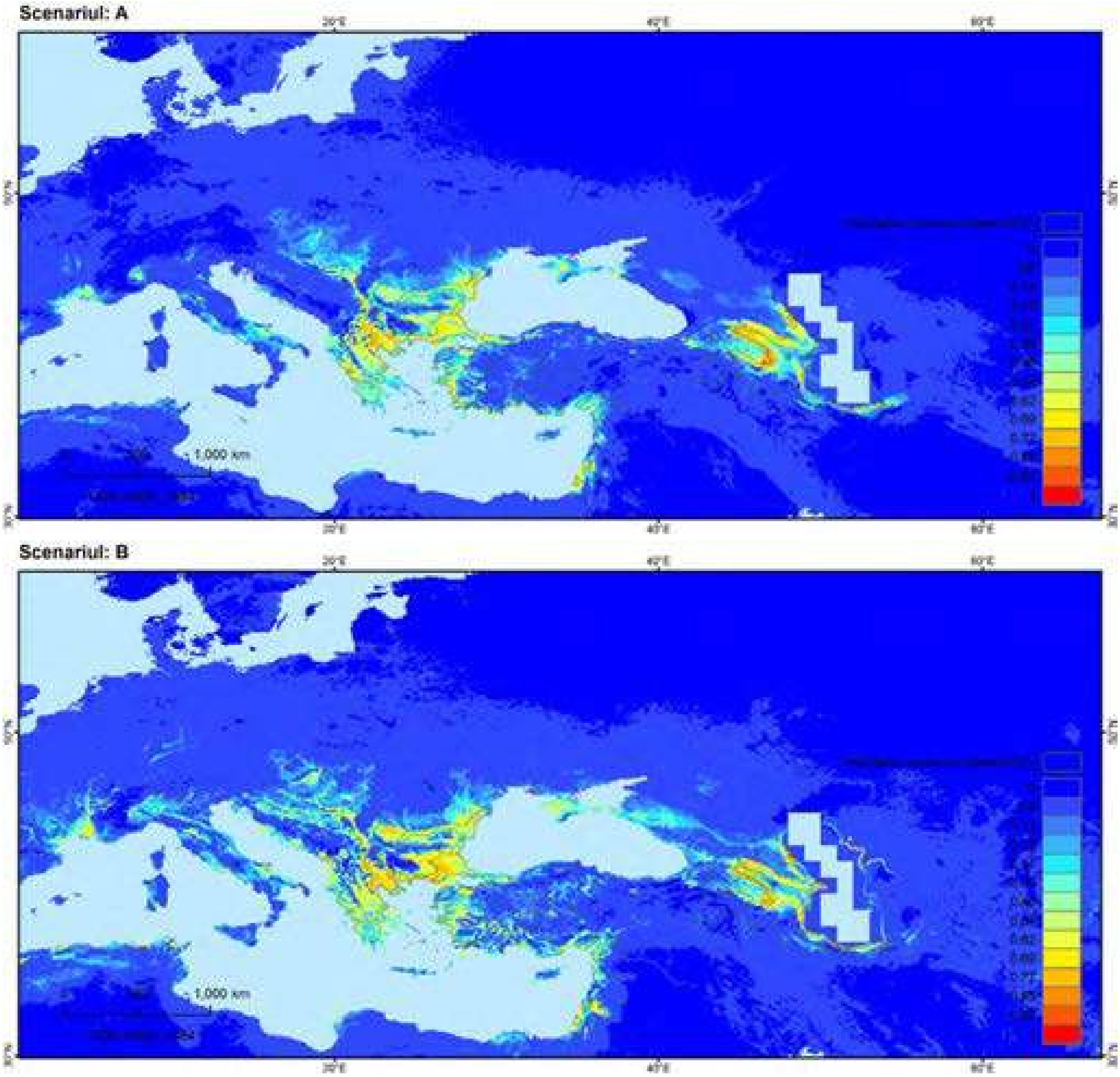


Fig. 4.10 - Scenarios A and B of predictive modelling for *Pelobates syriacus* in Maxent. The green line delineates the species range limit according to IUCN.

Taking into consideration the influence of presence occurrences upon the exaggeration of the predictive modelling of *Pelobates syriacus,* the greatest weight in favourable habitats was given by scenario B with 4.19% where I used a set of variables selected upon personal considerations (**Fig. 4.11 – 4.12**).

