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RESEARCH ARTICLE



## Biological invasions and invasive species in freshwaters: perception of the general public

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### ABSTRACT

For management strategies aimed at biological invasions, a detailed survey of the general public’s knowledge is crucial. For this purpose, our present study aimed to (i) investigate the level of comprehension regarding biological invasions, (ii) assess the ability of responders to discriminate between invasive and native species, and (iii) evaluate the conservation support. Increased awareness of biological invasions on the part of the respondents positively influences the willingness to protect native fish and crayfish species and not their invasive counterparts. Higher identification scores of species by participants significantly decreased the conservation support of invasive species. Female respondents were more willing to protect a species, including invasive ones. Respondents could discriminate between native and invasive fish species to a significantly better extent than between native and invasive crayfish. Without public awareness and citizen-aimed education, we will be unable to conduct sustainable management and prevent further species’ introductions and translocations.

### KEYWORDS

Crayfish; fish; nature conservation; questionnaire

In this era of rapid changes in the physical world through human activities (facilitated by the destruction of natural habitats and the introduction of non-indigenous species), nature conservation is urgently needed. A considerable amount of scientific research focuses on biological invasions, an increasingly recognized problem that threatens biodiversity and complicates nature conservation worldwide. Biological invasions negatively affect the ecosystem at its fundamental level by energy and food web alternations (Lipták et al., 2019), changes in the species assemblages (Haubrock, Pilotto, et al., 2021a), modifications of the physical and chemical aspects of sites (Kouba et al., 2016; Souty-Grosset et al., 2014), and so threatening its functionality and existence (Pyšek & Richardson, 2010; Pyšek et al., 2020). Invasive species are identified as a driver of recent mass species extinctions (Bellard et al., 2016) and tackling them is challenging. One of the main components of effective and sustainable management of biological invasions and success in nature conservation, which

is often overlooked, is communication with and the awareness of the general public about biological invasions, including laypersons (conservationist pastime).

To date, hundreds of invasive species have successfully established new populations outside their native ranges, with the diverse negative impacts costing billions of USD (Diagne et al., 2021; Haubrock et al., 2021b; Renault et al., 2021). For these reasons, biological invasions are among the key components in the new era of mass extinction of organisms induced in the Anthropocene (Bellard et al., 2016). The freshwater environment is particularly sensitive to changes in its environment (biological, chemical and physical) (Haubrock, Pilotto, et al., 2021a). Biological invasions facilitated by human-driven species introductions and translocations promote negative changes in the ecosystem, and even lead to the disappearance of some native biota (Blackburn et al., 2019; Ellender & Weyl, 2014; Gergs & Rothhaupt, 2014; Haubrock, Pilotto, et al., 2021a; Kouba et al., 2022). It is thus of particular interest to focus on aquatic invasive species threatening these vulnerable ecosystems (Kaminskas, 2022).

Angling is identified as a source of non-native freshwater fish species, with some species becoming invasive with a severe environmental impact on many European regions (Carpio et al., 2019). Introducing species with commercial and ornamental value, together with poor knowledge on the topic of biological invasions, continues in the present without fully considered consequences (Ellender & Weyl, 2014; Keller et al., 2011; Novák et al., 2020). Biological invasions caused by these species have been widely discussed for their significant negative impacts on the invaded ecosystems and biodiversity (Gallardo & Aldridge, 2020). Research and management of invasive species are particularly problematic due to the very demanding efforts (and low eradication success) involved in their control. Also, reliable and sustainable management practices that do not negatively affect other taxa and the whole ecosystem (Simberloff, 2021) and missing strategies preventing repeated introductions (Patoka et al., 2018). Another important aspect is the rapid range expansion of aquatic invasive species. They are often migratory r-strategists that are tolerant to a broad range of stressors, exhibit considerable adaptability and plasticity, and exploit the ecosystem at different trophic levels (Britton et al., 2010; Lipták et al., 2019).

Many cases of biological invasions are of known origins, such as intentional release (Chapple et al., 2012; Pyšek et al., 2020). Introductions of animals with the potential to become invasive were rarely rigorously evaluated in terms of risks they can represent; instead, their potential economic, agricultural or aesthetic values take priority over the potential threats that the species pose (Gunnthorsdottir, 2001; Prokop & Frančovičová, Prokop & Frančovičová, 2013; Lipták & Vitázková, 2015; Chucholl & Wendler, 2017).

