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Authors: Piria, Marina, Stroil, Belma Kalamujić, Giannetto, Daniela, Tarkan, Ali Serhan, Gavrilović, Ana, et al.

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An assessment of regulation, education practices and socio-economic perceptions of non-native aquatic species in the Balkans

Marina PIRIA[1], Belma KALAMUJIĆ STROIL[2], Daniela GIANNETTO[3*], Ali Serhan TARKAN[4,5], Ana GAVRILOVIĆ[1], Ivan ŠPELIĆ[1], Tena RADOČAJ[1], Nurçin KILLI[4], Halit FILIZ[4], Tuğba UÇMA UYSAL[6], Ceray ALDEMIR[6], Elvis KAMBERI[7], Edmond HALA[7], Rigers BAKIU[7,8], Jerina KOLITARI[7,8], Enkelejda BUDA[7], Silvia DURMISHAJ BAKIU[8], Edlira SADIKU[7], Azra BAKRAČ[9], Emir MUJIĆ[9], Subha AVDIĆ[9], Nikos DOUMPAS[10], Ioannis GIOVOS[10], Irsida DINOSHI[11], Lejla UŠANOVIĆ[2], Abdurahim KALAJDŽIĆ[2], Ana PEŠIĆ[12], Ilija ĆETKOVIĆ[12], Olivera MARKOVIĆ[12], Dragana MILOŠEVIĆ[13], Danilo MRDAK[13], Gianluca SARÁ[14], Mar BOSCH BELMAR[14], Guillaume MARCHESSAUX[14], Sasho TRAJANOVSKI[15] and Konstantin ZDRAVESKI[16]

[1] *Department of Fisheries, Apiculture, Wildlife Management and Special Zoology, Faculty of Agriculture, University of Zagreb, Zagreb, Croatia; e-mail: marina.piria@gmail.com, agavrilster@gmail.com, ivanspelic@gmail.com, tena.djakovo@gmail.com*

[2] *Institute for Genetic Engineering and Biotechnology, University of Sarajevo, Sarajevo, Bosnia and Herzegovina; e-mail: belma.k@gmail.com, usanovic.lejla@gmail.com, abdurahim.k@gmail.com*

[3] *Faculty of Science, Muğla Sıtkı Koçman University, Menteşe, Muğla, Turkey; e-mail: danielagiannetto@gmail.com*

[4] *Faculty of Fisheries, Muğla Sıtkı Koçman University, Menteşe, Muğla, Turkey; e-mail: serhantarkan@gmail.com, nurcinkilli@mu.edu.tr, halit.filiz@mu.edu.tr*

[5] *Department of Ecology and Vertebrate Zoology, Faculty of Biology and Environmental Protection, University of Łódź, Łódź, Poland*

[6] *Faculty of Economics and Administrative Sciences, Muğla Sıtkı Koçman University, Muğla, Turkey; e-mail: ucmatugba@gmail.com, cerayceylan@gmail.com*

[7] *Department of Aquaculture and Fisheries, Faculty of Agriculture and Environment, Agricultural University of Tirana, Tirana, Albania; e-mail: ekamberi@ubt.edu.al, hiedmo@yahoo.com, bakiurigers@gmail.com, j.kolitari@gmail.com, ebuda@ubt.edu.al, edlira.sadiku@gmail.com*

[8] *Albanian Center for Environmental Protection and Sustainable Development, Tirana, Albania; e-mail: albaniancenterforepsd@gmail.com*

[9] *Biotechnical Faculty, University of Bihać, Bihać, Bosnia and Herzegovina; e-mail: azra_bakrac_beciraj@yahoo.com, emir.mujic@unbi.ba, subhaavdic8@gmail.com*

[10] *iSea, Environmental Organisation for the Preservation of Aquatic Ecosystems, Thessaloniki, Greece; e-mail: nikos.doumpas@gmail.com, ioannis.giovos@gmail.com*

[11] *Faculty of Economy, University College of Business, Tirana, Albania; e-mail: idinoshi@kub.edu.al*

