Research Article

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Actual and Potential Distribution of the European Pond Turtle, *Emys orbicularis* (L., 1758) in Serbia, with Conservation Implications

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Abstract: Although the European Pond Turtle (*Emys orbicularis*) attracts considerable conservation efforts across its distribution range, in Serbia, it is understudied and assessed as Data Deficient at the national level. We surveyed approximately 10% of the territory of Serbia and noted turtles at 76 separate 10 × 10 km MGRS squares, 43 of which were noted for the first time. Turtles were usually observed in oxbows, scattered small water bodies, canals and in water-filled and vegetated, abandoned gravel pits. Models with these accurate distribution data and set of climate, topographic and land cover variables are used to explain the turtle's ecological niche and predict where the species presence is to be expected in Serbia. In Vojvodina, turtles are limited to industrial, urban and semi-natural habitats not used for agriculture, while in the rest of Serbia it occurs in more natural habitats and small scale agriculture practice even seems to be preferred. Further studies are necessary for adequate management planning and effective protection of *E. orbicularis* in Serbia. More data on distribution need to be collected, especially in central and southern Serbia. Conservation efforts should focus to prevent illegal collection of turtles and destruction of their habitats i.e. should control illegal dumping places and overusing of agriculture machinery and chemicals.

Key words: ecological niche model, species distribution model, Maxent, habitat suitability, Emydidae, Balkans

Introduction

The European Pond Turtle, *Emys orbicularis* (Linnaeus, 1758) (Testudines: Emydidae), is the only autochthonous species of freshwater turtle in Serbia (Krizmanić et al. 2015). Its natural distribution includes most of Europe (except north and parts of centre), western Asia and northern Africa (Arnold & Ovenden 2002). At the international level, the European Pond Turtle attracts considerable conservation efforts. It was recognized as Near Threatened in the IUCN Red List (Tortoise and Freshwater Turtle Specialist Group 2016), listed in Annexes II and IV of the Habitats Directive (European Commission, No. 92/43/EEC a, b) and Appendix II of the Bern Convention on the Conservation of European Wildlife and Natural Habitats (Council of Europe, 1979).

In Serbia, *E. orbicularis* was protected as natural rarity since 1993 (Official Gazette of the Republic of Serbia, No. 50/93, 93/93) and is now considered strictly protected (Official Gazette of the Republic of Serbia, No. 5/10). After substantial efforts to collect all available literature and unpublished field data (Krizmanić et al. 2015), it was assigned to the Data Deficient category at the national level (Red Book of Fauna of Serbia II – Reptiles: Krizmanić & Džukić 2015). Furthermore, the only so far realized project dedicated to *E. orbicularis* was restricted to the Vojvodina province, north of the Danube and Sava rivers (Crnobrnja-Isailović & Mesaroš 2013). Consequently, this part of the Pannonian Plain represents approximately 68% of the so far known distribution range of this species in Serbia (Krizmanić et al. 2015). On the other hand, the central part of the country was not previously studied, thus a vast area of potentially suitable habitats remained unexplored.

The high level of both international and national protection, along with general lack of faunistic and ecological records on *E. orbicularis* in Serbia, raised the urgency for gathering additional data (Krizmanić et al. 2015). This triggered our field studies on the distribution of the turtle and threats to its habitats. Here we present all distribution data gathered to date on *E. orbicularis* in Serbia. Also, we constructed an ecological niche model and a habitat suitability map, to aid in future research and conservation actions.

Materials and Methods

We performed field surveys from May to September 2015, corresponding to the period of highest activity of the animals. Most of the effort was dedicated to small ponds near large watercourses which were neglected in previous studies (Velika Morava, Zapadna Morava, Južna Morava, Drina, Kolubara, Mlava, Pek and Timok). Beside targeted surveys in 2015, the data included individual observations covering period from 2001 to 2016, and significant proportion of these observations came from numerous volunteers. Turtles were usually recorded during aerial or water-surface basking (including the use of binoculars) and on few occasions they were caught in funnel traps (150 cm long and 50 cm in diameter) baited with fish offal. The data used in this study included only species presence, regardless of its population size.

To make an overview of known distribution of the pond turtles in Serbia, gathered data were first overlapped with recently published records by Krizmanić et al. (2015) and shown as a MGRS 10 × 10 km map. We created an ecological niche model to get insights into the ecological requirements and potential distribution of *E. orbicularis* (details in: Guisan & Zimmermann 2000, Elith & Leathwick 2009, Sillero 2011) using Maxent v. 3.3.3k (Phillips & Dudík 2008). Maxent was run through the 'dismo' package in R v. 3.3.1 (R Core Team 2016). Before any analysis, occurrences (observations of turtles given in Table S1.1) were subsampled by randomly selecting single occurrence within each 10 × 10 km MGRS square. This procedure helps to remove sampling bias and increases model accuracy (Fourcade et al. 2014). Known occurrences were compared to 10000 background (pseudo-absence) points randomly sampled in 100 km buffer zone surrounding the confirmed occurrences (Barbet-Massin et al. 2012).

Environmental parameters were extracted from a set of freely available GIS layers: Bioclim (Hijmans et al. 2005), digital elevation model (EEA 2013a), NDVI (LP DAAC 2000) and land cover (EEA 2013b). All layers were reprojected to ETRS89 / ETRS-LAEA coordinate reference system and resampled to the highest resolution layer, digital elevation model with a pixel size of 25 m^2. We used bilinear interpolation for layers with numerical variables and near interpolation for layer with categorical predictors (i.e. land cover). Bioclim is a set of 19 variables representing biologically meaningful interpretation of precipitation and temperature over a 30 years period. We selected only five Bioclim variables which are not autocorelated and enable simple, straightforward interpretation of the results. These were: annual mean temperature and precipitation variables, their seasonality and isothermality. GRASS GIS v. 7.0.1 software (Neteler et al. 2012) was used to calculate slope, aspect northeness and aspect eastness from the digital elevation and also to produce average, minimal and maximal value NDVI layers out of the original 15-days NDVI composite acquired in 2009–2013. NDVI (Normalized Difference Vegetation Index) or so called "greenness index" provides remote sensed, usually satellite acquired, data about plant productivity i.e. photosynthetic activity. We believe this index could detect aquatic habitats and/or dense vegetation surrounding ponds where the turtles naturally occur. Our ecological niche model thus included variables describing climate (Bioclim), topography (slope and aspect) and species habitats (land cover and NDVI) (Table 1).

After fitting the ecological niche model, we evaluated its performance, using the modified null-model validation procedure of Raes & ter Steege (2007). This involved sampling the same number of random points as the original number of occurrences and fitting the null-model. To minimise the chance of error, the procedure was repeated 100 times. At the end, we compared AUC values of species niche model and 100 randomly constructed null-models using one sample t-test (one tailed test, alternative hypothesis $\mu < \mu_0$). After model validation, final maps were shown as Maxent's logistic output and visually arranged in QGIS v. 2.16.1 (QGIS Development Team 2009).

Contribution of variables was assessed using Maxent's contribution table and Jackknife analysis.

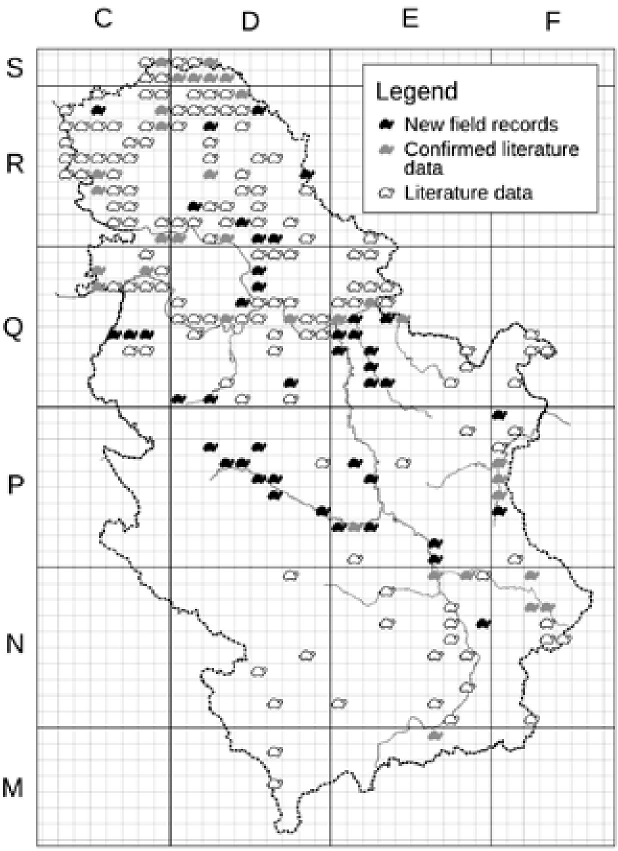

Fig. 1. Records of European Pond Turtle in Serbia shown on MGRS map (zone 34T). Letters represent large 100 × 100 km MGRS squares displayed as thick lines, while small grid cells are given in thin lines delimiting areas of 10 × 10 km

