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Proceeding Paper

Modeling the Influence of Invasive Fish Species *Perccottus glenii* (Dybowski, 1877) on the Distribution of Newts in Eastern Europe, Exemplified by *Lissotriton vulgaris* (Linnaeus, 1758) and Preserved *Triturus cristatus* (Laurenti, 1768), Using a GIS Approach †

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Abstract: Along with decrease in numbers among amphibians in Eastern Europe nowadays newts especially suffer from invasive predatory fish and turtles. Such aggressive predator as *P. glenii* has recently occupied water bodies important for newts' breeding. The fish eat eggs, larvae and even adult individuals. Using the ecological niche approach, it was showed that for built distribution models based on certain climatic scenario Coefficient of determination (R^2) between Chinese sleeper and preserved *T. cristatus* with *L. vulgaris* to 2090 will grow from 44% to 66% in Eastern Europe highlighting expanding of new territories by the fish as a real threat to biodiversity.

Keywords: climate change; GIS-analysis; modelling; invasive species; amphibians; Urodela; Europe; niche modelling

1. Introduction

Recently, a decrease in the numbers of amphibians in Eastern Europe was reported multiple times. Suitable habitats that are important for amphibians at certain stages of their lives shrink and degrade due to climate change [1,2], anthropogenic impact and the animals suffer from pollution and appearance of alien invasive species [2]. Alien invasive species often appear and adapt in new places far from their natural range for example as a result of uncontrolled release into the wild from the terrariums or being accidently transported as a result of developing aquaculture [3–6]. Thus, the appearance of Chinese sleeper—*Perccottus glenii* (Dybowski, 1877) in Europe in the water bodies of cities can also be explained by the deliberate release of amateur aquarists and fishermen in the early 20th century. Until now *P. glenii* is considered ornamental, and due to its ability to survive in any conditions, aggressiveness, flexible and wide range of food and ecological plasticity, this species has spread quite widely both in the North and in the South of Europe [7–11].

In Europe since 2016 Chinese sleeper is included in the list of Invasive Alien Species of Union concern (the Union list) [1].

According to the literature resources *P. glenii* is a great threat for local biota. It was reported, that its diet consists of macro- and micro crustaceans (Ostracoda, Copepoda, Cladocera, Isopoda, Amphipoda, Gastropoda), highly mobile invertebrates such as Coleoptera and Heteroptera [12]. Additionally, to direct preying this species also affects the feeding base for local inhabitants acting as a trophic competitor and a predator competing for the resources. Habitats heavily invaded by *P. glenii* are usually associated with lower fish species richness and diversity [13,14]. Moreover *P. glenii* can be a vector for transporting of several species of parasites, that can lead to significant damage in local balance of biocenosis or aquaculture [15–17]. Also, by feeding on macro- and micro-invertebrates *P. glenii* effectively reduces the transport of nitrogen from aquatic to terrestrial environments [18].

Of all amphibian species newts are especially vulnerable and suffer from climate change, anthropogenic influence and, as a result, the emergence of new invasive predator species, diseases and habitat loss. The two most widely distributed species of newts in Eastern Europe—preserved in European Union crested newt *Triturus cristatus* (Laurenti, 1768) and smooth newt *Lissotriton vulgaris* (Linnaeus, 1758) are the two species that can demonstrate potential connection between decrease in their numbers and expansive moving of *P. glenii* to new territories in the investigated region.

Therefore, the purpose of our work was to identify the most potentially suitable habitats for these species in Eastern Europe, as well as to make a prediction about the threats and expansion of the *P. glenii* as aggressive predator on native species of newts.

2. Materials and Methods

Occurrence data on the studied species referred to the entire territory of Europe in order to increase the accuracy of models built, despite the fact that main focus of the investigation was to evaluate species potential future overlap in Eastern part of Europe. The data was collected from the original datasets [19], collection materials (I. I. Schmalhausen Institute of Zoology, National Academy of Sciences of Ukraine, Kyiv; Department of Ecology, Institute of Life Sciences and Technologies, Daugavpils University, Daugavpils, Latvia), literature resources [7–10,20,21], GBIF databases [22–24]—all non-duplicate. To account for sampling bias, we used the nearest neighbor distance ('ntbox' package in R [25]) method to thin the data, where occurrence points that were ≤0.1 units away from each other were removed to avoid errors due to spatial autocorrelation. As a result, the number of points significantly decreased to total of 2096 for *L. vulgaris*—(127,715 initial records within Europe downloaded from GBIF), *T. cristatus*—2277 (132,121 initial records within Europe downloaded from GBIF), *P. glenii*—944 (842 initial records within Europe downloaded from GBIF).