[12] *Institute of Marine Biology, University of Montenegro, Kotor, Montenegro; e-mail: pesica@ucg.ac.me, ilija.cetkovic65@gmail.com, omarkovic@ucg.ac.me*

[13] *Faculty of Science and Mathematics, University of Montenegro, Podgorica, Montenegro; e-mail: draganam25@gmail.com, danilomrdak@gmail.com*

* *Corresponding Author*

[14] *Department of Earth and Marine Science, University of Palermo, Palermo, Italy; e-mail: gianluca.sara@unipa.it, mar.b.belmar@gmail.com, guillaume.gmarchessaux@gmail.com*

[15] *Public Scientific Institution Hydrobiological Institute Ohrid, Ohrid, North Macedonia; e-mail: trajsa@hio.edu.mk*

[16] *Association for Ecology EKOMENLOG, Ohrid, North Macedonia; e-mail: konstantin@galicica.org.mk*

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Abstract. Alongside climate change, the introduction of non-native species (NNS) is widely recognized as one of the main threats to aquatic biodiversity and human wellbeing. Non-native species and biodiversity are generally low priority issues on the political agendas of many countries, particularly in European countries outside the European Union (EU). The objectives and tasks of this study were to address the policy regulation, education level, education practices, and socioeconomic perceptions of NNS in the Balkans. A questionnaire-based survey was conducted in Albania, Bosnia and Herzegovina, Montenegro, North Macedonia and Turkey (Balkan EU candidate and potential candidate members), in Croatia and Greece (Balkan EU Member States) and Italy (non-Balkan EU Member State). The EU Alien Regulation (1143/2014) concerning NNS is implemented in EU Member States and Montenegro, whereas Albania, Bosnia and Herzegovina and Turkey have not reported specific policy regulations for NNS. Permanent monitoring programmes specifically designed for NNS have not yet been established in the EU Member States. Most countries tackle the issue of NNS through educational activities as part of specific projects. Education level is indicative of the implementation of NNS policy regulation, and efforts are needed for the proper development of relative study programmes. Public awareness and educational preparedness concerning NNS in the Balkans were identified as poor. Strong programmes for management and education should be developed to increase public awareness to prevent further biodiversity losses in the Balkan region.

Key words: invasive aquatic species, legislation, public awareness, western Balkans, EU

Introduction

The introduction of non-native species (NNS) is widely recognized as one of the main threats to aquatic biodiversity (Katsanevakis et al. 2014, Roy et al. 2019), and it also impacts human wellbeing (Bacher et al. 2018). The Balkan Peninsula (hereafter Balkans) is considered one of the world biodiversity hotspots (Mittermeier et al. 2011) and, alongside the Iberian and Apennine Peninsulas, harbours vast genetic and species diversity (Hewitt 2011). Many aquatic animals are long-established in the Balkans, though there are numerous recently introduced species, even in isolated lakes (Bănărescu 2004, Piria et al. 2018). The Mediterranean Sea is also a hotspot of biodiversity (Coll et al. 2010), and NNS introduction, as one of the main threats, may disrupt its ecosystem structure and function (Sabelli & Taviani 2014, Slišković et al. 2021). In recent decades, increasing reports of NNS in the Mediterranean and Adriatic Sea have been made, suggesting this could soon be a serious threat to native biodiversity and the natural environment (Zenetos et al. 2012, Katsanevakis et al. 2013, Slišković et al. 2021).