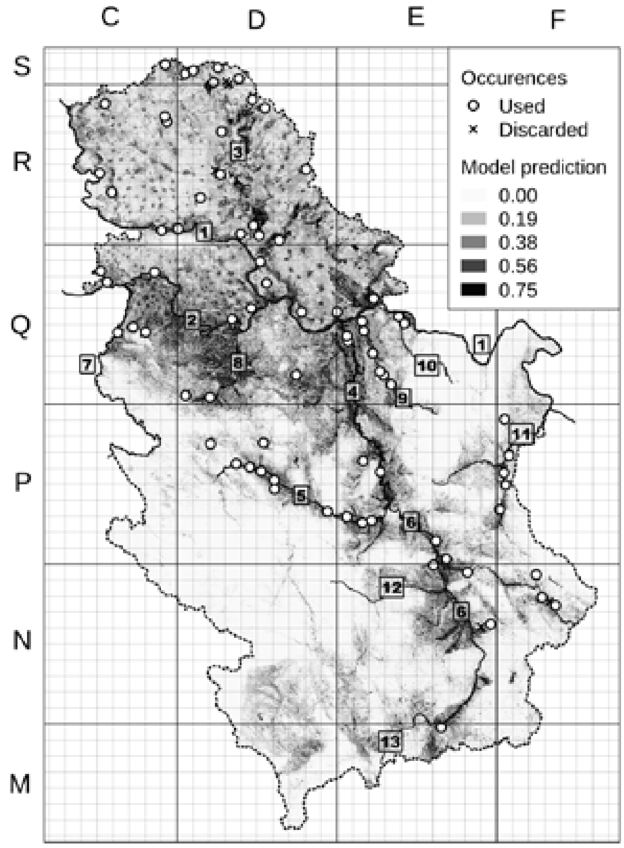

Fig. 2. Habitat suitability (with MGRS grid) for the European Pond Turtle in Serbia predicted by the Maxent ecological niche model using a set of climatic, topographic and habitat layers. The levels of gray on the map are showing Maxent's logistic output, i.e. probability of species presence ranging between 0 and 1. Numbered Rivers: 1. Danube, 2. Sava, 3. Tisa, 4. Velika Morava, 5. Zapadna Morava, 6. Južna Morava, 7. Drina, 8. Kolubara, 9. Mlava, 10. Pek, 11. Timok, 12. Toplica, 13. Binačka Morava

In the Jackknife procedure the model was fitted multiple times and each time one of the variables was excluded from it. In addition, univariate models were fitted and the gain of all fits was visually compared. Variables that best explain the species' ecological niche should have good gain when used alone and decrease the model gain if excluded. Effects of the most important variables on the species distribution were explored using their response curves. For this purpose, only univariate models were used, to exclude the possibility of inadequate responses of correlated variables.

We should note that ecological niche model created an obscure response for land cover variable (Fig. 2). Assuming this response came due to different habitat characteristics in Vojvodina province and the rest of the country, we divided occurrence records and made two separate ecological niche models to ease the interpretation of the results (Supplementary data 2).

Results

Data gathered during this study covered 100 MGRS squares of 10 × 10 km, which is about 10% of the territory of Republic of Serbia. We gathered a total of 90 occurrences of *E. orbicularis* across 76 separate MGRS squares, while in 24 squares the turtle presence could not be confirmed (Fig. 1; Table S1.1). Out of 76 squares where the species was recorded, 43 are noted for the first time, while in 33 the presence of *E. orbicularis* was already known from literature.

After subsampling of the occurrence records, 76 of them remained to be used for niche modelling. The model reported an AUC value of 0.93, which

Table 1. List of variables with resolution of raster layers used in ecological niche model of European Pond Turtle. Relative percentage of contribution for each variable to the final model, and their permutational importance are taken from Maxent results page

Name of the variable	Layer resolution (m)	Contribution (%)	Permutational importance (%)
Slope	30	33	22
Land Cover	100	31	22
NDVI Maximum	250	12	14
Isothermality	1000	6	1
Temperature Seasonality	1000	6	15
Annual Mean Temperature	1000	4	17
Aspect Northness	30	2	1
Annual Precipitation	1000	2	7
Precipitation Seasonality	1000	2	1
Aspect Eastness	30	1	1
NDVI Average	250	1	1
NDVI Minimum	250	0	0

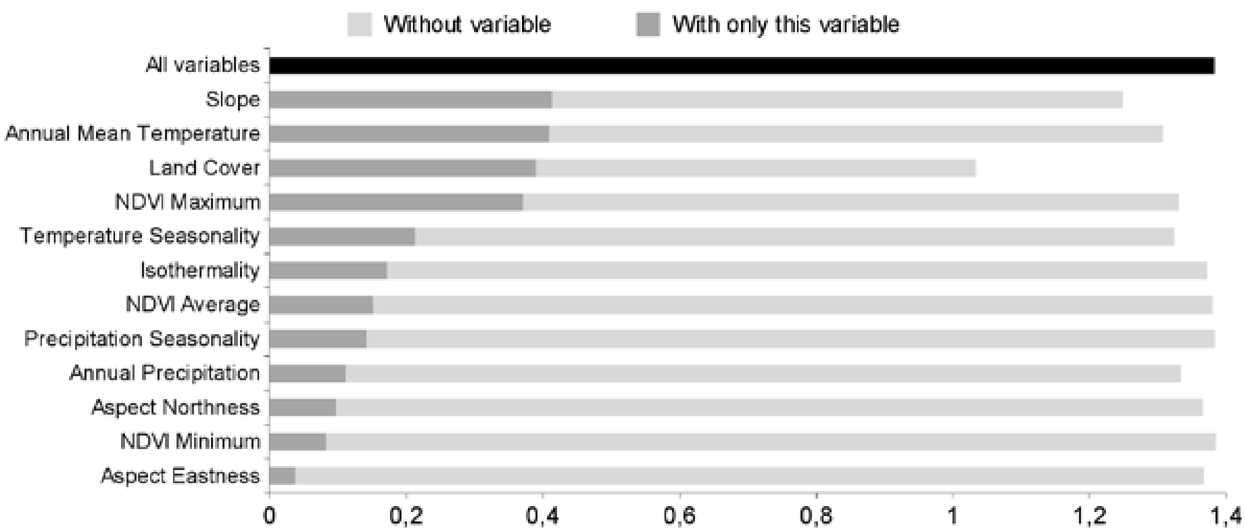

Fig. 3. Jackknife test of variable importance in modelling ecological niche of European Pond Turtle. A variable contains more useful information if it achieves higher gain when used alone and if it lowers the gain when excluded

was significantly higher than the mean AUC value of 0.73 (range: 0.67–0.80) reported from null models ($p = 2\times10^{-16}$). This proved that the *E. orbicularis* niche model performed better than the random null-models, and allowed us to use it for further analysis.

Overall, the model suggested that potentially suitable areas for *E. orbicularis* exist throughout Serbia, mainly in flatland and lowland areas, and along larger watercourses (Fig. 2). Obtained habitat suitability map matches the already known distribution (Figs. 1, 2). According to the literature data, southern part of the country seems to be well predicted, even though precise observations from this region were not available for fitting the model.