The public has been identified as one of the main components in the effective management of biological invasions through education and citizen science (Kobori et al., 2016). Therefore, it plays an important role in nature conservation through environmental responsibility (Novoa et al., 2017; Rodríguez-Rey et al., 2022). The management of biological invasions does not only rely on source awareness or intentional cases of introductions of new and potentially invasive species, but also aims toward an active citizen-driven science that includes the public in nature conservation and management activities (Encarnação et al., 2021). Finally, in the ideal state, this can lead to self-sustainable nature conservation and impact the decision-making of stakeholders (Encarnação et al., 2021; Shackleton et al., 2019). Thus, invasive species management and awareness about high-risk taxa are crucial.

Therefore, we investigated the level of knowledge about biological invasions and aquatic non-indigenous invasive species in the general public survey. An anonymous online questionnaire was developed and distributed in the Czech and Slovak republics through social media (such as Meta, Facebook). In the first section, we addressed the general awareness of biological invasions, whether the participants are aware that biological invasions are happening in their regions, and whether they know that biological invasions pose a high threat to biodiversity. In the second section, realistic examples of native and invasive species of fish and crayfish taxa were presented in an anonymous online questionnaire to (i) distinguish whether the responders know how to identify invasive species from their native counterparts, and (ii) to evaluate the conservation efforts of the presented fish and crayfish species.

## **Methods**

### ***Ethics Statement***

All procedures performed in studies involving human participants follow the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The research and the survey used respected the dignity of the respondents. The research was not backed by the Respondents Consent Form (informed consent); however, respondents were informed about the handling and management of data (they were anonymous) by the research team. Participants were assured of the confidentiality of the obtained data. Instructions for the survey were available to the respondents and provided all the necessary information explaining the aim of the research, with guarantees to the respondents about data management. Personal information in the survey disabled any potential identification of a specific respondent, and the questions asked did not pose ethical dilemmas regarding the answers. Thereby the questionnaire survey was in agreement with the standard ethical procedure used in research in social sciences.

### ***Participants***

Participants from the Czech and Slovak republics were recruited for this questionnaire. The two countries neighbor each other in Central Europe and share similar invasive and native species. All selected species in this questionnaire are established or have the potential to occur in both countries (Kouba et al., 2014; Koščo et al., 2010; Lusk et al., 2010). The responders were pooled together and analyzed as a whole as differences between the two groups were not within the scope of this research.

### ***Questionnaire***

The questionnaire was produced in the Google Form application (full version available in the corresponding author upon request). The form was bilingual, containing text in both Czech and Slovak languages. The questionnaire was anonymous, and all participants were blind to our research hypotheses. All responders were informed that the output of this research was going to be published in a scientific paper and were provided with further reference to the published work.

In the first section of the questionnaire, we collected information about the participants' country, age, sex, and education level.

In the second section, we aimed to investigate general knowledge regarding biological invasions. The following questions were put forward: Are you familiar with the issue of biological invasions? Do you know that biological invasions are occurring in your country? Do you think that biological invasions pose a serious threat to indigenous biodiversity? The participants rated each of the three questions on a 7-point scale, ranging from 1 = absolutely not, to 7 = absolutely yes, according to Prokop and Fančovičová (2013).

In the third section, we investigated the participant's ability to recognize invasive species amongst native equivalents. Table 1a introduces the selected species for the questionnaire.

A total of 12 questions (Which of the two species do you think is invasive?), were presented to the participant, out of which 10 questions contained fish and two contained crayfish species. This section used the forced-choice method, presenting two original illustrations of fish and crayfish species. Fish and crayfish species were compared in random order. The participant could choose between the two options.

In the fourth section, we aimed to determine whether the participant would rather protect the invasive or the native species (Table 1b). A total of 11 questions were asked, of which 8 contained a single picture of a fish and three questions contained crayfish species. The participants rated each of the 11 questions (Would you protect this species and put it on the list of protected species?) in a 7-point scale, ranging from 1 = absolutely not, to 7 = absolutely yes.

**Table 1.** Selected native and invasive counterparts used in questions to determine the ability to recognize the invasive species beside the native one (A), and selected native and invasive species used for the evaluation of the willingness to protect (B). The questions were rated in a 7-point scale, ranging from 1 = absolutely not, to 7 = absolutely yes.