Across Europe, a wide range of policies, legislation, and management approaches (including public awareness initiatives) have been developed to address the issue of NNS and invasive alien species (IAS) (see Copp et al. 2005 for definition). Regulation (EU) no. 1143/2014 of the European Parliament and of the Council on the prevention and management of the introduction and spread of invasive alien species (hereinafter the Regulation) came into force from 2015 (January 1st) with the aim of laying down rules to prevent, minimize and mitigate adverse impacts on biodiversity from the introduction and spread of invasive alien species within the Union, both intentional and unintentional (EC 2014). The Regulation also includes an initial list of Invasive Alien Species of Union concern (2016) with two updates (2017 and 2019; EC 2014, 2016, 2017, 2019). Member States (MS) are required to take action on pathways of unintentional introduction, to take measures for the early detection and rapid eradication of these species, and to manage species that are already widely spread in their territory (https://ec.europa.eu/environment/nature/invasivealien/list/index_en.htm) (Piria et al. 2017). In several European

countries, lists of alien species have been compiled (e.g. Belgium, Portugal, UK (Boon et al. 2020)), and an inventory of alien species present in Europe has been established by the European Alien Species Information Network (EASIN) (Katsanevakis et al. 2012).

However, it is still not known whether this Regulation has prompted further actions in non-EU Balkan countries. Non-EU bordering countries are not obliged to enforce EU laws concerning NNS, potentially leaving open invasion corridors (Hulme 2015, Piria et al. 2017). In most non-EU Balkan countries, a lack of effective measures to control the introduction or translocation of NNS has been identified (Piria et al. 2017). Issues associated with IAS are cross-border and cannot be managed exclusively at the intra-EU level, as Member States along the EU borders may potentially be at greater risk of new bio-invasions via their non-EU neighbours (EC 2008). Common ground in the implementation of legislation between the EU and its neighbouring countries has been proposed (Piria et al. 2017), but as yet not developed. NNS and biodiversity are generally of low priority on the political agendas of many countries, and this hampers the implementation of EC directives and/or regulations (Piria et al. 2017). In addition, cross-border management of IAS between EU and non-EU countries is poorly funded and fragmented in nature, which limits the extent or impedes the existence of NNS monitoring projects for early warning and rapid response systems at a pan-European level. Finally, the lack of coordination of scientific effort and dialogue between public institutions on IAS between EU and non-EU countries has been identified as a major drawback in the implementation of cross-border legislative action (Piria et al. 2017, Rak et al. 2019).

The topic of biological invasions is relatively new in education, and has only recently come to the attention of environmental educators (Verbrugge et al. 2021). There is still a general lack of environmental science programmes at primary and secondary school levels and in some university curricula, especially concerning invasion biology and native biodiversity (Piria et al. 2017). However, environmental education can play an important role by providing relevant learning outcomes and experiences for students and professionals in different sectors associated with introduction pathways or those involved in the mitigation and eradication of IAS (Verbrugge et al. 2021).

Many non-native taxa are known to have socio-economic impacts, affecting different aspects of human wellbeing (security; material and non-material assets; health; social, spiritual, and cultural relations; freedom of choice and action; Bacher et al. 2018), and to generate considerable environmental and economic losses (dos Santos et al. 2019, Cuthbert et al. 2021). Understanding public perceptions of IAS is crucial for understanding behaviour and developing effective management strategies to maintain, preserve and improve biodiversity, ecosystem services and human well-being (Shackleton et al. 2019a). Socio-economic perception of IAS and NNS in the Balkan countries that are EU member candidates is still unknown and needs to be addressed as soon as possible.

The main aim of this paper was to survey the policy-level documents and principles addressing NNS in the Balkans. Also, education and socio-economic perceptions regarding NNS in the Balkans were assessed and opportunities for policy development and implementation of risk management for NNS in the Balkans are discussed.

Material and Methods

The questionnaire was prepared under Work Package 1 of the ERASMUS+ project ''Educational capacity strengthening for risk management of non-native aquatic species in the Western Balkans (Albania, Bosnia and Herzegovina, and Montenegro) (see Acknowledgements) and comprised 21 questions addressing four areas (Table 1): A) policy, B) general environmental perception, C) educational issues, and D) socio-economic perception. Specific questions related to environmental definitions and specific education were modified according to Boon et al. (2020) and Smith et al. (2011).