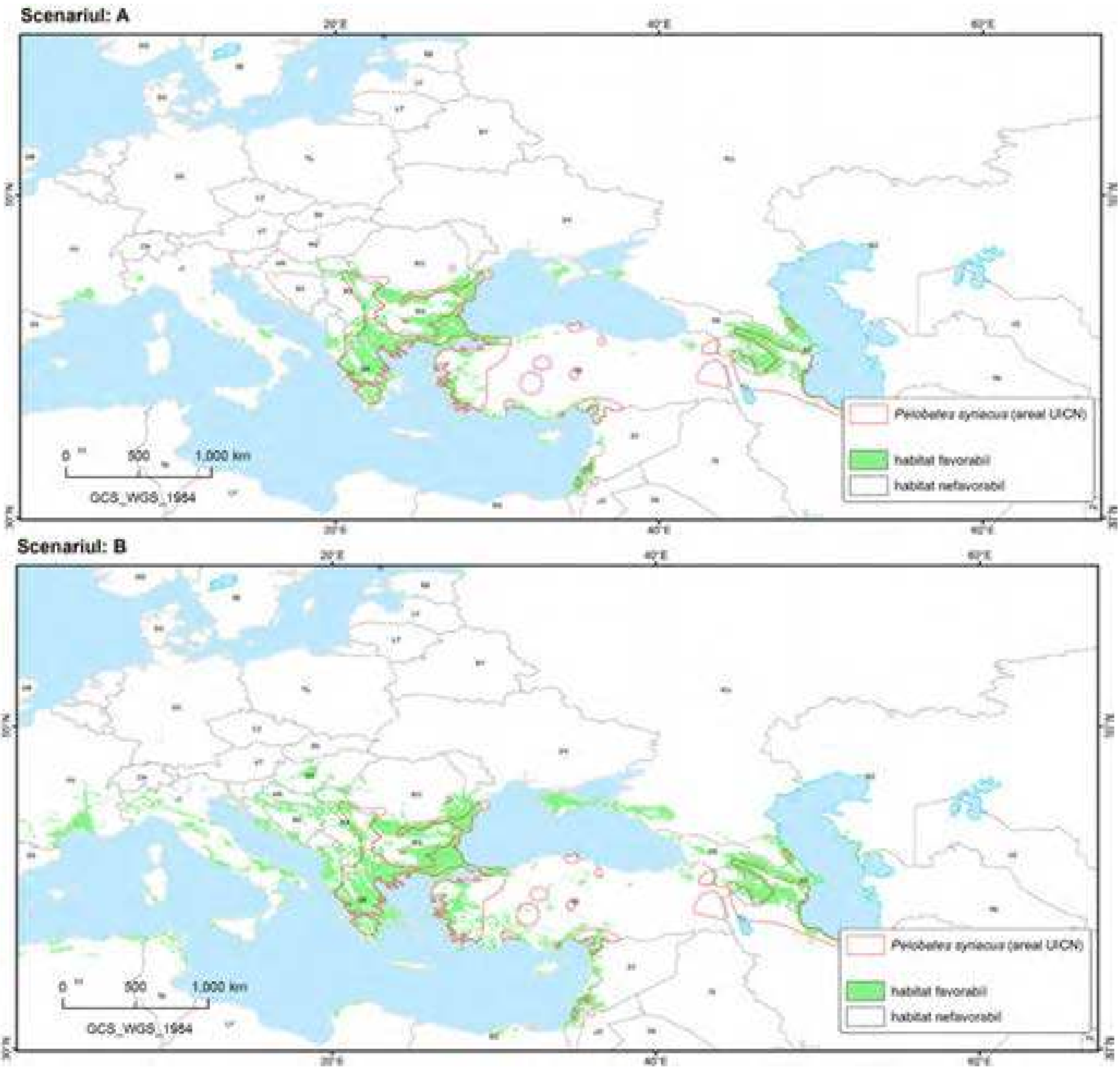
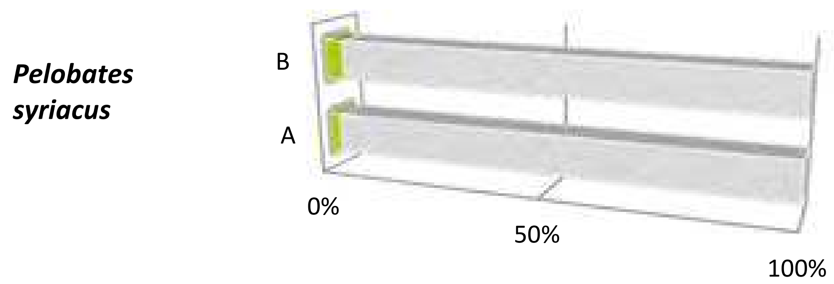


Fig. 4.11 - The favourable and unfavourable habitats for *Pelobates syriacus.* The green line delineates the species range limit according to IUCN.



	A	B
Habitat favorabil	2.43%	4.19%
Habitat nefavorabil	97.57%	95.81%

Fig. 4.12 - The percentage of favourable and unfavourable habitats predicted for *P. syriacus* in Maxent.

