Prospects for the distribution of the North American Signal crayfish *Pacifastacus leniusculus* in Europe by 2050

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INTRODUCTION

Object of the study. Signal crayfish *Pacifastacus leniusculus* (Dana, 1852), omnivorous crayfish, total length – 6-20 cm, a North American species that was introduced to Europe in the 1960s to supplement the fisheries of North European crayfish *Astacus astacus* (Linnaeus, 1758), which were being damaged by crayfish plague.
Subject of the study. Distribution and its changes with changing climate.
Natural distribution. This species originated from North America and has been introduced into Europe on purpose to counteract the decline in catch per unit effort of native crayfish species.
Actuality. In the current context of accelerating climate change and biodiversity erosion, invasive aquatic species are carving out ecological niches in new areas of Europe. This was facilitated by the popularity of some species for aquaculture and aquarist amateurs that were introduced in Europe since decades. Yet the introduced signal crayfish is a voracious carnivorous species carrying the crayfish plague disease agent and provoked massive deleterious impacts on native species and ecosystems throughout Europe, conflicting reintroduction efforts for native species such as the European pond turtle *Emys orbicularis* (Linnaeus, 1758). Forecasting the extend of the Signal crayfish expansion is urgently needed to anticipate and implement appropriate adaptive management for ensuring both ecological and economic sustainability.

Fig. 1. Field studying of invasive crayfish fauna.

MATERIALS AND METHODS

For modeling the near future expansion of the Signal crayfish, we collected data on the distribution of P. leniusculus worldwide – 101207 points (Fig. 2), from the natural range and areas where it has been introduced on other continents.

GIS modeling was used to explore the potential distribution of the species worldwide. Modeling and calculations were carried out using Maxent v3.3.3 software with 25 replicates, 25% test (Phillips 2005) and employing 35 bioclimatic variables (CliMond; Kriticos et al. 2014; https://www.climond.org/, accessed 27 December 2020).

Fig. 2. Distribution of records of P. leniusculus where it has been introduced in Europe (https://www.gbif.org/uk/occurrence/map?taxon_key=2226990).

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RESULTS AND DISCUSSION

Our model predicts a major expansion of the Signal crayfish throughout Europe by 2050, with a shift of its range by more than 500 km to Northern countries (to the Baltic countries, where this species has already been recorded in several localities). Out of 35 factors provided by CliMond database, the most significant factors to such distribution shift were associated with solar radiation - bio23 (radiation seasonality: percent contribution - 30%; permutation importance - 32%) and humidity - bio35 (mean moisture index of coldest quarter: percent contribution - 17%; permutation importance - 1%) (Fig. 3A and 3B, respectively).