The questionnaire was completed by experts from 11 institutions located in EU candidate and potential candidate countries (hereinafter EU candidate countries) in the Balkans (Albania, Bosnia and Herzegovina, Montenegro, North Macedonia and Turkey), Balkan EU Member States (Croatia and Greece), and one non-Balkan EU Member State (Italy). Bosnia and Herzegovina is a potential candidate country whose application was endorsed by the EU in December 2019 (https://ec.europa.eu/neighbourhood-enlargement/countries/detailed-country-information/bosnia-herzegovina_en). The questionnaire was completed by two different

Table 1. Content of the questionnaire on alien species policy, education, and socio-economic issues.

No. question
A. General – related to the policy
1. Is there any impact of the EU Alien regulation (EU no. 1143/2014) on the formation of activities related to the NNS (citizen science development, research, education progress)?
2. List and briefly describe the documents addressing NNS (environment, aquaculture). Provide references with links for policy documents (if applicable).
B. Specific – environmental definitions and management plans, please provide examples if possible
1. How are "alien species" defined in your country? Are translocated native species considered alien species? If "yes", please give some examples.
2. Are casual alien species considered alien species?
3. Are species that have expanded their range as a result of climate change considered alien species?
4. Are all introduced species considered alien species, regardless of the date of introduction? If not, what cut-off date is used? Is it useful to apply a historical date as one of the criteria to determine the non-native status of a species?
5. Are there lists of alien species available in your country? Do you consider only those alien species known to be invasive, or all alien species?
6. Are there monitoring programmes specifically designed for the detection of alien species or the expansion of their ranges? Would the routine monitoring programmes used in your country detect plants, invertebrates and fish in each of the aquatic habitats (i.e. rivers, lakes, transitional waters, coastal waters, marine environment)? If "yes", what action is taken when an alien species is detected?
7. Are there specific measures identified in the river basin plans or marine environment in your country for controlling alien species or preventing their spread? If "yes", please provide web-links.
8. Are there any experiences in the field of risk management of NN species? If yes, please describe briefly.
C. Specific – educational
1. Do any educational programmes/training exist that focus specifically on the significant global environmental challenge of NNS or IAS?
2. Do any programs and/or individual courses approach NNS issues from an interdisciplinary perspective? If yes, please describe briefly.
3. What is your opinion on which target groups are priorities in developing NNS educational programmes in your country?
4. Explain your vision for the approach of educational programmes.
5. What is your opinion on how to improve educational preparedness?
D. Specific – socio-economic
1. How do citizens of your country perceive alien species?
2. Is there an example of where an alien species has stopped a common activity of citizens? If yes, give an example.
3. Is there an example of where alien species have been economically exploited in your country?
4. Have there been any attempts to remove alien species from the environment in your country?
5. Have there been any visible economic and financial losses due to the spread of NNS? If yes, give an example.

institutions from each of the three EU candidate countries (Albania, Bosnia and Herzegovina and North Macedonia) and the text was then summarized and compiled into one document per country. Only one institution from the other two EU candidate countries (Montenegro and Turkey) and the Balkan (Croatia and Greece) and non-Balkan EU Member States (Italy) completed the questionnaire.

Results

The responses of each country are presented in Table S1.

Policy level documents and principles

The impact of the Regulation on the formation of activities concerning aquatic NNS was identified

as poor in most of the EU candidate countries in the Balkans. Higher impact has been identified in research and education related to horticulture and forestry than in the aquatic environment. In EU Member States, in addition to research and education, the impact of citizen science initiatives has been identified. In this regard, Greece is very active with numerous ongoing citizen science projects on the topic of marine and freshwater NNS that are implemented by national bodies and NGOs. Italy is more focused on terrestrial NNS, while Croatia is equally focused on aquatic and terrestrial ecosystems.

Specific policy regulation is well developed in Montenegro, where a new legislative framework aligned with the Regulation was recently adopted, applicable as of 1 March 2021 through the Act on Alien and IAS of Plants, Animals and Fungi. Albania, Bosnia and Herzegovina, North Macedonia and Turkey have not reported specific policy regulations concerning NNS. In Albania, policy preparation activities on NNS/IAS regulations are ongoing. In Bosnia and Herzegovina and Turkey, some NNS issues are regulated by laws and subordinate legislation. Although there are no specific acts in effect in North Macedonia, all activities related to NNS are generally associated with the EU Directive or are based on the requirements of the EU Directive. EU Member States (Croatia, Greece and Italy) have transposed the provisions of the Regulation into their policy documents.