Slope (33%) and land cover (31%) were by far the most significant predictors, followed by temperature variables (16%) and NDVI (13%) which also considerably contributed to the model prediction (Table 1), while annual precipitation is not shown as a direct limiting factor for this species. These results are also supported by permutational importance of the variables (Table 1) and Jackknife analysis (Fig. 3) which additionally emphasised the importance of temperature. Response curves of the three most significant numerical variables suggest that *E. orbicularis* prefers annual mean temperatures above 10°C, flatlands with slope under 10 degrees and open areas rather than dense forests (Fig. 4a-c). Looking at the land cover response curves (Fig. 4d), there is no clear preference for any habitat type. However, separate analysis for Vojvodina region shows that the habitats are mostly associated with industrial or commercial

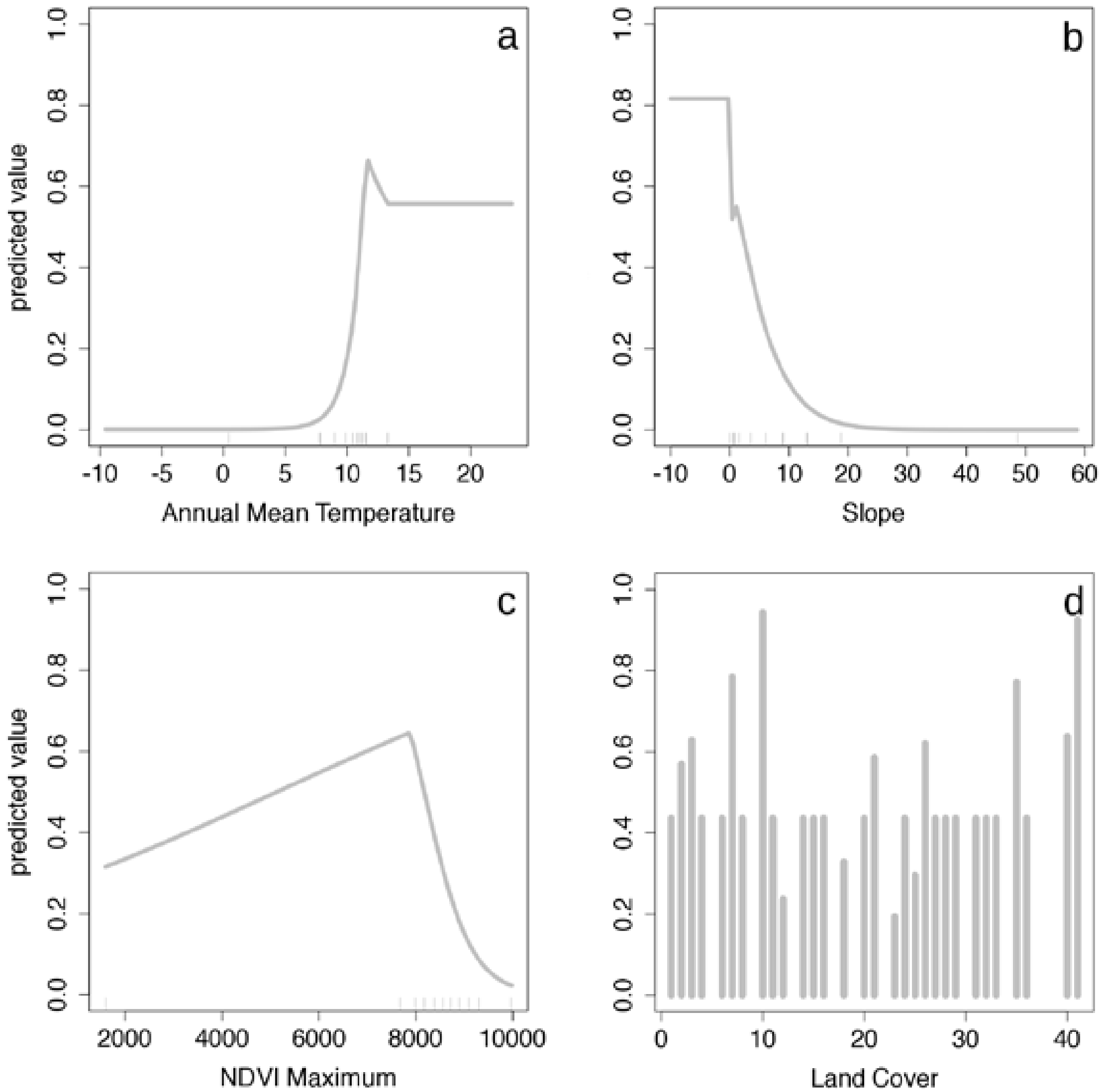

Fig. 4. Response curves of four most important variables affecting ecological niche model of European Pond Turtle. Annual mean temperature is given in °C, while slope is given in degrees. NDVI index is remote sensed data showing vegetation greenness and has no measuring units. Land cover variable is given as classes of land cover types (see EEA 2013b for details)

units, mineral extraction sites, green urban areas, natural grasslands, inland water bodies and water courses (Fig. S2.2). On the other hand, habitats south of Danube and Sava Rivers are primarily associated to inland marshes and land principally occupied by agriculture, with significant areas of natural vegetation (Fig. S2.5). Generally, it seems that all analysed predictor variables have wider response curves in Vojvodina comparing to Serbia south from Danube and Sava Rivers (Figs. S2.2, S2.5).

Discussion

Although *E. orbicularis* is one of the conservation priority species in Europe, and strictly protected in Serbia, data on its distribution, population status and threatening factors on a national level are scarce. The most evident contribution of the present publication are new observations of the European Pond Turtle in central Serbia (Fig. 1), especially along rivers Zapadna Morava and Mlava, where the species is abundant, although not previously recorded (see Krizmanić et al. 2015). Good overlapping of habitat suitability map (Fig. 2) and literature data (Fig. 1) suggested that niche models could also be a valuable aid in planning faunistic studies and in discovering previously undetected populations of rare and threatened species (e.g. Kumar & Stohlgren 2009, Verovnik et al. 2014, Fois et al. 2015). Habitat suitability map points out further surveys in central and southern Serbia i.e. regions along Velika Morava, Kolubara, Pek, Binačka Morava and Toplica rivers to extend the known distribution of the European Pond Turtle. This map and knowledge about the location of small water bodies could help us to quickly locate unrecorded habitats of pond turtle. This way we could allocate the usually limited resources to the most suitable areas and possibly facilitate conservation actions.

Our model showed that slope, land cover, temperature and vegetation index could significantly explain the European Pond Turtle's ecological niche in Serbia (Figs. 3, 4, Supplementary data 2). The true potential of exploring ecological niche of this species came when distribution ranges were analysed separately for the area north and south of Danube and Sava Rivers (Supplementary data 2). It seems that habitats of European Pond Turtles in Vojvodina have wider ecological responses for land cover, temperature and NDVI (Figs. S2.2, S2.5). Facing the threat from agricultural intensification, it is possible that turtles are forced to use wider range of the remaining, scarce habitats. To complement this conclusion, the prevailing effect on distribution of this species in Vojvodina came from just a single variable which explains current land use practices (Table S2.1, Fig. S2.1). Additionally, Vojvodina is characterised by flatland terrain, thus small contribution of topographic variables is expected. In rest of Serbia, where agriculture is not so intensive and natural habitats are relatively preserved, climate and topography played more important roles (Table S2.2, Fig. S2.4). However, we should be cautious since the choice of variables and their mutual relations could strongly affect our results. Variables might be associated with other factors (such as soil characteristics, food availability and microhabitat features), which could additionally affect the distribution of the species (Guisan & Zimmermann 2000).

Available distribution data for Vojvodina province suggest that the European Pond Turtle is abundant in this region (see Krizmanić et al. 2015 and this paper, Fig. 1). This is also suggested by habitat suitability map (Fig. 2), but could lead to an erroneous conclusion that populations here are abundant and healthy. Vojvodina underwent considerable changes (e.g. drainage, irrigation, agricultural chemical and mechanical treatments), especially during the last 300 years: currently 92% of its territory, i.e. 2 million ha, is suitable for agricultural use (Dragović et al. 2005) hence the largest portion of its area quickly become unsuitable for wildlife. Turtles in Vojvodina seem to prefer habitats in urban, industrial or seminatural areas, while they avoid land used for intensive agriculture (Fig. S2.2). Turtles are observed in scattered, usually small water bodies which still have not been drained for human usage, or along the artificial canals which crisscross this region. Evidently this is not a sole example, since *E. orbicularis* were noticed in similar habitats in other parts of the species range (e.g. Kotenko 2004). Turtles can freely roam across the vast area of Vojvodina through a network of canals of 20,000 km in total length (Dragović et al. 2005), and presumably they form a large metapopulation with restricted gene flow. This hypothesis should be explored in future genetic and population studies.