Ecological niche modeling and species distribution modelling (SDM) methods have been used to determine the potential home range of invasive species in new environments (MaxEnt [26] with 25 replicates, DivaGis (Bioclim). We used 35 bioclimatic variables from the CliMond dataset [27,28]. Of 35 bioclimatic variables (V), highly correlated (>0.7) predictors were removed using the 'virtualspecies' package in R, resulting in a selection of 18 for 1975 (1970–2000), 2090 (2081–2100). The area under the receiver operating characteristic (ROC) curve (AUC) was used for assessing the discriminatory capacity of the models: AUC > 0.85 is considered excellent. We carried out separate modelling for each set of factors and for each species. Logistic output format was used to describe the relative probability of presence, which is a continuous habitat suitability (HS) range between 0 (unsuitable) and 1 (the most suitable). Using the Coefficient of determination, we assessed statistically significant to assess similarity ($p < 0.05$) between the predicted HS map obtained through Maxent for every single target species across the study area. GIS-modelling was accomplished using SagaGis, DivaGis, QGis [12]. Statistical processing of the obtained data was carried out using Statistica for Windows v.8.0.

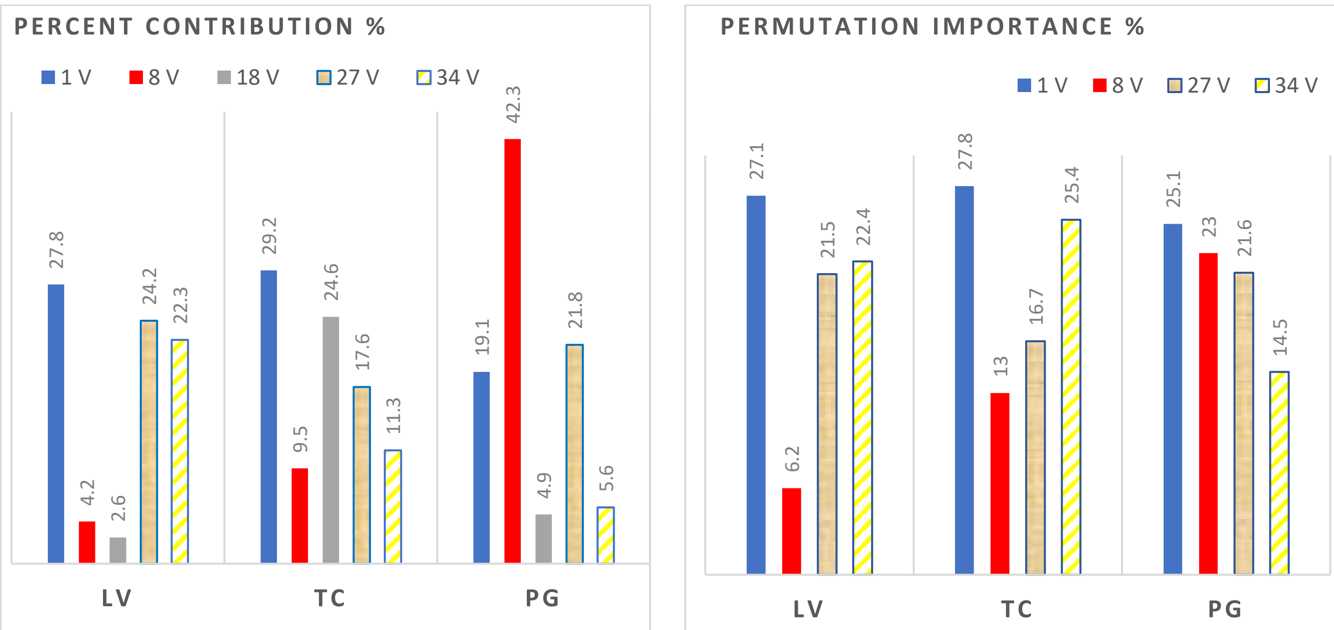
3. Results

According to our own data and published information, in spring and in the first half of summer, newts are found mainly in small reservoirs, streams and ditches, where they spawn. However, after active expansion of *P. glenii* throughout Europe, this predator appeared in the same biotopes. Being less whimsical and more ecologically plastic, rather active predator *P. glenii* is capable of displacing amphibians sensitive to water quality. For example, according to our data, in the Volyn, Rivne, Zhytomyr and Kyiv regions of Ukraine during field expeditions in 2017–2021 newts were found only in water bodies where *P. glenii* was not registered.