All EU candidate countries are signatories to the Convention on Biological Diversity and the Cartagena Protocol on Biosafety to the Convention on Biological Diversity (CBD) (https://www.cbd.int/convention/). Additionally, Albania has a Document of Strategic Policies for the Protection of Biodiversity, which also addresses NNS. The Convention on the Control and Management of Ship Ballast Water and Sediments (BWM; https://www.imo.org/en) has been signed by all these countries except Bosnia and Herzegovina. However, Bosnia and Herzegovina has prepared a Strategy and Action Plan for the Protection of Biological Diversity 2015-2020, and Montenegro has prepared a National Biodiversity Strategy with the Action Plan for the period 2016-2020, also addressing NNS.

Environmental definitions and management plans

There are numerous definitions on NNS but only Montenegro and Croatia reported that NNS are defined by a specific policy act with a definition aligned with that in the Regulation, "any live specimen of a species, subspecies or lower taxon of animals, plants, fungi or microorganisms introduced outside its natural range; it includes any part, gametes, seeds, eggs or propagules of such species, as well as any hybrids, varieties or breeds that might survive and subsequently reproduce". Most EU Member States and candidate countries consider NNS to be species that have expanded their range as a result of climate change; though this is not the case in Bosnia and Herzegovina. In Croatia, scientists consider such species as NNS but they are not defined as such under regulation. Casual species are not considered alien species in North Macedonia.

Introduced species are considered alien species regardless of the date of introduction by both EU Member States and candidate countries, but no countries specified the use of a cut-off date. Only Albania stated that it considers a historical date as one of the criteria to determine the non-nativeness of a species.

A national list of alien species has been created by EU Member States and candidate countries. The list needs to be updated in Albania, Italy and Montenegro, and finalized in Turkey. Albania, Croatia, Greece and Montenegro have reported non-invasive alien species on their lists.

Only in Croatia are permanent monitoring programmes specifically designed for NNS being developed. Montenegro, Greece, Italy and Turkey have reported sporadic, project-based monitoring activities without any indication of how long these programmes will continue.

Know-how in risk management tools, such as the Aquatic Species Invasiveness Screening Kit (AS-ISK) (Copp et al. 2021), has only been utilized at an academic level, though risk management of NNS has not been conducted in the field in any EU Member State or candidate country.

Educational level and practices

EU Member States and candidate countries have addressed NNS through educational courses related to project activities, which represent the principal educational practice. Albania, Bosnia and Herzegovina, Croatia and Turkey organize undergraduate, master and PhD lectures on the ecological and/or socio-economic impacts

of NNS and IAS. Lectures are given from an interdisciplinary perspective only in Bosnia and Herzegovina. Target groups identified for NNS educational programmes in the EU Member States and candidate countries in the Balkans include students, stakeholders such as small-medium enterprises (SMEs) in fisheries, agriculture, tourism industry (national parks, fisher associations, sports and recreational associations, etc.) and policy makers (local self-government and central government authorities). Different visions of approach were identified, from global to specific, depending on the target group. Educational preparedness in both EU Member States and candidate countries addressing NNS was identified as poor.

Socio-economic perceptions

The public awareness of NNS and IAS in EU Member States and candidate countries varies, but in general, the perception is low. Citizens of countries with a coastline (Albania, Montenegro, Croatia, Turkey and likely also Greece and Italy) perceive marine NNS fish and crayfish but no other NNS. Countries with an orientation toward freshwaters (Bosnia and Herzegovina, and North Macedonia) reported poorly developed public awareness. However, it seems that citizens of Turkey better perceive aquatic NNS than other Balkan countries, including EU Member States and candidate countries, due to the information available through the press and social media.