In other parts of Serbia, *E. orbicularis* is found in areas that are under lower anthropogenic influences, including marshland areas and places with low intensity agriculture (Fig. S2.5). Two types of habitats are typical for this species here: oxbows and water-filled abandoned gravel pits. Natural oxbows are rare nowadays, and their number still decrease due to human maintenance of river courses. On the other hand, existing gravel mining practice results in creation of artificial ponds, which, once abandoned, become suitable habitats for *E. orbicularis*. Considering that effects of quality of aquatic and terrestrial habitats on the distribution of the turtle are still not fully understood (Ficetola et al. 2004 and references therein), it is possible that water-filled abandoned gravel pits could have played a significant role in survival and distribution of the species in recent history. However, biodiversity recovery rates after gravel mining are yet to be explored (Price et al. 2005, Kowalska & Sobczyk 2014, Klimaszewski et al. 2015).

Populations of the European Pond Turtle seem to decline across the species' range and most of conservation efforts are focused on preservation of sparse and isolated populations, or at species' reintroduction into areas it already disappeared from (Cadi & Miquet 2004, Mignet et al. 2014, Masin et al. 2015 and references therein). Despite dedication, current reintroduction efforts on wild animal populations are shown to have limited efficiency, with only one-third being successful (Tavecchia et al. 2009 and references therein), while effectiveness of reptiles' reintroduction is considered to be even lower (Dodd & Seigel 1991 and references therein). On the other hand, in Serbia *E. orbicularis* is evidently understudied, while populations seem to be in good condition. This calls for additional studies and urgent adoption of management plans, for timely protection of this species. Effective conservation of healthy populations and their habitats requires far less effort and funding than attempts of restoration of severely degraded habitats and declined populations.

Along with further research on distribution of *E. orbicularis*, long-term population studies should be established across this turtle's range. As far as we know, the first long-term (Capture-Mark-Recapture) population study in Serbia was established six years ago at Ludaš Lake, at the very north of Vojvodina (Grabovac & Golubović, unpublished data) and another study was started during 2015 in central Serbia (Golubović & Popović, unpublished data). Education of residents, precluding of illegal collecting of turtles from nature and preventing destruction of their habitats (i.e. control of illegal dumping and overusing of agriculture machinery and chemicals) should be further conservation steps for protecting this threatened species in Serbia.

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Supplementary Materials: This article is associated with supplementary materials, which are available in the online version only.

References

Arnold E. N. & Owenden D. W. 2002. A field guide to the reptiles and amphibians of Britain and Europe. London: Harper Collins Publishers Ltd. 288 p.

Barbet-Massin M., Jiguet F., Albert C. H. & Thuiller W. 2012. Selecting pseudo-absences for species distribution models: how, where and how many? Methods in Ecology and Evolution 3 (2): 327–338.

Cadi A. & Miquet A. 2004. A reintroduction programme for the European Pond Turtle (*Emys orbicularis*) in Lake Bourget (Savoie, France): first results after two years. Biologia, Bratislava 59 (Suppl. 14): 155–159.

Crnobrnja-Isailović J. & Mesaroš G. 2013. Conservation activities for the European Pond Turtle (*Emys orbicularis*) in Serbia. Herpetology Notes 6: 119–121.

Dodd C. K. & Seigel R. A. 1991. Relocation, repatriation, and translocation of amphibians and reptiles: are they conservation strategies that work? Herpetologica 47: 336–350.

Dragović S., Maksimović L., Radojević V., Cicmil M. & Pantelić S. 2005. Historical development of soil water regime management using drainage and irrigation in Vojvodina. Vodoprivreda 37 (4–6): 287–298.

EEA 2013a. Digital elevation model over Europe (EU-DEM). The European Environment Agency. Available at: http://www.eea.europa.eu/data-and-maps/data/eu-dem (accessed on 29/11/2015).

EEA 2013b. Corine Land Cover 2006 raster data, version 17. The European Environment Agency. Available at: http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2006-raster-3 (accessed on 25/12/2014).

Elith J. & Leathwick J. R. 2009. Species distribution models: ecological explanation and prediction across space and time. Annual Review of Ecology, Evolution, and Systematics 40 (1): 677–697.

Ficetola G. F., Padoa-Schioppa E., Monti A., Massa R., Bernardi F. D. & Bottoni L. 2004. The importance of aquatic and terrestrial habitat for the European Pond Turtle (*Emys orbicularis*): implications for conservation planning and management. Canadian Journal of Zoology 82 (11): 1704–1712.

Fois M., Fenu G., Cuena Lombraña A., Cogoni D. & Bacchetta G. 2015. A practical method to speed up the discovery of unknown populations using species distribution models. Journal for Nature Conservation 24: 42–48.

Fourcade Y., Engler J. O., Rödder D. & Secondi J. 2014. Mapping species distributions with Maxent using a geographically biased sample of presence data: a performance assessment of methods for correcting sampling bias. PLoS ONE 9 (5): e97122.

Guisan A. & Zimmermann N. E. 2000. Predictive habitat distribution models in ecology. Ecological modelling 135 (2): 147–186.

Hijmans R. J., Cameron S. E., Parra J. L., Jones P. G. & Jarvis A. 2005. Very high resolution interpolated climate surfaces for global land areas. International journal of climatology 25 (15): 1965–1978.

Klimaszewski K., Pacholik E. & Snopek A. 2015. Can we enhance amphibians' habitat restoration in the post-mining areas? Environmental Science and Pollution Research doi 10.1007/s11356-015-5279-8.

Kotenko T. 2004. Distribution, habitats, abundance and problems of conservation of the European Pond Turtle (*Emys orbicularis*) in the Crimea (Ukraine): first results. Biologia, Bratislava 59 (Suppl. 14): 33–46.

Kowalska A. & Sobczyk W. 2014. Valuable deposits of sand and gravel in the valleys of Carpathian rivers (Poland) VS protected areas. Journal of the Polish Mineral Engineering Society 15 (1): 167–174.

Krizmanić I. & Džukić G. 2015. European Pond Turtle *Emys orbicularis* Linnaeus, 1758 – In: Tomović L., Kalezić M. L. & Džukić G. (Eds.): Red Book of Fauna of Serbia II – Reptiles. Belgrade: Faculty of Biology, University of Belgrade and Institute for Nature Conservation of Serbia, pp. 137–143.

Krizmanić I., Urošević A., Simović A., Krstić M., Jović D., Ajtić R., Anđelković M., Slijepčević M., Đorđević S., Golubović A., Žikić V. & Džukić G. 2015. Updated distribution of the European Pond Turtle *Emys orbicularis* (Linnaeus, 1758) and its conservation issues in Serbia. Archives of Biological Sciences 67 (3): 1043–1053.

Kumar S. & Stohlgren T. J. 2009. Maxent modeling for predicting suitable habitat for threatened and endangered tree *Canacomyrica monticola* in New Caledonia. Journal of Ecology and the Natural Environment 1 (4): 094–098.

LP DAAC 2000. Vegetation Indices 16-Day L3 Global 250m (MOD13Q1 product). USGS/Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota. Available at: https://lpdaac.usgs.gov/data_access (accessed on 14/1/2015).

Masin S., Ficetola G. F. & Bottoni L. 2015. Head starting European Pond Turtle (*Emys orbicularis*) for reintrodution:

patterns of growth rates. Herpetological Conservation and Biology 10 (Symposium): 516–524.

Mignet F., Gendre T., Reudet D., Malgoire F., Cheylan M. & Besnard A. 2014. Short-term evaluation of the success of a reintroduction program of the European Pond Turtle: the contribution of space-use modeling. Chelonian Conservation and Biology 13 (1): 72–80.

Neteler M., Bowman M. H., Landa M. & Metz M. 2012. GRASS GIS: a multi-purpose Open Source GIS. Environmental Modelling & Software 31: 124–130.

Phillips S. J. & Dudík M. 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography 31 (2): 161–175.

Price O., Milne D. & Tynan C. 2005. Poor recovery of woody vegetation on sand and gravel mines in the Darwin region of the Northern Territory. Ecological Management and Restoration 6 (2): 118–123.

QGIS Development Team 2009. QGIS Geographic Information System. Open Source Geospatial Foundation.

Raes N. & ter Steege H. 2007. A null-model for significance testing of presence-only species distribution models. Ecography 30 (5): 727–736.

R Core Team 2016. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Sillero N. 2011. What does ecological modelling model? A proposed classification of ecological niche models based on their underlying methods. Ecological Modelling 222 (8): 1343–1346.

