Introductory Article

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ESENIAS and DIAS Networks and Highlights of the 7th ESENIAS Workshop with Scientific Conference 'Networking and Regional Cooperation towards Invasive Alien Species Prevention and Management in Europe'

Teodora Trichkova[1], Rumen Tomov[1,2], Vladimir Vladimirov[3], Hristina Kalcheva[1] & Ahmet Uludağ [4,5]

[1] Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences (IBER-BAS), 1 Tsar Osvoboditel Blvd., 1000 Sofia, Bulgaria; E-mail: trichkova@gmail.com
[2] Department of Plant Protection, Faculty of Agriculture, University of Forestry, 10 Kliment Ohridski Blvd., 1797 Sofia, Bulgaria
[3] Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Acad. Georgi Bonchev Street, Bl. 23, 1113 Sofia, Bulgaria
[4] Faculty of Forestry, Düzce University, Düzce, Turkey
[5] Faculty of Agriculture, Çanakkale Onsekiz Mart University, Çanakkale, Turkey

Abstract: Recently, the introductions and spread of invasive alien species (IAS) in Europe have increased and different regions are affected by their impact (East and South Europe, Danube Region). Two new regional networks have been created and developed: the East and South European Network for Invasive Alien Species (ESENIAS) and the Danube Region Invasive Alien Species Network (DIAS). Information about the establishment, structure, mission and activities of the two networks is presented. ESENIAS promotes awareness raising and capacity building initiatives at yearly workshops, conducts scientific research and exchanges and disseminates IAS information and research results by the ESENIAS Internet portal (www.esenias.org) and by joint publications. The largest project implemented by the ESENIAS countries is the ESENIAS-TOOLS project funded by the Financial Mechanism of the European Economic Area 2009-2014. Currently, DIAS focuses on the completion of the DIAS strategy and work plan, as well as on the implementation of the Danube-IASapp project funded by the European Commission. The 7th ESENIAS Workshop with Scientific Conference 'Networking and Regional Cooperation Towards Invasive Alien Species Prevention and Management in Europe', co-organised by the Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, ESENIAS and DIAS, was held on 28-30 March 2017, in Sofia, Bulgaria. The scientific outcomes of the Conference are reviewed here under the following topics: 1) Alien species trends in the ESENIAS countries: Introduction and establishment success; 2) Alien species trends in the ESENIAS countries: Range expansion; 3) Vectors and pathways of introduction and spread of alien species in the ESENIAS countries; 4) Invasive alien species traits; 5) Invasive alien species impact in the ESENIAS countries; and 6) Invasive alien species prevention and management.

Key words: Invasive alien species, regional cooperation, networks, ESENIAS, DIAS, Scientific Conference, outcomes

Introduction

Invasive alien species (IAS) are species whose introduction or spread outside their natural range has been found to threaten or adversely impact upon biodiversity and related ecosystem services (EU 2014). Recently, the introductions and spread of invasive alien species worldwide have increased due to human activities and global change (Murphy & Cheesman 2006, Essl et al. 2015, NOBANIS

2015, Roques 2010, 2015, Seebens et al. 2017). In Europe, it is estimated that there are already over 14,000 alien species present, of which around 10% are invasive (Deriu et al. 2017). The biodiversity and ecosystems in Europe are severely affected by biological invasions and there is an increasing trend toward the alien species introductions (Kettunen et al. 2009, Shine et al. 2010, Vilà et al. 2010, Katsanevakis et al. 2014, Jeschke et al. 2014, Vaes-Petignat & Nentwig 2014, Essl et al. 2015, Roques 2015, Roques et al. 2016). Adverse socio-economic impact and impact on human health have also been documented (Kettunen et al. 2009, Shine et al. 2010, Williams et al. 2010, Kelly et al. 2013, Bayliss et al. 2015). A conservative estimate of the annual damage caused in the European Union (EU) by alien species is €12 billion (Kettunen et al. 2009, Shine et al. 2010), but cumulated costs probably reach €20 billion per year (IEEP 2017).

The introduction and expansion of alien species in different regions in Europe have been reported. As a result of the most recent study in East and South European countries (members of the ESENIAS network), data have been collected and lists of alien and priority species compiled. The results show that the number of alien species in the studied taxonomic and ecological groups (alien marine and freshwater species, terrestrial vascular plants, fungi and animal species) amounts to nearly 2,800 species. Based on the assessed impact, 265 alien species have been classified as priority for the ESENIAS countries (ESENIAS-TOOLS project results).

The Danube River Basin (DRB) has also been exposed to intensive colonisation and influence of alien species. In most of the cases of introduction and establishment of these species, negative impact was reported. During the Joint Danube Survey 3 (JDS3) (2013), 25 neophytes (four aquatic), 34 alien aquatic macroinvertebrates (out of 460 benthic invertebrate taxa) and 12 alien fish species (out of 67 fish taxa) were recorded (Paunović et al. 2015). The level of biocontamination of the section of the Danube River covered by the investigation was estimated as moderate to high, with a higher level of biocontamination for the Upper Danube River (high to severe biocontamination) and Middle Danube River (moderate to high biocontamination), in comparison to the Lower Danube River (low biocontamination). The comparison with the results of previous Danube Surveys (in 2001, 2004 and 2007) clearly showed a constant impact of invasive alien species on native biota and a considerable increase in the number of non-native aquatic macroinvertebrate species (Paunović et al. 2015).