In EU Member States and candidate countries with a coastline (Italy, Albania, Montenegro and Turkey), blue crab *Callinectes sapidus* invasions have affected the activities of citizens and fishermen. In addition, jellyfish species (e.g. *Rhopilema nomadica*, *Phyllorhiza punctata*) have become problematic, especially along the Aegean and the Mediterranean coasts of Turkey, affecting both fishing activities and tourism. Species reported as preventing angling and recreational fishing activities in lakes include gibel carp *Carassius gibelio* (Turkey, Croatia and North Macedonia), and North American catfishes *Ameiurus* sp. (Croatia).

The economic value of NNS is recognized in EU Member States and candidate countries. The most exploited groups are fish and crayfish, both marine and freshwater. Blue crab is recognized in Albania, Italy and Turkey at the market and is served in local restaurants. Marine NNS fish have commercial value in countries with a coastline. Turkey reported 19 NNS fish species that are commercially important, including: rabbitfish *Siganus rivulatus*, dusky spinefoot *Siganus luridus*, goldband goatfish *Upeneus moluccensis*, narrow-barred Spanish mackerel *Scomboremorus commersoni*, black-barred halfbeak *Hemiramphus far*, orange-spotted grouper *Epinephelus coioides*, Arabian scad *Trachurus indicus*, lesser amberjack *Seriola fasciata*, keeled mullet *Liza carinata*, yellowstripe barracuda *Sphyraena chrysotaenia*, etc.

Freshwater NNS/IAS fish also have economic value. Species such as grass carp *Ctenopharyngodon idella*, bighead carp *Hypophthalmichthys nobilis*, silver carp *Hypophthalmichthys molitrix*, sander *Sander lucioperca* and gibel carp, were reported as commercially important by Albania, Bosnia and Herzegovina, Croatia, North Macedonia and Turkey.

In two EU candidate countries (Albania and Bosnia and Herzegovina), there have been no attempts to remove any NNS or IAS. Montenegro has attempted to remove *Caulerpa* sp. and blue crab. In addition to attempts to remove freshwater IAS, Turkey rewards local licensed fishermen for the capture of species such as pufferfishes *Lagocephalus* sp. In EU Member States, there have been attempts to remove aquatic alien species, though efforts were sporadic and focused on several species.

Economic and financial losses induced by IAS were reported only by Albania, Montenegro and Turkey. The main economic damage to the marine environment identified in those countries was related to losses suffered by fishermen in the form of reduced catch of economically important fish due to NNS fish invasion, abandoned nets due a heavy catch of jellyfish and damaged gear caused by blue crab and pufferfishes. In freshwaters, gibel carp has negatively affected the local fishing economy due to a reduction in native fish abundance, an important economic resource for local markets. In addition, in some lakes of Central Anatolia in Turkey, the occurrence of a non-native crayfish plague has led to a decrease in native crayfish species that are an important source of income locally.

Discussion

The EU Regulation affects EU Member States and candidate countries by encouraging the development of activities concerning aquatic NNS in education, research, and citizen science

initiatives, though this not has developed uniformly in the countries surveyed. Nevertheless, it is important to underline that as only one or two institutions per country were involved in this survey, the finding from the questionnaire may not be fully representative of the true situation.

Based on the results of this survey, countries with a coastline seem more focused on marine than freshwater environments. Citizen science initiatives on NNS are well developed in marine ecosystems in Greece (Perdikaris et al. 2017, Zenetos 2017, Giovos et al. 2019) and have begun in Albania (Tanduo et al. 2020) and Turkey (Huseyinoglu et al. 2021). Montenegro seems to be focusing NNS research and education toward the marine environment, while Bosnia and Herzegovina is focused mainly on freshwater. Bosnia and Herzegovina is considered a Mediterranean country, despite having only 20 km of coastline, but research and protection efforts towards the marine environment remain underdeveloped.