Tavecchia G., Viedma C., Martínez-Abraín A., Bartolomé M. A., Gómez J. A. & Oro D. 2009. Maximizing re-introduction success: assessing the immediate cost of release in a threatened waterfowl. Biological Conservation 142 (12): 3005–3012.

Tortoise and Freshwater Turtle Specialist Group. 2016. *Emys orbicularis*. The IUCN Red List of Threatened Species 2016: e.T7717A97292665. Downloaded on 27 August 2016.

Verovnik R., Popović M., Šašić M., Cuvelier S. & Maes D. 2014. Wanted! Dead or alive: the tale of the Brown's Grayling (*Pseudochazara amymone*). Journal of Insect Conservation 18 (4): 675–682.

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Supplementary Data 1

Table S1.1. Exact coordinates with altitude (Alt.) where European Pond Turtles were observed in Serbia during our study. Novel 10 × 10 km MGRS squares (zone 34T) are bolded. For observations made by authors initials are given instead of full names

Latitude (N)	Longitude (E)	Alt.	MGRS	Observer	Year	Locality
44°55'35.29"	19°10'46.27"	80	CQ57	D. G.	2016	Bosutska šuma
44°59'16.65"	19°07'35.97"	82	CQ58	D. G.	2016	Bosutska šuma
44°38'38.39"	19°16'15.60"	103	**CQ64**	A. G., M. P.	2015	Lešnica
44°40'34.83"	19°23'27.44"	97	**CQ74**	Slobidan Puzović	2016	Poćerski kanal
44°38'40.60"	19°28'45.89"	145		Slobidan Puzović	2016	Stream Bela reka
44°38'59.29"	19°29'28.14"	125	**CQ84**	Slobidan Puzović	2016	Vlg. Bela reka
44°59'18.58"	19°33'11.28"	73	CQ88	Marko Šćiban	2015	Laćarak
45°25'59.81"	19°11'57.59"	79	CR53	D. G., Varga Balaž	2015	Bač
45°32'18.63"	19°5'59.89"	77	CR54	D. G., Viktor Sabo	2010	Bogojevo
45°55'47.51"	19°7'42.04"	86	**CR58**	Jelena Šeat	2015	Kruševlje
45°13'26.15"	19°36'9.889"	74	CR90	D. G.	2011	Begečka jama
45°50'13.98"	19°37'48.83"	91	CR97	Šandor Klimo	2015	Bačka Topola
45°51'59.06"	19°36'47.19"	91	CR98	Jožef Dožai	2009	Bačka Topola
46°9'26.94"	19°36'32.77"	122	CS91	D. G., Jožef Dožai	2012	Kelebija
44°1'32.40"	20°0'47.40"	671	**DP27**	Brano Rudić	2015	Tometino polje
43°54'54.48"	20°12'59.42"	271	**DP36**	Uroš Pantović	2015	Ovčar banja
43°54'59.11"	20°12'56.12"	271				
43°53'56.75"	20°19'24.59"	242	**DP46**	Dragiša Petrović, A. G., M. P.	2015	Suva Morava
43°53'53.10"	20°19'22.53"	242				
43°53'48.13"	20°20'4.671"	240		Uroš Pantović	2012	Suva Morava
43°53'51.99"	20°19'18.10"	242				Trbušani
43°52'28.56"	20°24'38.87"	226	**DP55**	A. G., M. P.	2015	Baluga
44°2'5.359"	20°25'35.26"	430	**DP57**	Miroslav Miljević	2015	Brusnica
43°46'30.79"	20°30'55.36"	248	**DP64**	M. P.	2015	Samaila
43°49'32.88"	20°30'48.96"	209	**DP65**	A. G., M. P.	2015	Katrga
43°38'58.55"	20°55'37.19"	166	**DP93**	A. G., M. P.	2015	Vrnjci
44°17'48.78"	19°48'45.25"	229	**DQ00**	Vladan Vučković	2010	Bukovica
44°17'17.16"	20°0'17.27"	143	**DQ20**	A. G., M. P.	2015	Divci
44°43'47.97"	20°10'15.30"	69	DQ35	A. G., Sonja Đorđević	2014	Živača
44°47'33.36"	20°19'21.72"	68	**DQ46**	A. G.	2016	Galovica
45°57'58.43"	20°18'59.74"	74	DQ49	Aleksandar Lazić	2016	Letkov salaš
44°56'01.31"	20°26'29.17"	68	**DQ57**	Milan Đurić	2014	Lisičiji jarak
45°3'19.14"	20°23'23.00"	70	**DQ58**	Tamara Karan Žnidaršič	2015	Opovo
44°25'1.750"	20°40'49.06"	160	**DQ71**	Maniša Ribar	2015	Mladenovac
44°46'23.91"	20°43'14.88"	68	DQ75	Slobodan Panjković	2015	Omoljica
45°14'4.398"	19°44'4.808"	77	DR00	Slobodan Ivković	2014	Futog
45°24'20.63"	19°53'38.55"	81	**DR12**	Deneš Varga	2015	Temerin
45°24'40.20"	19°54'32.51"	76				
45°33'55.86"	20°1'36.36"	68	DR24	D. G., Varga Balaž	2015	Bečej
45°32'37.37"	20°3'58.43"	69		D. G., Bohocki Zoltan	2015	Bačko Gradište
45°47'5.089"	20°4'20.55"	73	**DR27**	D. G.	2009	Ada
45°12'36.47"	20°13'58.76"	74	DR30	D. G.	2009	Lok

45°15’27.65”	20°20’0.589”	65	**DR41**	D. G.	2008	Ečka
45°59’9.211”	20°19’12.54”	74	DR49	D. G., Anita Šušić	2015	Vrbica
45°12’06.04”	20°22’45.85”	80	**DR50**	Tamara Karan Žnidaršič	2016	Perlez
45°55’11.83”	20°25’8.439”	74	**DR58**	D. G., Stevan Popadić	2015	Mokrin
45°10’33.54”	20°32’28.62”	70	**DR60**	Slobodan Ivković	2015	Idvor
45°34’37.34”	20°45’38.49”	73	**DR84**	D. G., Varga Balaž	2015	Srpski Itebej
45°34’32.13”	20°45’13.03”	77		Ivan Ilievski		
46°6’25.88”	19°46’16.25”	100	DS00	D. G.	2012	Subotica
46°7’37.44”	19°50’11.41”	99	DS10	D. G., Jožef Dožai	2011	Bački Vinogradi
46°3’40.29”	20°0’5.641”	79	DS20	D. G.	2015	Kanjiža
46°8’40.41”	20°2’9.531”	71	DS21	D. G., Viktor Sabo	2010	Martonoš
46°3’7.588”	20°7’37.45”	71	DS30	D. G.	2015	Novi Kneževac
46°5’2.889”	20°12’23.15”	72			2015	
46°04’04.94”	20°06’12.58”	73			2016	
42°25’52.64”	21°47’33.87”	430	EM69	Miroslav Miljević	2016	Žuželjica
43°20’42.69”	21°44’43.50”	247	**EN69**	Bojan Zlatković	2016	Lalinačka slatina
43°18’8.704”	22°0’24.65”	205	EN89	M. P.	2011	Niška banja
42°59’43.45”	22°6’17.74”	356	**EN96**	Vladica Stojadinović	2001	Jezero Šišava
43°0’33.36”	22°10’48.34”	691			2005	Kruševica
43°37’12.71”	21°4’36.83”	159	**EP02**	A. G., M. P.	2015	Medvedja
43°35’9.960”	21°11’49.55”	147	EP12	A. G., M. P.	2015	Bresno Polje
43°56’01.92”	21°12’13.55”	151	**EP16**	Đorđe Jocić	2016	Dragocvet
43°35’52.07”	21°16’10.92”	139	**EP22**	A. G., M. P.	2015	Čitluk
43°52’18.44”	21°20’17.88”	119	**EP25**	A. G., M. P.	2015	Trešnjevica
43°22’48.00”	21°50’41.99”	299	**EP60**	Slobodan Ivković	2015	Čamurlija
43°28’55.21”	21°46’0.461”	167	**EP61**	A. G., M. P.	2015	Katun
44°36’30.20”	21°5’13.81”	71	**EQ03**	A. G., M. P.	2015	Dragovac
44°38’18.34”	21°4’43.46”	72	**EQ04**	A. G., M. P.	2015	Živica
44°46’26.40”	21°0’3.960”	74	EQ05	A. G., Sonja Đorđević, Imre Krizmanić	2015	Kovin
44°39’58.32”	21°12’44.99”	75	**EQ14**	A. G., M. P.	2015	Ćirkovac
44°43’13.08”	21°11’53.87”	71	**EQ15**	A. G., M. P.	2015	Drmna
44°25’0.119”	21°21’57.59”	110	**EQ21**	A. G., M. P.	2015	Trnovce
44°26’13.91”	21°20’16.08”	105	**EQ22**	A. G., M. P.	2015	Orljevo
44°32’27.96”	21°16’55.91”	87	**EQ23**	A. G., M. P.	2015	Malo Crniće
44°50’51.47”	21°17’25.61”	70	EQ26	Milivoj Krstić	2015	Kajtasovo
44°21’51.11”	21°25’29.64”	122	**EQ31**	A. G., M. P.	2015	Petrovac
44°44’47.04”	21°29’18.23”	67	**EQ35**	A. G., M. P.	2015	Veliko Gradište
44°42’22.67”	21°31’57.71”	76	EQ45	A. G., M. P.	2015	Braničevo
43°9’18.70”	22°34’38.14”	363	FN27	Ivan Medenica	2015	Pirot
43°17’1.672”	22°32’12.36”	566	FN29	M. P.	2009	Rudinje
43°6’30.17”	22°40’49.98”	397	FN37	Ivan Medenica	2015	Krupac
43°7’48.11”	22°38’5.531”	380			2014	Poljska Ržana
43°39’11.45”	22°15’45.13”	186	**FP03**	A. G., M. P.	2015	Vlg. Debelica
43°47’29.99”	22°18’41.75”	154	FP04	M. P.	2015	Mali Beograd
43°51’35.34”	22°18’0.478”	133	FP05	A. G., M. P.	2015	Grljanske bare
43°52’45.71”	22°17’50.22”	129		M. P.	2011	Lubnička reka
43°57’23.04”	22°20’31.88”	111	FP06	M. P.	2014	Vražogrnac
44°9’41.35”	22°18’40.76”	367	**FP09**	M. P.	2011	Sikole