4.3. Conclusions

Modelling the distribution of several species of reptiles and amphibians

The prediction models offer us a particular image about the species distribution in terms of using standard parameters and medium to high resolution data such as the bioclim variables from Worldclim and the digital elevation models of 90 m resolution. We can observe the limitations of some models that need an additional input of data with higher accuracy or a revision of the used ones.

The prediction models can be improved and need to be calibrated for better results. Nevertheless, algorithms such as Maxent may offer us valuable results that need to be validated in the field, concurrently with repeating the models with input of new samples or variables.

The techniques described herein demand a longer learning curve, but once mastered they may produce an efficient management of spatial information. The efficient collection and spatial analyses of data required for the management of one or more species are necessary and preceding steps to a predictive modelling process with decent results. On the criterion “Garbage in, garbage out”, the more detailed and accurate bioclim variables (temperature, precipitations) or other terrain factors such as altitude or slope that may be accounted for limiting factors of the studied species, the better the predictive model will be. The most important factors that contributed to the predictive modelling of the species were the precipitation and temperature variables.

The bioclimatic variables offered by Worldclim at a resolution of 30 arc seconds (~ 1km) do not accurately represent the regional climate in Dobrogea because of the interpolation of data from few meteorological stations included in the international network. There are necessary climate data with higher accuracy from national agencies such as the National Administration of Meteorology of Romania. Furthermore, the horizontal accuracy of the distribution data of over 1 km and the altitude values extracted from the SRTM v4.1 digital elevation model induced high errors in estimating the altitudinal distribution of the species, thus the predictive distribution is overestimated.

The necessity of predictive modelling such as the case of the spur-thighed tortoise in Dobrogea or the other two species *Pelobates fuscus* and *P. syriacus*, helps the specialists and the managers of protected areas, exactly because of the inconvenience in researching large areas through direct observation methods.

The modelling of spatial distributions also allow evaluating the efficiency of the network of natural protected areas and is a useful tool in designating new protected areas.

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Annex 1. The author's scientific papers based on this doctoral thesis

Scientific article forwarded for publishing

1. Ruben, I., Papeş, M., Samoilă, C., Cogălniceanu, D. (xxxx). Climate induced shifts in the niche similarity of two related spadefoot toads (genus *Pelobates*). *Journal of Biogeography.*

Scientific article published in ISI journals

1. Cogălniceanu, D., Szekely, P., **Samoilă, C.**, Ruben, I., Tudor, M., Plăiaşu, R., Stănescu, F. şi Rozylowicz, L. (2013). Diversity and distribution of amphibians in Romania. *ZooKeys* 296:35-37. doi.10.3897/zookeys.296.4872
2. Cogălniceanu, D., Rozylowicz, L., Szekely, P., **Samoilă, C.**, Stănescu, Florina, Tudor, M., Szekely, Diana şi Ruben, I. (2013). Diversity and distribution of reptiles in Romania. ZooKeys 341:49-76.
3. Băncilă, R., Plăiaşu, R., Tudor, M., **Samoilă, C.** şi Cogălniceanu, D. (2012). Fluctuating asymmetry in the Eurasian Spur-Thighed Tortoise, *Testudo graeca ibera* Linneaus, 1758 (Testudines: Testudinidae). Chelonian Conservation and Biology, 11(2): 234-239.
4. Cogălniceanu, D., Băncilă, R., Plăiaşu, R., **Samoilă, C.** şi Hartel, T. (2012). Aquatic habitat use by amphibians with specific reference to *Rana temporaria* at high elevations (Retezat Mountains National Park, Romania). *Annales de Limnologie - International Journal of Limnology*, **48**:355-362.
5. Plăiaşu, Rodica, Băncilă, Raluca, **Samoilă, C.**, Hartel, T. şi Cogălniceanu, D. (2012). Aquatic habitat availability and use by amphibian communities in a rural landscape. *Herpetological Journal,* **22**: 13-21.

Scientific articles published in ISI journals – no impact factor

1. Cogălniceanu, D., **Samoilă, C.**, Tudor, M. şi Tallowin, O. (2010). An extremely large spur-thighed tortoise male (*Testudo graeca*) from Măcin Mountains National Park, Romania, *Herpetology Notes*, **3**: 45-48.

Scientific articles in journals rated by CNCSIS B+

1. Plăiaşu, Rodica, Băncilă, Raluca, **Samoilă, C.** şi Cogălniceanu, D. (2010). Distribution and habitat use by amphibian communities in Retezat National Park. *Travaux du Museum d'Histoire Naturelle "Grigore Antipa",* **53**:469-478.
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