A) Which of the two species do you think is invasive?			B) Would you protect this species and put it on the list of protected species?	
Question	Native	Invasive	Question	Species
Q1	Wels catfish ( <i>Silurus glanis</i> )	Brown bullhead ( <i>Ameiurus nebulosus</i> )	Q1	Weatherfish ( <i>M. fossilis</i> )
Q2	Ide ( <i>Leuciscus idus</i> )	Topmouth gudgeon ( <i>Pseudorasbora parva</i> )	Q2	Brown bullhead ( <i>A. nebulosus</i> )
Q3	Bullhead ( <i>Cottus gobio</i> )	Racer goby ( <i>Babka gymnotrachelus</i> )	Q3	Spirilin ( <i>A. bipunctatus</i> )
Q4	Spirilin ( <i>Alburnoides bipunctatus</i> )	Three-spined stickleback ( <i>Gasterosteus aculeatus</i> )	Q4	Grayling ( <i>T. thymallus</i> )
Q5	Tench ( <i>Tinca tinca</i> )	Pumpkinseed ( <i>Lepomis gibbosus</i> )	Q5	Prussian carp ( <i>C. gibelio</i> )
Q6	Grayling ( <i>Thymallus thymallus</i> )	Round goby ( <i>Neogobius melanostomus</i> )	Q6	Topmouth gudgeon ( <i>P. parva</i> )
Q7	Pikeperch ( <i>Stizostedion lucioperca</i> )	Prussian carp ( <i>Carassius gibelio</i> )	Q7	Pikeperch ( <i>S. lucioperca</i> )
Q8	European eel ( <i>Anguilla anguilla</i> )	Racer goby ( <i>B. gymnotrachelus</i> )	Q8	Pumpkinseed ( <i>L. gibbosus</i> )
Q9	Northern pike ( <i>Esox lucius</i> )	Chinese sleeper ( <i>Perccottus glenii</i> )	Q9	Noble crayfish ( <i>A. astacus</i> )
Q10	Weatherfish ( <i>Misgurnus fossilis</i> )	Grass carp ( <i>Ctenopharyngodon idella</i> )	Q10	Marbled crayfish ( <i>Procambarus virginalis</i> )
Q11	Noble crayfish ( <i>Astacus astacus</i> )	Signal crayfish ( <i>Pacifastacus leniusculus</i> )	Q11	Red swamp crayfish ( <i>P. clarkii</i> )
Q12	Stone crayfish ( <i>Austropotamobius torrentium</i> )	Red swamp crayfish ( <i>Procambarus clarkii</i> )		

## Procedure

Participants were invited to participate by e-mail correspondence and social media (Meta, Facebook). A link to the questionnaire was inserted in the e-mail and sent to a mixture of contacts, including family members, colleagues and other unrelated contacts, such as former colleagues and project partners unrelated to science and research, completely unrelated to the subject of the questionnaire. Colleagues that were invited from the academic sector were directly and not directly involved with the topic of biological invasions and were invited to participate in the research as we wanted to have the answers from the academic sector as well. All the invited participants were asked to complete and share the questionnaire with other social circles. At the same time, the link to the questionnaire was shared on the Meta pages of some of the coauthors, colleagues, friends and third parties, with the aim of further distributing (sharing) the questionnaire to reach the general public (to involve as broad a circle of participants as possible, reduce bias, and to obtain a sufficient number of participants). The questionnaire was shared for about four months, from March to July 2021.

## Statistical Analysis

Mean scores from ratings of willingness to protect native and non-native fish species were defined as dependent variables in Generalised Linear Mixed Models (GLMM). Participant IDs were treated as a random effect; continuous predictors were the participants' age, mean general knowledge as regards biological invasions score, and fish and crayfish identification scores. Education level was an ordinal independent variable. The sex of participants and the animal category (native *vs.* invasive species) were predictors. Overall species identification scores were compared with t-tests. The part of the questionnaire dealing with biological invasions was very close to the acceptable minimum value of reliability (Cronbach  $\alpha = 0.69$ ); thus, we used mean scores from all three items (second part of the questionnaire) in subsequent analyses. All statistical tests were made in IBM SPSS Statistics ver. 26.