The reduction in the number and sometimes the disappearance of newts' micropopulations in the south of the range have led to the fact, that they were included in the Red Book in some countries, for example *T. cristatus* in Ukraine, and *L. vulgaris* is now a contender to be listed in Red Book of Ukraine in the nearest future [12,24,29].

An analysis of the distribution of newts in Eastern Europe showed that the continental biographical zone has the highest priority in terms of potentially suitable territories. In the western part of their range, newts can "descend" into the steppe zone along the eco-corridors of large rivers, such as the Danube and the Dniester. *P. glenii* has a similar range, but more fragmented. According to our data, the ranges of newts will be greatly reduced by 2090, while the range of the fish, on the contrary, will increase. We have been observing the rapid spread of *P. glenii* since 2010 in the continental zones of Ukraine and in the east of Latvia. In most cases temporary water bodies are left uninvaded playing role of place, where many amphibians have time to breed, but, on the contrary, Chinese sleeper does not have time to breed and establish.

As a result of the modelling, it was revealed that the complex of factors associated with average temperature amplitudes for different periods and humidity has the greatest influence on the spatial distribution of the studied species and the Radiation of coldest quarter (27 V) factor complements this complex of factors and affects the humidity of habitats. Naturally, according to a number of factors, *P. glenii* as an aquatic animal differs from semi-terrestrial amphibians (Figure 1).



(**A**) (**B**)

Figure 1. Graph of most contributing predictors (V (bio), %) for building SSDM 3 species of Eastern Europe: (**A**)—Percent contribution and (**B**)—Permutation importance; LV—*L. vulgaris;* TC—*T. cristatus;* PG—*P. glenii;* 1 V—Annual mean temperature (°C); 8 V—Mean temperature of wettest quarter

(°C); 18 V—Precipitation of warmest quarter (mm); 27 V—Radiation of coldest quarter (W m^{-2}); 34 V—Mean moisture index of warmest quarter.

Moreover, *P. glenii* appeared to be the most tolerant and resistant to the temperature regime with such factor as Annual mean temperature having its optimal values in the range from +2 to +12 ° C (Figure 2).