Supplementary Data 2

Ecological niche model of *Emys orbicularis* for Vojvodina

In total, 33 occurrence points were used in the separate ecological niche model for the region of Vojvodina (Serbia, north of Danube and Sava Rivers). Model reported AUC value of 0.96, which was significantly higher than the AUC values of the null models 0.80 (range: 0.71-0.88) ($P = 2\times10^{-16}$). Variable contribution is shown in Table S2.1 and Fig. S2.1 of this supplementary data. The response curves for five variables that were the most important and easiest to interpret are shown in Fig. S2.2. Final map predicting habitat suitability is given in Fig. S2.3.

Table S2.1. List of variables, their percent of contribution and permutational importance used in ecological niche model of European Pond Turtle (*Emys orbicularis*) in Vojvodina region

Variable name	Contribution (%)	Permutational importance (%)
Land Cover	54	13
Annual Mean Temperature	12	32
Temperature Seasonality	10	12
Annual Precipitation	10	26
Slope	6	1
NDVI Maximum	3	4
Aspect Northness	2	1
Isothermality	1	7
Aspect Eastness	1	1
NDVI Minimum	0	0
NDVI Average	0	3
Precipitation Seasonality	0	1

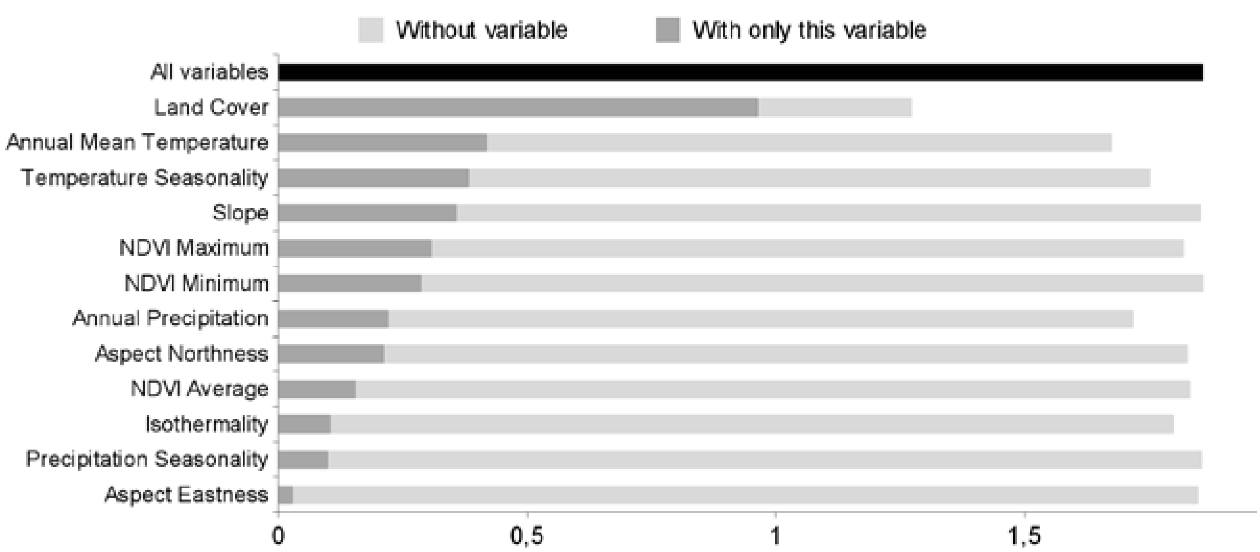

Fig. S2.1. Jackknife test of variable importance in modelling ecological niche of European Pond Turtle from Vojvodina region. A variable contains more useful information if it achieves higher gain when used alone and if it lowers the gain when excluded

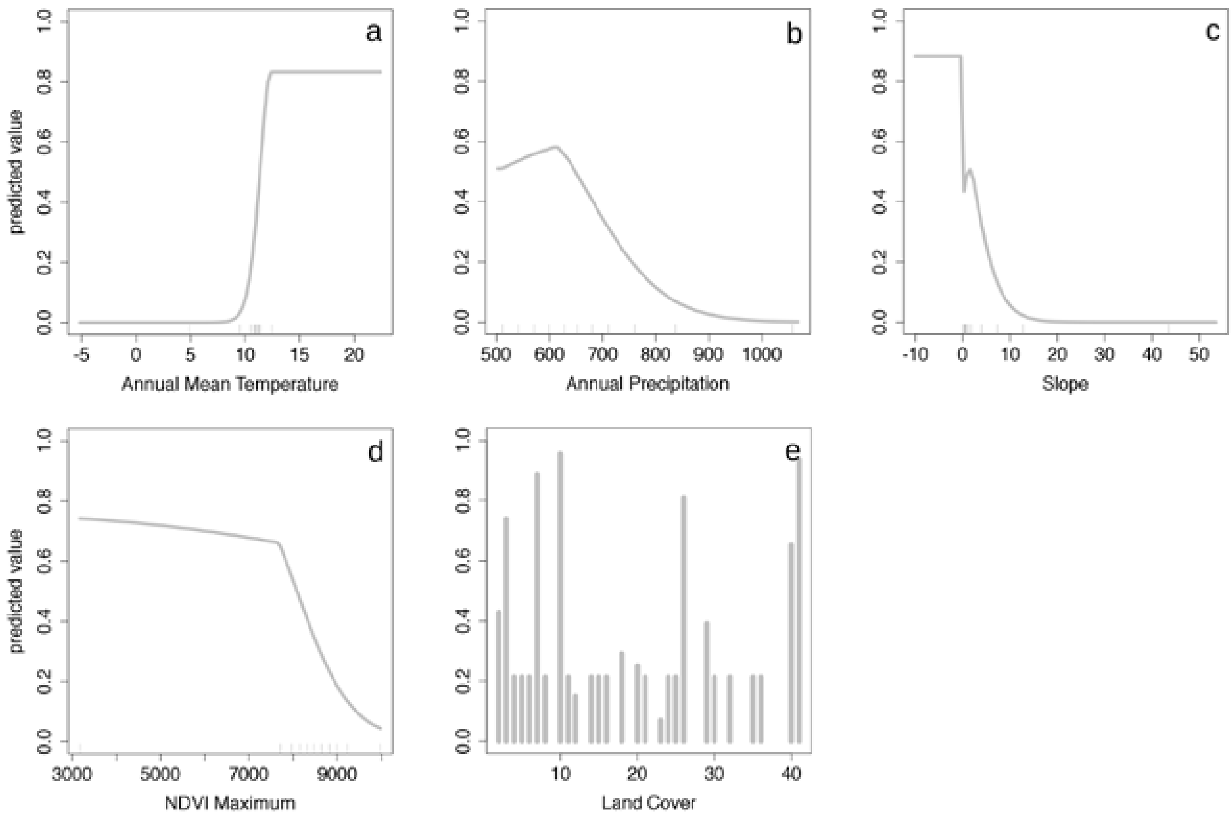

Fig. S2.2. Response curves of the most important variables affecting ecological niche model of European Pond Turtle in Vojvodina region. Annual mean temperature is given in °C. Annual precipitation in mm and the slope is given in degrees. NDVI index is remote sensed data showing vegetation greenness and has no measuring units. Land cover variable is given as classes of land cover types