## Results

The sample of participants consisted of 304 responders (221 were males and 83 females); 183 responders (60%) were from the Czech Republic, and 121 (40%) were from the Slovak Republic. It corresponds well with the number of inhabitants in both countries, being ~10.7 and 5.5 million, respectively (<https://www.worldometers.info/>). Given the close historical, political, cultural and geographical proximity of the two countries (formerly known as Czechoslovakia; [www.indexmundi.com/factbook/compare/czech-republic.slovakia](http://www.indexmundi.com/factbook/compare/czech-republic.slovakia)), the data were considered as one sample (Šaffa et al., 2021). The average age of the participants was 38 years. Twelve (4%) of the participants had primary education, 109 (36%) had secondary education, 25 (8%) of the participants were bachelors, 100 (33%) were masters, and 58 (19%) had PhDs, with 24 (8%) in social/technical sciences and 34 (11%) in natural sciences.

Based on the results obtained from the first set of questions, the responders displayed a range of familiarity with biological invasions, while a majority of responders

acknowledged that biological invasions are occurring in their countries and are a serious threat to native biodiversity (Figure 1).

The identification success of invasive fish and crayfish species is shown in Figure 2. Invasive species were generally correctly identified. Fish species (mean = 0.73, SE = 0.01) were identified significantly better than crayfish species (mean = 0.68, SE = 0.02) (t-test,  $t = 2.19$ ,  $df = 606$ ,  $p = .03$ ).

Better acquaintance with biological invasions negatively influenced the willingness to protect all fish and crayfish species the respondents were asked about ( $\beta = -0.12$ ). The interaction effect suggested that biological invasion knowledge positively influenced native fish and crayfish, but negatively invasive fish and crayfish. This finding suggested that participants with better biological invasion scores supported the conservation of native species, but did not support the conservation of invasive species. Although the effect of education on the readiness to protect animals was significant (Table 2), only participants with a doctoral degree in social/educational sciences scored better than others (all  $p < .001$ ), while differences among participants from other education levels were negligible.

In general, native species received a higher willingness to protect score than invasive counterparts (Figure 3a). Native crayfish received the highest willingness to protect score, followed by native fish, while invasive fish received the lowest score (Figure 3b, Table 3). Contrast analyses showed that differences among all groups were statistically significant (all  $p < .001$ ). The effects of age and identification scores on willingness to protect all species were not considered because neither factor was significant.

Female respondents to our survey appeared to be more willing to protect animals the respondents were asked about than males (Figure 3c). Concerning interaction terms,