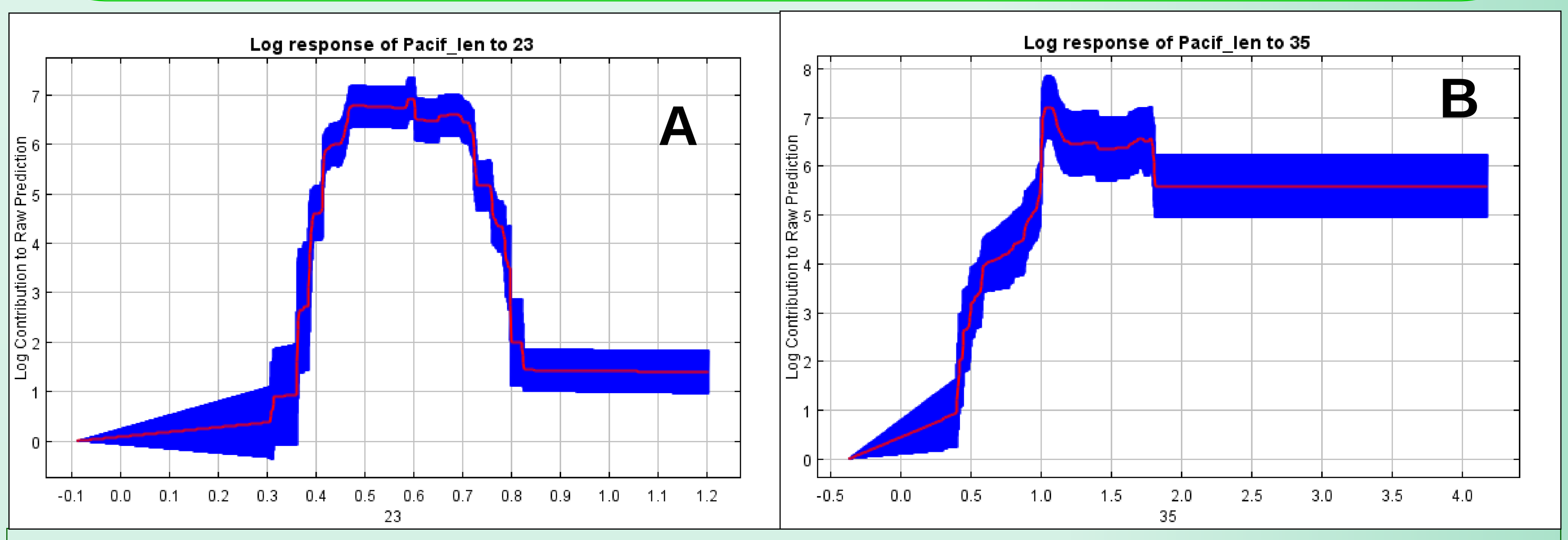


Fig. 3. Response curves generated by Maxent for *P. leniusculus* for the variable: A) bio23; B) bio35.

Variable	Variable meaning	Percent contribution	Permutation importance
bio23	radiation seasonality	30	32.2
bio35	mean moisture index of coldest quarter	16.8	0.7
bio4	temperature seasonality	16.2	26.8

Table 1. Results of modeling the spread of *P. leniusculus* (CliMond, Maxent).

