1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title: Invasive *Procambarus* crayfish as consumers, prey and competitors in freshwater communities

1.1. Project goals

We intend to determine the role of North American *Procambarus* crayfishes (*P. clarkii*, *P. virginalis*) as emerging invaders in European freshwater communities, and their traits facilitating establishment in novel areas. We are going to focus on their competition for limiting resources with native species and other aliens (including earlier crayfish invaders), responses to predation cues, and learning abilities, to test the following general hypothesis: *Procambarus* spp. are more efficient invaders than other American crayfishes, exerting negative effects on local communities due to their plastic behaviour and high learning ability.

1.2. Outline

Biological invasions are one of the main contemporary threats to the global biodiversity (Simberloff et al. 2013), especially in fresh waters (Ricciardi & MacIsaac 2010). Alien species appear outside their native ranges due to human impact: removal of natural barriers, international trade, intentional introductions and releases of unwanted pets by irresponsible owners. Some of them become invasive, negatively affecting local ecosystems and/or economy (Simberloff et al. 2013).

American crayfishes belong to the most successful invaders in European fresh waters. Populations of the local species have been greatly reduced due to over-exploitation and the expansion of the crayfish plague, a lethal pathogen of American origin. They have been replaced to a high extent by North American species intentionally introduced in Europe: *Faxonius limosus* (in the 19th century) (Kouba et al. 2014), *Pacifastacus leniusculus* (in 1960s) (Petrusek et al. 2017) and *P. clarkii* (in 1970s) (Gherardi & Acquistapace 2007). Among them, *P. clarkii* is the most widespread in non-native areas throughout the world, heavily affecting local ecosystems through predation, consuming macrophytes, and increasing water turbidity by burrowing (Gherardi & Acquistapace 2007). In Europe, it has colonized mainly the southern part of the continent, but global warming and thermal pollution of aquatic habitats may also enable its future establishment in Poland (Maciaszek et al. 2019). Nowadays, we observe the ongoing invasion of another *Procambarus* species: *P. virginalis*, a triploid and parthenogenetic form obtained artificially in the aquarium hobby from a Florida species *P. fallax* (Martin et

al. 2010). Wild populations of *P. virginalis* have been observed so far in many European countries, including Poland, and, due to its high environmental resistance, specifically to low temperature, its further expansion is predicted (Vogt 2020).
Given the high importance of crayfish in ecosystem functioning (Statzner et al. 2000), interactions and differences of the emerging invasive species with the local biota (both native and earlier invaders), including their competitors, predators and prey, must be recognized to assess their invasive potential and impact. We plan to experimentally test these interactions, shedding the new light on the future functioning of European freshwater ecosystems and contributing to general understanding of mechanisms of biological invasions.

1.3. Work plan

- Experiments on habitat and food preferences, and mobility of the selected crayfish species (*P. clarkii*, *P. virginalis*, *F. limosus*, *P. leniusculus*): preliminary tests to establish conditions for subsequent experiments
- Experiments on competition between *Procambarus* spp. and other crayfish invaders, as well as native and alien bottom-dwelling fishes, for habitat, shelter and food
- Experiments on anti-predatory responses of crayfishes (intra- and interspecific alarm cues, predator kairomones): comparison between the species
- Experiments on crayfish learning capabilities: comparison between the species
- After each set of experiments: data analysis, presentation of results at conferences, writing scientific papers

1.4. Literature

- Gherardi F., Acquistapace P. 2007. Invasive crayfish in Europe: the impact of *Procambarus clarkii* on the littoral community of a Mediterranean lake. Freshw. Biol. 52: 1249-1259
- Kouba A., Petrusek A., Kozák, P., 2014. Continental-wide distribution of crayfish species in Europe: update and maps. Knowl. Manag. Aquat. Ecosyst. 413: 5
- Maciaszek R., Bonk M., Strużyński W. 2019. New records of the invasive red swamp crayfish *Procambarus clarkii* (Girard, 1852) (Decapoda: Cambaridae) from Poland. Knowl. Manag. Aquat. Ecosyst. 420: 39
- Martin P., Dorn N.J., Kawai T., van der Heiden C., Scholtz G. 2010. The enigmatic Marmorkrebs (marbled crayfish) is the parthenogenetic form of *Procambarus fallax* (Hagen, 1870). Contrib. Zool. 79: 107-118

- Petrusek A., Filipová L., Kozubíková-Balcarová E., Grandjean, F. 2017. High genetic variation of invasive signal crayfish in Europe reflects multiple introductions and secondary translocations. Freshw. Sci. 36: 838-850
- Ricciardi A., MacIsaac H.J. 2010. Impacts of biological invasions on freshwater ecosystems. In: Richardson D.M. (ed.) Fifty years of invasion ecology: the legacy of Charles Elton. Wiley-Blackwell, Hoboken, New Jersey: 211–224
- Simberloff D., Martin J.L., Genovesi P., Maris V., Wardle D.A., Aronson J., Courchamp F., Galil B., García-Berthou E., Pascal M., Pyšek P., Sousa R., Tabacchi E., Vilà M. 2013. Impacts of biological invasions: what's what and the way forward. Trends Ecol. Evol. 28: 58–66
- Statzner B., Fièvet E., Champagne J.Y., Morel R., Herouin E. 2000. Crayfish as geomorphic agents and ecosystem engineers: biological behavior affects sand and gravel erosion in experimental streams. Limnol. Oceanogr. 45: 1030-1040
- Vogt G. 2020. Biology, ecology, evolution, systematics and utilization of the parthenogenetic marbled crayfish, *Procambarus virginalis*. In: Ribeiro F.B. (ed.), Crayfish: evolution, habitat and conservation strategies. Nova Sci. Publ., Hauppauge, NY: 137-227

1.5. Required initial knowledge and skills of the PhD candidate

- Knowledge in zoology and aquatic ecology
- Experience in work with aquatic animals (preparing and sustaining aquarium cultures, conducting observations, manipulating animals and aquarium equipment)
- Basic experience in planning and conducting experiments in the field of animal behaviour and ecology
- Willingness to conduct experimental research on animals
- Critical thinking
- English communication skills (reading, speaking and writing)

1.6. Expected development of the PhD candidate's knowledge and skills

- In-depth knowledge in the fields of animal behaviour, biological invasions and aquatic ecology
- Designing and conducting ecological experiments
- Analysis of experimental data (tools for recording and analysing animal behaviour, statistical data analysis)
- Presentation of scientific data (writing scientific papers, conference presentations)

- Team work: cooperation within the research team, external scientific contacts