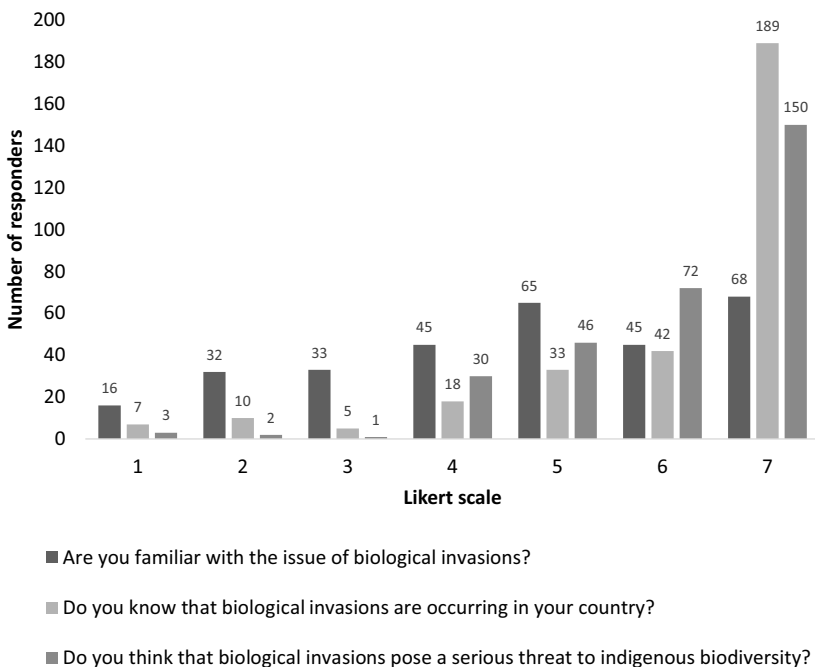
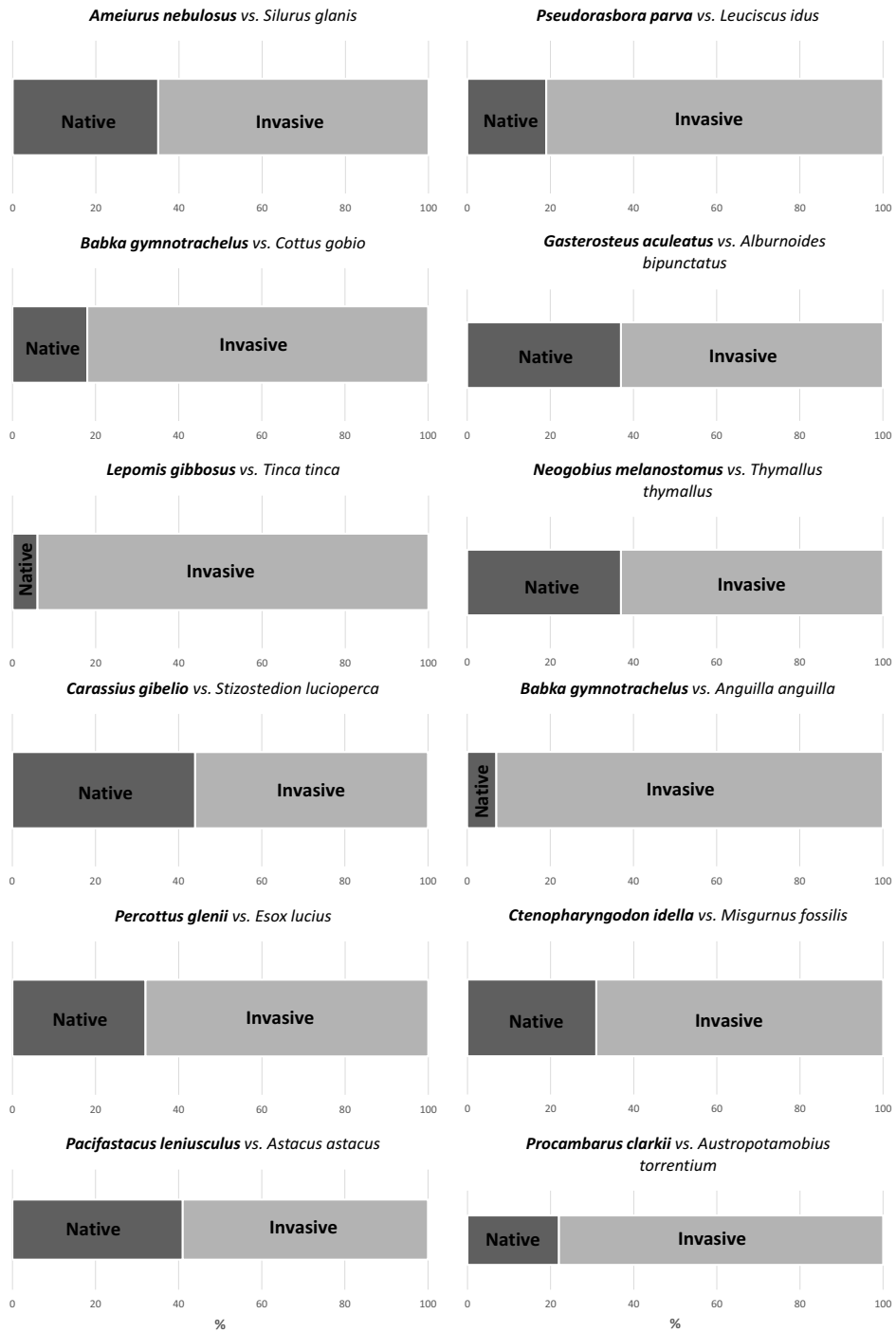