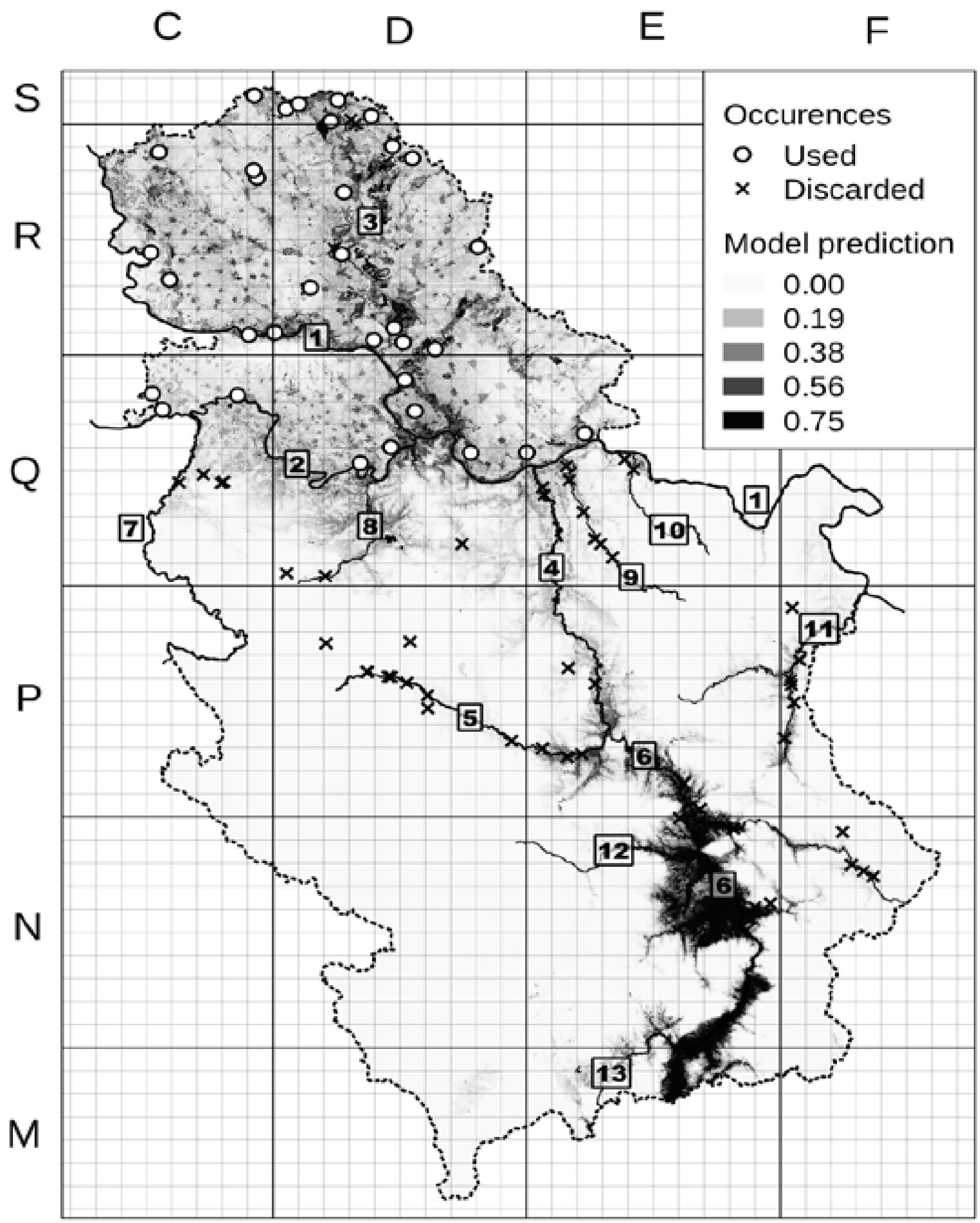

Fig. S2.3. Habitat suitability for European Pond Turtle in Serbia predicted by the Maxent ecological niche model using a set of climatic, topographic and vegetation habitat layers and occurrence records from Vojvodina region. The level of gray on the map is shown Maxent's logistic output, which could be interpreted as species probability of presence ranging between 0 and 1. Map shows MGRS grid lines delimiting areas of 100 × 100 km. Numbered Rivers: 1. Danube, 2. Sava, 3. Tisa, 4. Velika Morava, 5. Zapadna Morava, 6. Južna Morava, 7. Drina, 8. Kolubara, 9. Mlava, 10. Pek, 11. Timok, 12. Toplica, 13. Binačka Morava

Ecological niche model of *Emys orbicularis* for Serbia, south of Danube and Sava Rivers

In total, 43 occurrence points were used in the separate ecological niche model for the region of Serbia south of Danube River. Model reported AUC value of 0.95, which was significantly higher than the AUC values of the null models 0.78 (range: 0.71-0.85) ($P = 2\times10^{-16}$). Variable contribution is shown in Table S2.2 and Fig. S2.4 of this supplementary data. The response curves for five variables that were the most important and easiest to interpret are shown in Fig. S2.5. Final map predicting habitat suitability is given in Fig. S2.6.

Table S2.2. List of variables, their percent of contribution and permutational importance used in ecological niche model of European Pond Turtle (*Emys orbicularis*) Serbia south of Danube and Sava Rivers

Variable name	Contribution (%)	Permutational importance (%)
Slope	36	27
Land Cover	31	12
NDVI Maximum	12	10
Temperature Seasonality	10	25
Annual Precipitation	3	6
Precipitation Seasonality	2	2
Annual Mean Temperature	2	12
Aspect Eastness	2	0
Aspect Northness	2	0
NDVI Minimum	1	0
Isothermality	0	4
NDVI Average	0	0

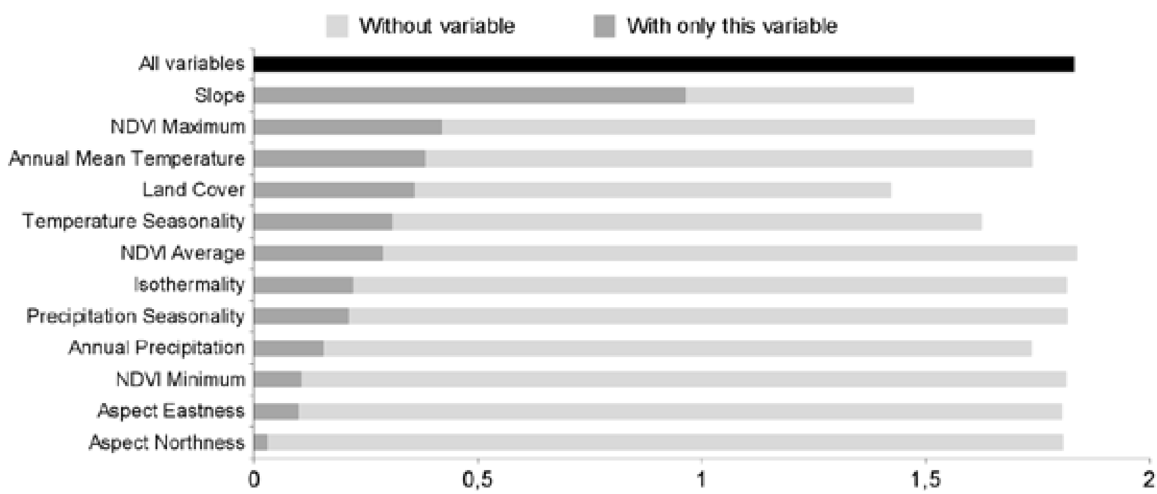

Fig. S2.4. Jackknife test of variable importance in modelling ecological niche of European Pond Turtle from Serbia south of Danube and Sava Rivers. A variable contains more useful information if it achieves higher gain when used alone and if it lowers the gain when excluded