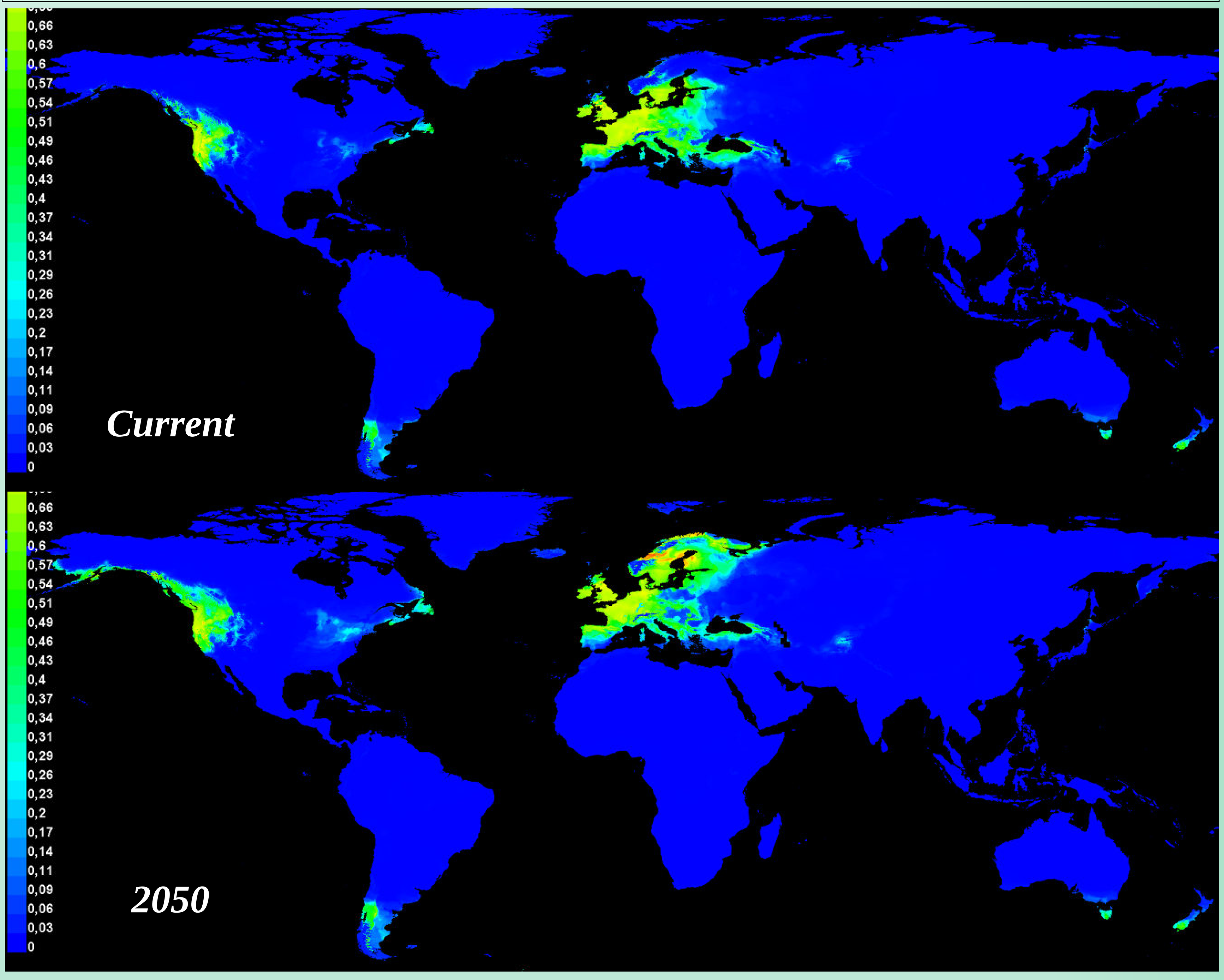
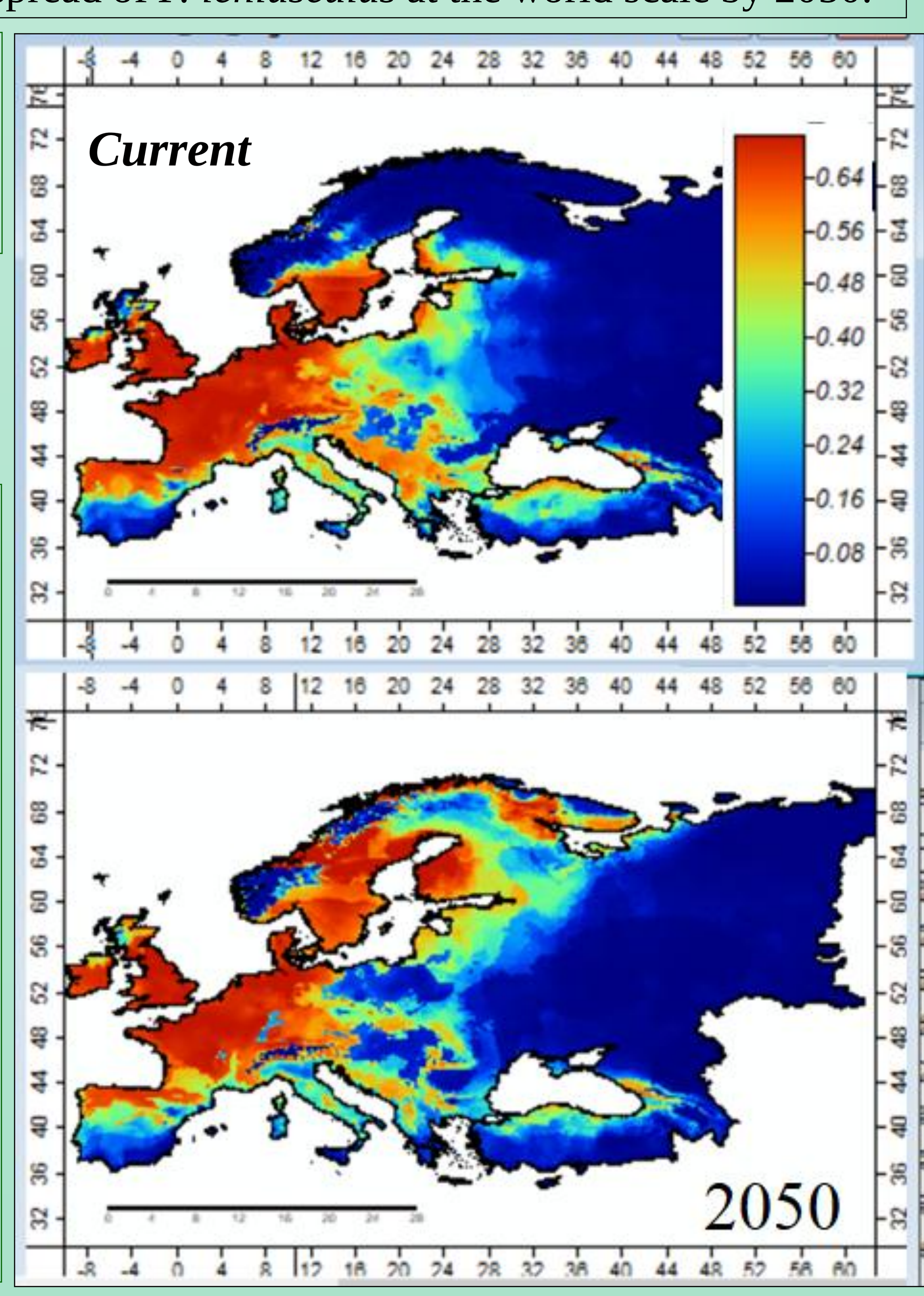


Fig. 4. Results of modeling the spread of *P. leniusculus* at the world scale by 2050.

Fig. 5. Results of modeling the spread of *P. leniusculus* at the European scale by 2050 (SAGA GIS, red color > 0.5).



CONCLUSIONS

The signal crayfish is known to be sensitive to water quality and. Thus, as for most freshwater invasive species, areas in Southern Europe will be less suitable for the signal crayfish compared to the Baltic countries, where humidity will remain at a high level. Our predictions of trends and threats may constitute a scientific-grounded basis for appropriate management in favor of native species throughout Europe.