The EU Regulation has been implemented in the EU Member States (Italy, Greece and Croatia) and in Montenegro as an EU country candidate. Candidate countries are not obliged to strictly follow all EU regulations, though in this regard, Montenegro appears to be better prepared than other EU candidate countries for further implementation and development of the IAS strategy. Besides, Montenegro borders on Albania and Bosnia and Herzegovina and shares inland waters and a marine coastline with these countries. In turn, Albania and Bosnia and Herzegovina border on EU Member States (Croatia and Greece) that share river basins (e.g. the Black Sea Basin) and marine territory, which could enable the entry of IAS into EU waters. Such open invasion corridors highlight the urgency for a consensus on law enforcement and the need for a joint IAS strategy (Piria et al. 2017).

Both EU Member States and candidate countries are party to the CBD. Similarly, all countries with a coastline, except Bosnia and Herzegovina, are party to the BWM, allowing for action towards managing NNS via shipping. The BWM and the Regulation were developed in parallel, though the BWM did not make any cross reference to NIS or IAS environmental legislation, which was neither amended nor integrated to address the new environmental aspects needed for implementation (Rak et al. 2019).

The definition of NNS of Montenegro is regulated by policy acts and corresponds to the NNS definition stipulated in the policy acts of Croatia. However, in other Balkan countries, as in the EU Member States, there is no consistent definition of NNS (Boon et al. 2020). Furthermore, EU candidate countries, with the exception of Bosnia and Herzegovina, responded that native species that have expanded their range as a result of climate change are considered as NNS, contrary to the recently surveyed EU Member States (Boon et al. 2020).

National lists of alien species are still in the initial stages in EU candidate countries in the Balkans. Albania and Montenegro have included non-invasive NNS on their lists. A similar response was also given by Greece, a Member State. These results correspond with those obtained by Boon et al. (2020) who stated that countries do not restrict their consideration to IAS, and some countries (e.g. Spain) place more attention on species that are known to be invasive compared with those that are not. An additional problem with Bosnia and Herzegovina's IAS list is its complex governmental structure and lack of national legislation (Hitchner 2006). Thus, the list is only partially developed for the Federation of Bosnia and Herzegovina and does not include the Republic of Srpska.

Monitoring programmes specifically designed for alien species are generally lacking in Europe (Boon et al. 2020). The establishment of such activities is most often constrained due to a lack of funding (Piria et al. 2017). However, another problem in EU candidate countries is likely to be the low priority of environmental issues in comparison to economic welfare (Popović & Erić 2018). Nevertheless, several EU candidate countries are working on project-based monitoring activities (e.g. Turkey, Montenegro) although without any clear indication as to its permanence. Bosnia and Herzegovina and Albania still need to invest greater efforts in NNS project development, as no such projects have been identified.

The use of Risk Management Tools like AS-ISK is limited to academic institutions in both Member States and candidate countries (Simonović et al. 2013, Piria et al. 2016, Tarkan et al. 2017, Radočaj et al. 2021). Although the tool is available in almost all local languages (Copp et al. 2021) to facilitate Risk Assessment, in the field, risk management of NNS has not been conducted in any of the countries surveyed.