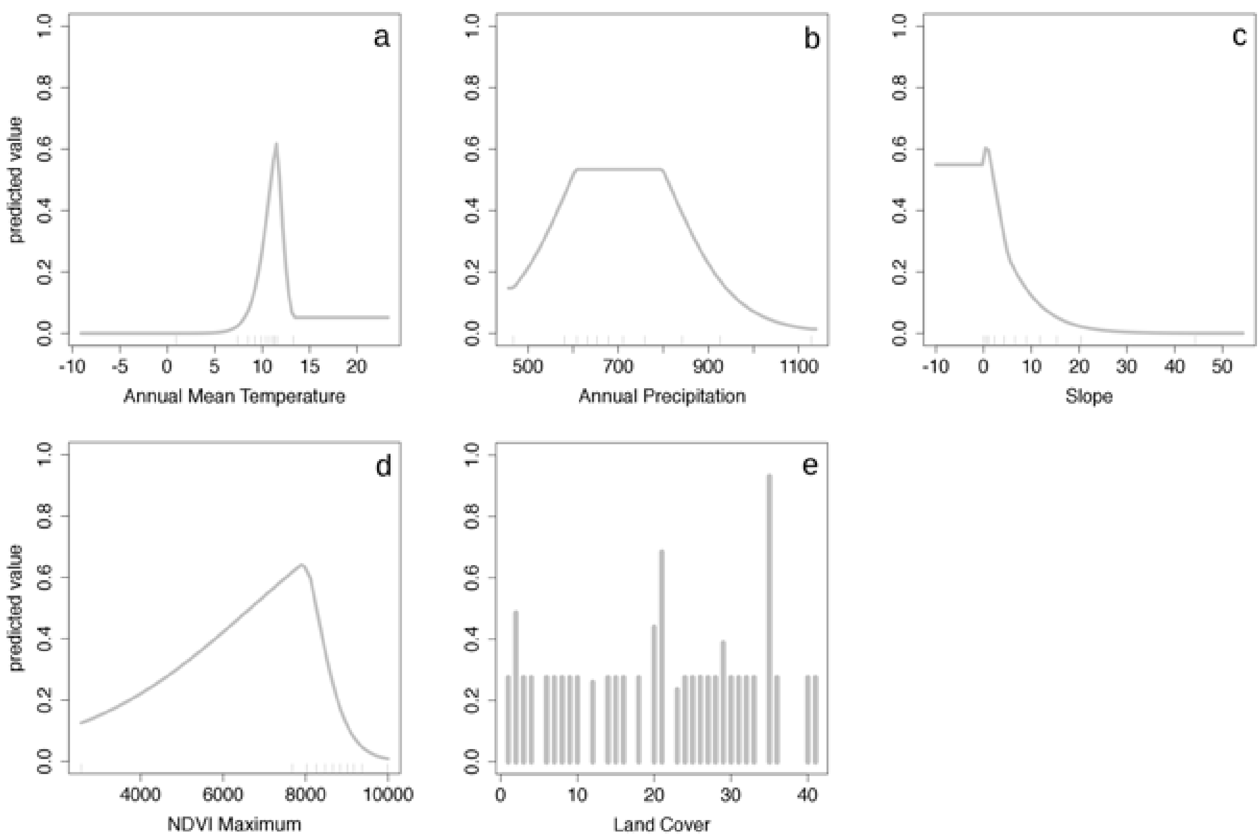

Fig. S2.5. Response curves of the most important variables affecting ecological niche model of European Pond Turtle in Serbia south of Danube and Sava Rivers. Annual mean temperature is given in °C. Annual precipitation in mm and the slope is given in degrees. NDVI index is remote sensed data showing vegetation greenness and has no measuring units. Land cover variable is given as classes of land cover types

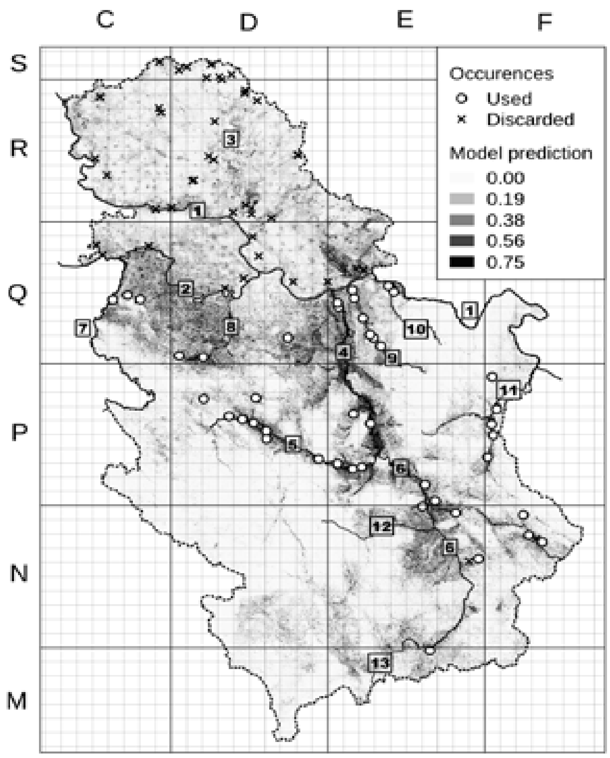

Fig. S2.6. Habitat suitability for European Pond Turtle in Serbia predicted by the Maxent ecological niche model using a set of climatic, topographic and vegetation habitat layers and occurrence records from Serbia south of Danube and Sava rivers. The level of gray on the map is showing Maxent's logistic output, which could be interpreted as species probability of presence ranging between 0 and 1. Map shows MGRS grid lines delimiting areas of 100 × 100 km. Numbered Rivers: 1. Danube, 2. Sava, 3. Tisa, 4. Velika Morava, 5. Zapadna Morava, 6. Južna Morava, 7. Drina, 8. Kolubara, 9. Mlava, 10. Pek, 11. Timok, 12. Toplica, 13. Binačka Morava

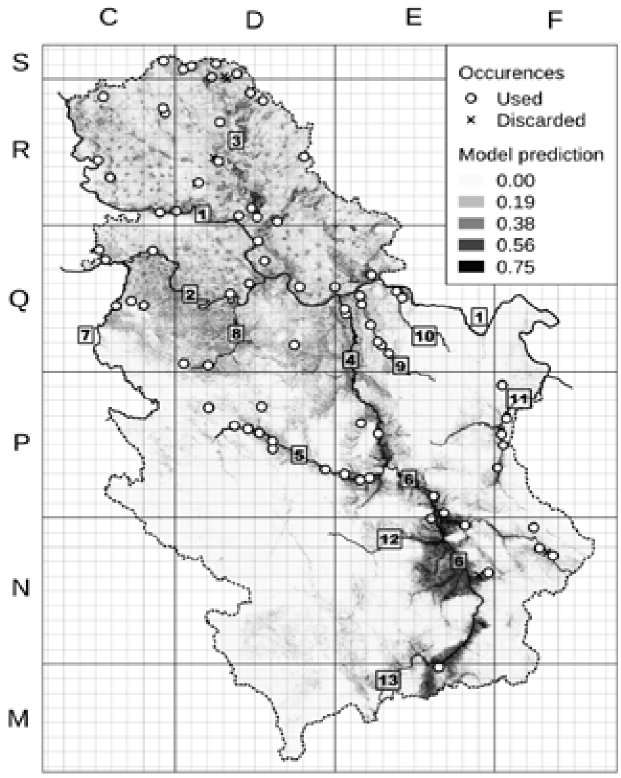

Fig. S2.7. Habitat suitability for European Pond Turtle in Serbia, predicted by the Maxent ecological niche model, made by overlaying two separate maps from Figures S2.3 and S2.6. The level of gray on the map is shown Maxent's logistic output, which could be interpreted as species probability of presence ranging between 0 and 1. Map shows MGRS grid lines delimiting areas of 100 × 100 km. Numbered Rivers: 1. Danube, 2. Sava, 3. Tisa, 4. Velika Morava, 5. Zapadna Morava, 6. Južna Morava, 7. Drina, 8. Kolubara, 9. Mlava, 10. Pek, 11. Timok, 12. Toplica, 13. Binačka Morava