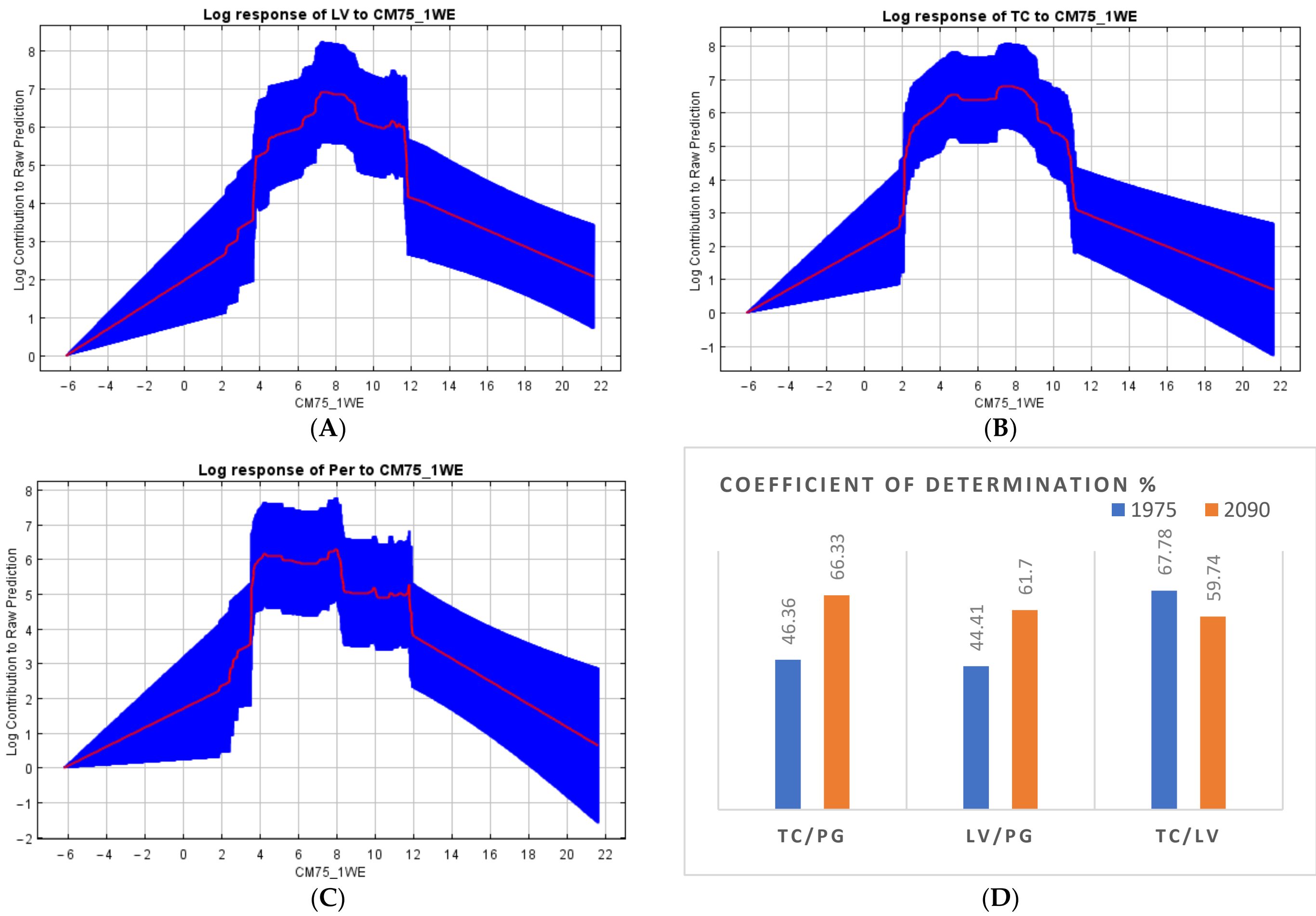


Figure 2. Maxent model created using only the variable (1 V)—Annual mean temperature (°C, CliMond) from: (**A**)—*L. vulgaris*; (**B**)—*T. cristatus*; (**C**)—*P. glenii*; (**D**)—dependence graphs of grid SDM different species (HS, Coefficient of determination % R^2, Saga): LV—*L. vulgaris;* TC—*T. cristatus;* PG—*P. glenii*.

Statistical analysis of the results showed high accuracy of the model. Despite the sufficient scatter and the existing accumulations of locality points in certain areas due to the characteristics of the type of range of the species under study, the data on test locations are in good agreement with the predicted dynamics calculated for the test data obtained from the Maxent distribution. The high area under the curve (AUC) > 0.85 confirms our assumptions.

Analyzing the obtained models, we came to the conclusion that the greatest similarity of SDM HS is achieved by newt species, Coefficient of determination—67.78% (Figure 2D, TC/LV) and this is explained by the fact that they can live together in similar biotopes. Although earlier, at the end of the 20th century, biotopic specialization and different calendar periods in reproduction were observed among amphibians. Recently, suitable reservoirs for amphibian breeding have become smaller, and breeding times have also shifted (phenology has shifted), and therefore it is common to see several species of amphibians breeding in the same reservoir and at the same period. This leads to the fact that not all amphibians will be able to breed in such conditions, especially newts. According to GIS modeling data, the range of newts and their abundance will be greatly reduced by 2090, especially in the south. *T. cristatus* will be especially affected. As for the Chinese sleeper, the number and range of which will increase significantly and by 2090 potentially suitable sites will increase significantly and the Coefficient of determination will increase significantly—to 44% to 66% (Figure 2D, TC/PG and LV/PG) with *T. cristatus* and *L. vulgaris* respectively.

4. Discussion

The results of the GIS-analysis are supported in recent years by numerous field investigations when lakes, ponds and streams heavily invaded by *P. glenii* showed either no signs of *L. vulgaris* or *T. cristatus*, or only separate individuals were found even during the peak of breeding season. However, the Chinese sleeper can also serve as a food base for some species of reptiles, for example, *Natrix tessellata* (Laurenti, 1768) [30], rare and preserved in Europe *Emys orbicularis* (Linnaeus, 1758) [31] and *Bombina bombina* (Linnaeus, 1761), or the invasive exotic species *Trachemys scripta* (Thunberg in Schoepff, 1792) [4,25,26,32]. Moreover, in depleted anthropogenic urban ecosystems, where water quality does not allow native fish species to survive, this invasive species, like other aquarium fish, can occupy its ecological niche and act as a biological method of combating dangerous blood-sucking invasive insects [5,27,33].

5. Conclusions

As a result of our research, it was found that in the future, due to climatic and anthropogenic changes, two most widely distributed species of newts—*L. vulgaris* and preserved in European Union *T. cristatus*—will suffer, their range and abundance will decrease, and the expansion of such an invasive Chinese sleeper will intensify. Therefore, it is necessary to establish management plans for the protection of native amphibian species taking into account heavy influence of invasive species adequately taking their further expansion into strict control.

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