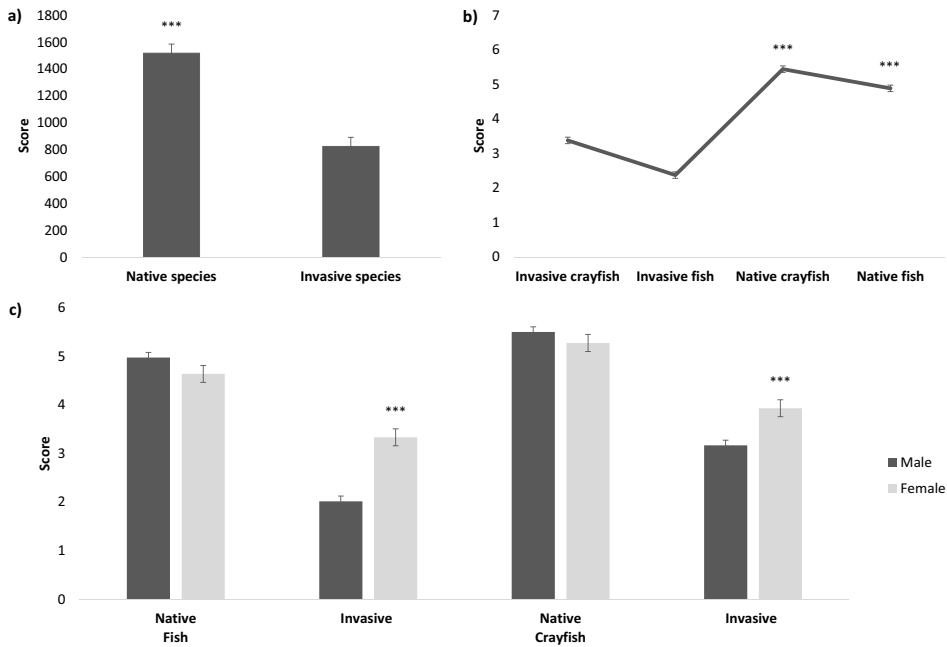
Figure 1. Responders and their relationship to biological invasions.



**Figure 2.** Identification success of invasive vs. native species. Invasive species are marked with bold. The horizontal bars represent the invasive species consideration as native or invasive.

**Table 2.** Results of GLMM on the willingness to protect invasive and native fish and crayfish species.

	F	df	P
Corrected Model	54.5	19. 119	<0.001
Gender	11.9	1. 119	<0.001
Education	3.9	5. 119	<0.001
Native/non-indigenous species (NNS)	13.03	3. 119	<0.001
Age	3.4	1. 119	0.062
Fish knowledge	2.8	1. 119	0.093
Crayfish knowledge	2.4	1. 119	0.119
Biological Invasion Score (BIS)	8.3	1. 119	<b>0.004</b>
Gender × NNS	11.7	3. 119	<0.001
BIS × NNS	36.6	3. 119	<0.001



**Figure 3.** a) Willingness to protect native and invasive counterparts ( $p < .001$  for native species vs. invasive species), b) Willingness to protect invasive and native fish and crayfish species ( $p < .001$  for invasive crayfish vs. native crayfish and invasive fish vs. native fish, respectively), and c) Gender effect to willingness to protect native and invasive species ( $p < .001$  for invasive fish and crayfish species).

**Table 3.** Willingness to protect scores. Continuous predictors are fixed at the following values: Age = 37.72, FishKnow = 37.73, CrayKnow = 37.68, BioInvasScore = 5.62.

Willingness to protect	Mean	Standard error	95% Confidence interval	
			Lower	Upper
Invasive crayfish	3.52	0.105	3.31	3.73
Invasive fish	2.52	0.105	2.31	2.72
Native crayfish	5.59	0.105	5.38	5.79
Native fish	5.03	0.105	4.82	5.23

females were more prone to protect invasive fish and crayfish than males (analysis of contrasts, both  $p < .001$ ). On the contrary, there were no gender differences in the willingness to protect native fish and crayfish (analysis of contrasts,  $p = .11$  and  $0.29$ , respectively).

## Discussion

Obtained results indicated that increased awareness of the public about biological invasions and the related risks positively influences the willingness to protect native fish and crayfish species while fish were commonly known to the respondents in comparison with crayfish. One can conclude that people who can distinguish native and non-native species are not keen to support invasive species and their spreading (Kochalski et al., 2018).