Educational preparedness addressing NNS was identified as poor in all countries covered by the questionnaire. Countries address NNS through educational courses related to project activities that represent the main educational practices. Albania, Bosnia and Herzegovina, Croatia and Turkey, organise undergraduate and master/PhD lectures on ecological and/or socio-economic impacts of NNS and IAS, but despite this it appears the educational preparedness is underdeveloped. According to Verbrugge et al. (2021), the main challenges for IAS education are related to the inconsistent and ambiguous terminology, communicating risk, implementing education materials, and evaluating learning outcomes. Possible topics may cover the identification, distribution and environmental biology of NNS as well as the risks associated with NNS introduction, establishment, dispersal and impacts on native species and ecosystems. Recent studies have identified examples of best practice, such as the use of smartphone applications and gaming elements, place-based education and exhibitions. The importance of open access publishing of educational materials to make them readily available was also identified (Verbrugge et al. 2021). The range of educational activities related to NNS issues could also involve summer schools, workshop activities and master classes for local school groups, as well as participation in local "citizen science" initiatives (e.g. Dickinson et al. 2010, Cardoso et al. 2017, Piria et al. 2017, Mannino & Balistreri 2018). Novel, user-friendly educational materials and tools should be developed to support the inclusion of IAS in education, either in formal or informal contexts (Verbrugge et al. 2021). The lack of formal education about NNS and the consequent low awareness of their overall impact on biodiversity and local economies may have serious implications for decision-making, such as commensurability (e.g. the impacts in natural ecosystems may be valued as more important than those in other ecosystems), context-dependency (e.g. the impacts of alien species may be valued differently inside or outside the region of interest), or personal decision biases that can lead to conflicts in NNS valuation and management (Piria et al. 2017). Public educational approaches could help to improve citizen knowledge and management, with some differences due to socio-demographic factors (Li et al. 2021). Pressure from a well-informed public could drive political actions vital to improving policy and management practices on IAS (Piria et al. 2017 and references within). Improving the design and implementation of public education could contribute to effective communication among stakeholders and the long-term management of IAS (Li et al. 2021).

In all the countries surveyed, public awareness of invasive species is not well developed and recognition of the economic value and market recognition of newly established invaders, with the potential to become commercially important, remains low. However, a good proportion of the NNS species have become established and are now economically valuable. A good example is rainbow trout *Oncorhynchus mykiss* in freshwaters. Citizens in Europe in general, as well as in the Balkans perceive this species as native (Kochalski et al. 2019). In addition, it is perceived as a benefit for aquaculture and well-being, but is also recognized as high risk in inland waters and the species is possibly responsible for the decline of endemic species in the Mediterranean region due to its predation (Piria et al. 2018, Radočaj et al. 2021). There is a lack of research and knowledge in Europe about the role of invasive species on livelihoods and human well-being and only a few case studies have focused on marine or freshwater ecosystems (Shackleton et al. 2019b). Several species are recognized as having the potential to benefit the economy, such as blue crab (Mancinelli et al. 2017) or marine species, such as rabbitfish and dusky spinefoot (Patrick Saoud et al. 2008). However, the problem remains with species without any commercial value (e.g. jellyfishes, pufferfishes), with which people (e.g. anglers) have had negative experiences (e.g. *Ameiurus* sp.), or which are not valued as a valuable food item (e.g. gibel carp). The impacts on livelihoods of invasive species are highly variable and depend on the socio-ecological context. These negative implications can reduce the resilience and adaptive capacity of households and communities thereby increasing their vulnerability to change. Hence, efforts for managing invasive species need to safeguard livelihoods while mitigating negative impacts (Shackleton et al. 2019b).

Some economic and financial losses arising from IAS have been reported in EU candidate countries. Albania and Montenegro referred to losses caused by marine IAS, North Macedonia to freshwater IAS, and Turkey both marine and freshwater. However, these losses are only based on complaints from fishermen and citizens, and in most of cases have not yet been fully evaluated. In general, aquatic IAS costs are likely considerably

underrepresented and underreported compared to those of terrestrial IAS. It is expected that costs associated with IAS will increase over time and are expected to continue rising with future invasions (Cuthbert et al. 2021).

Although the EU Directive is in force, EU Member States covered by this research still need further NNS implementation in practice, and the development of good quality education is highly recommended. The majority of EU candidate countries in the Balkans do not possess any clear strategy or relevant acts for NNS and a lack of awareness and education were identified as critical for future NNS/IAS management. With joint effort and good communication, the development of sound programmes for management and education is essential to increase public awareness and prevent further biodiversity losses.

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Supplementary online material

Table S1. Responses from Albania, Bosnia and Herzegovina, Croatia, Greece, Italy, Montenegro, North Macedonia and Turkey to a questionnaire on alien species policy, education, and socio-economic issues (https://www.ivb.cz/wp-content/uploads/JVB-vol.-70-4-2021-Piria-et-al.-Tables-S1.xlsx).