Human-mediated species introductions can result in biological invasions that negatively affect freshwater ecosystems (Arthington, 2021) and serves as a road to disease transmission that can even affect human health (Keesing et al., 2010), making the issue even more important. Both fish and crayfish species play key roles in freshwater ecosystems. However, many of them face some sort of endangerment (Kouba et al., 2014; van der Veer & Nentwig, 2015). A good example are native European crayfish species, which with the introduction of non-indigenous North American counterparts have dramatically decreased in numbers (Holdich et al., 2009). These North American species were thought to supplement challenged native crayfish species (Theissinger et al., 2022). However, it turned out that the introduced crayfish species themselves are out-competing them (Holdich et al., 2009). Furthermore, they are the reservoirs of the crayfish plague (*Aphanomyces astaci*) pathogen (Svoboda et al., 2017; Theissinger et al., 2021). Since its introduction in the 19<sup>th</sup> century, many crayfish plague outbreaks have occurred consequently, causing mass mortalities of native crayfish species (Kozubíková et al., 2007; Mojžišová et al., 2022), and even local extinctions of their populations (Bonelli et al., 2017; Jussila et al., 2021; Sandström et al., 2014). Poor knowledge can additionally lead, for example, to unintentional overharvesting of fish species of conservation interest and thus to a decline of the already strained populations (Page et al., 2012). Recreational fishing is a good example of species introductions, which is responsible for introductions and translocations of invasive species solely for the sport, ignoring the potential consequences caused by such actions (Cambray, 2003). Invasive species are even introduced when they are well recognized by some circles of the population (such as conservationists, biologists, ecologists and others), but without communication to a broad audience. Then the species are introduced and/or translocated further (Holdich et al., 2014).

The level of awareness of biological invasions, and the ability to distinguish native and invasive species in the aquatic environment is pivotal and multidimensional (Jubase et al., 2021; Somaweera et al., 2010). The considered invasive fish and crayfish species were relatively well identified by the public, but this identification was not straightforward in all cases. Many species, such as the topmouth gudgeon (*Pseudorasbora parva*), racer goby (*Babka gymnotrachelus*), pumpkinseed (*Lepomis gibbosus*) and the red swamp crayfish (*Procambarus clarkii*), were often correctly identified as invasive species, while other invasive species such as the brown bullhead (*Ameiurus nebulosus*), three-spined stickleback (*Gasterosteus aculeatus*), round goby (*Neogobius melanostomus*), Prussian carp (*Carassius gibelio*) and the signal crayfish (*Pacifastacus leniusculus*), were less frequently correctly

identified. Misidentification of the invasive species can lead to disastrous consequences, as was the case for the crayfish species' human-driven mass mortality related to the crayfish plague's spread (Bonelli et al., 2017). There may be several reasons for this result. For instance, topmouth gudgeon and pumpkinseed were the most correctly identified, perhaps due to their well-established roles as successful invaders, which are used as examples in educating students, or because they are widely distributed in Central Europe (Keller et al., 2011). Pumpkinseed and the red swamp crayfish, which are quite colorful, could intuitively be classified as exotic creatures (Prokop & Fančovičová, 2013). Their unusual appearance makes them easy to remember, resulting in higher identification scores in our questionnaire. It is worth mentioning that typical native species (presuming that one has encountered these species at some point of its education or in media) such as the European eel (*Anguilla Anguilla*) and tench (*Tinca tinca*) were the most successfully correctly identified as native (when compared to racer goby and pumpkinseed, respectively). The highest conservation support was given to weatherfish (*Misgurnus fossilis*), grayling (*Thymallus thymallus*) and the noble crayfish (*Astacus astacus*), mainly because of the established perception as examples of native species fauna.

On the other hand, visual similarity can be the main reason for the incorrect identification of the species, as is the case for the signal crayfish and the noble crayfish. The same reasons could be behind the relatively high willingness to protect score for the marbled crayfish (*Procambarus virginalis*), which obtained around 50% conservation support. The reasons behind the high willingness to protect scores for the crayfish species (native and invasive alike) could be linked to fractioned information on how crayfish were formerly abundant in the brooks and rivers, or that they are often recognized as bioindicators of high-quality environment.

Invasive alien species received considerable support and a higher rate of willingness for protection among female respondents. This result is in accordance with the study of Czech et al. (2001), where a higher degree of protection of nonhuman species and a greater concern for species conservation among female participants.

Fish identification scores were higher than the scores for crayfish, which pointed to lower awareness and knowledge about crayfish species. This is mainly because crayfish issues are not frequently highlighted by media, where fish invaders are covered and exceed the crayfish invaders in numbers, distribution, economic values, popularity, but also impacts (van der Veer & Nentwig, 2015). We stressed the importance of invasive crayfish species, which should be implemented in curricula to a greater extent as they introduce serious negative effects in invaded ecosystems, comparable to those of fish invaders (Theissinger et al., 2021; Vaeßen & Hollert, 2015; van der Veer & Nentwig, 2015), resulting in serious economic losses (Haubrock et al., 2021b; Kouba et al., 2022). Gaps in knowledge are to be expected in other insufficiently known aquatic taxa, such as mussels (Haubrock et al., 2022; Renault et al., 2021), found to be a serious gap in knowledge for participants in Canada (Nanayakkara et al., 2017).

The rapid extension of the range of invaders, together with new introductions of species, is majorly facilitated by uninformed (uneducated or ignorant) citizens (Andriantsoa et al., 2019; Holdich et al., 2014). Freshwaters are closed and vulnerable ecosystems harboring rich freshwater biodiversity, which are nowadays confronted with impressive numbers of introduced species. The numbers and diversity of introduced species and their wide geographical distribution range complicate their successful management. One possibility that could

counteract their negative impact is a good citizen science (Encarnaç o et al., 2021; Rodr guez-Rey et al., 2022) and general public education (Somaweera et al., 2010). The general public, including laypersons, can provide an important source of information on the distribution and spread of invasive species, as they interact with the wildlife in many ways and cover wide geographical regions. The issue of biological invasions could be of interest to the public and a field of self-education as invasions can affect the environment to which they are directly related to.

Insufficient knowledge in this regard could lead to new invasions with globally deleterious consequences, particularly in aquatic environments (Gozlan et al., 2010; Jubase et al., 2021; Patoka et al., 2018). To avoid such errors in the future, there is an urgent need to share information regarding the threat and effects of biological invasions. The presented findings suggest that the public is aware of biological invasions in their countries and perceives that biological invasion poses a severe threat to native biodiversity. Our results, together with those of Sharp et al. (2011) and Sosa et al. (2021), show how awareness plays an important role in the field of biological invasions, species identification and approval of the management actions. Increased awareness of biological invasions results in increased conservation support for native species. This is important as many native species are already of conservation concern.

Citizen education sustains nature conservation and management. Well-informed, responsible citizens should avoid introductions of unknown species to the wild (Patoka et al., 2018) and value native species, supporting their conservation (Gallo & Waitt, 2011; Kovalenko et al., 2021). However, diverse taxa are differently perceived. For example, the European rabbit (*Oryctolagus cuniculus*), an invasive species in Australia, is easily identified as an invasive species whose management is implemented by citizen science; however, information on different taxa of invasive species, particularly in aquatic environments, is not so well established in the population (Azzurro et al., 2013). Our results indicate that fish species are more likely to be correctly identified than crayfish species. Since the correct identification of animals requires experts in the field, scientists and conservation managers are thus encouraged to collaborate in this field and work on recognizing the invasive species suitable for the educational purposes of the general public.

Citizen science programs have an important educational value. For instance, an education on marine conservation has successfully improved participants' knowledge (Branchini et al., 2015). Similarly, an educational program on invasive plants has significantly increased the knowledge of invasive plants and improved their identification (Jordan et al., 2011). Acknowledgement of the invasive species and the need for some form of their management was found mainly in older and more educated individuals (Sharp et al., 2011). Aquatic invasive species were more perceived by water-based recreationists and persons that were in some way interfering with the given ecosystem (Eiswerth et al., 2011).

The abovementioned strategies present possible routes to a more reliable citizen science and public awareness that leads to the successful management of invasive species (Sosa et al., 2021; Verbrugge et al., 2021). Broadcasts, social media, and workshops are excellent sources for citizens to obtain the required information and a great opportunity for researchers to build their credibility (Davis et al., 2018). We are calling for further innovative educational programs that incorporate knowledge regarding biological invasions in freshwater ecosystems and responsible actions involving all relevant stakeholders (Diagne et al., 2020).

## Conclusions

Education in biological invasions has emerged as an urgent need to form educational platforms with easily accessible information for citizens (Rodríguez-Rey et al., 2022). This is an excellent opportunity for wildlife managers, environmentalists, and educators to contribute to improving the quality of public education, citizen science and sustainable and effective conservation measurements. For instance, freely available applications for smartphone users, with all the necessary content regarding biological invasions, as well as manuals for the identification of species, are very useful (Verbrugge et al., 2021). It is of great importance that citizens can access reliable sources of information as part of their self-education (Somaweera et al., 2010).

Knowledge of biological invasions and related risks influence the correct identification of invasive or native species and the degree to which native species are likely to be protected. Fish species were more likely to be correctly distinguished than crayfish species; thus the effort to improve the knowledge about crayfish is required. Through correct species identification and conservation support of native species, the education of the general public plays a key role in biological invasion management as well as nature conservation.

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We have no known conflict of interest to disclose.

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