In response to this growing concern and the need for coordinated actions, significant global, European and regional instruments have recently been developed to address the issue of invasive alien species. The Convention on Biological Diversity (CBD 1992) approved the Aichi Target 9 under the Strategic Plan for Biodiversity 2011-2020 (CBD 2010), which states: 'By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment'.

The European Union adopted Target 5: *Combat Invasive Alien Species* under the EU Biodiversity Strategy to 2020 (EU 2011): 'By 2020, Invasive Alien Species (IAS) and their pathways are identified and prioritised, priority species are controlled or eradicated, and pathways are managed to prevent the introduction and establishment of new IAS'. Furthermore, the Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species (EU 2014) entered into force on 01 January 2015. A list of invasive alien species of EU concern (EU 2016) was adopted on 13 July 2016. The list contains 37 species that cause damages on a scale that justifies dedicated measures across the EU.

At regional level, the International Commission for the Protection of the Danube River (ICPDR) acknowledges that IAS have become a major concern for the Danube River and their further classification and analysis are vital for effective river basin management and the implementation of the Danube River Basin Management Plan (ICPDR 2009, 2015). The ICDPR is preparing a guidance document on Invasive Alien Species within the Danube River Basin. The EU Strategy for the Danube Region (EUSDR) (EU 2010), endorsed in 2011, also acknowledges IAS as one major threat to biodiversity and a livable Danube Region. Consequently, one of the targets of the EUSDR as defined in Priority Area 06 reads: 'By 2020, Invasive Alien Species and their pathways are identified and prioritised, priority species are controlled or eradicated, and pathways are managed to prevent the introduction and establishment of new IAS'. Proposed actions should include assessing the impact of IAS on the ecosystems in the Danube Region, identifying environmentally friendly ways to control their development, promoting research to identify ecologically sound ways to keep their population under control or eliminate them, and raising public awareness about the danger of IAS (EU 2010).

Networking and Regional Cooperation in the Area of Invasive Alien Species

Networking and cooperation on invasive alien species in different scales is crucial for the collection, harmonisaiton, standardisation, management and sharing of sufficient, high-quality and up-to-date scientific information (Katsanevakis et al. 2012, 2013, 2015, Gatto et al. 2013, Groom et al. 2015, 2017, Deriu et al. 2017). Networking can contribute to efficient prevention of new IAS introductions, early detection, rapid response, and management of already introduced and widely spread invasive alien species, and thus, can facilitate the implementation of existing IAS instruments at national, regional, European and global level (Panov et al. 2011, Katsanevakis et al. 2013, 2015, Groom et al. 2015, Lucy et al. 2016). The IAS Regulation 1143/2014 (EU 2014) focuses explicitly on regional cooperation, on species of regional concern, and also on river basin cooperation between countries. It is stated that 'Cross-border cooperation, particularly with neighbouring countries, and coordination between Member States, particularly within the same biogeographical region of the Union, should be fostered to contribute to the effective application of this Regulation'.

There are several IAS networks existing in Europe. Two large European IAS networks started as projects: the Delivering Alien Invasive Species In Europe (DAISIE, http://www.europe-aliens.org/) project funded by the Sixth Framework Programme of the European Commission (2003), and the project North European and Baltic Network on Invasive Alien Species (NOBANIS, https://www.nobanis.org/) funded by Denmark, Finland, Iceland, Norway and Sweden (2004). At present, 20 countries and autonomous areas are involved in the NOBANIS project. Since October 2016, the Icelandic Institute of Natural History has taken over the NOBANIS secretariat, which maintains the database and webpage (Gorner 2017).

The European Commission's Joint Research Centre (JRC) launched the European Alien Species Information Network (EASIN) in September 2012 (http://easin.jrc.ec.europa.eu), in order to meet the essential requirement of a comprehensive information system to support the new IAS Regulation 1143/2014 (EU 2014) and to enhance the knowledge base on biological invasions through scientific research. The aims of EASIN are to provide a single repository of alien species data for accessing all the information necessary to underpin alien-species-related policy and evidence-based decision-making (Katsanevakis et al. 2012, 2013, 2015, Deriu et al. 2017). Furthermore, the JRC has developed a smartphone application: the Invasive Alien Species in Europe app (http://digitalearthlab.jrc.ec.europa.eu/app/invasive-alien-species-europe). Its aim is to enable the general public (amateurs and professionals) to receive and share information about IAS of EU concern in Europe and to complement to collection of data in the frame of EASIN.

An International Association for Open Knowledge on Invasive Alien Species called 'INVASIVESNET' (http://www.invasivesnet.org/) has been launched in order to facilitate a greater understanding and improved management of biological invasions by creating a global sustainable network of networks for development and effective exchange of open high quality knowledge and open data on invasive species (Lucy et al. 2016).

Despite these initiatives, some gaps still existed in European countries and regions not involved in the above mentioned projects, such as: fragmented IAS information, lack of common methodological approaches and guidelines, low data harmonisation, and lack of region-wide information infrastructure, which made cross-border issues extremely difficult to tackle. This largely applied to East and South Europe, being a crossroad between Central Europe, Black Sea region, Asia and Eastern Mediterranean, as well as to the Danube River Basin recognised as part of the South European Invasion corridor, linking the Black and North Sea basins via the Danube-Main-Rhine waterway (Galil et al. 2007, Leuven et al. 2009, Panov et al. 2009). To meet the necessity of cooperation and coordinated actions related to IAS at regional level, two new networks have been established and developed in Europe: the East and South European Network for Invasive Alien Species (ESENIAS) and the Danube Region Invasive Alien Species Network (DIAS).

ESENIAS Network

The East and South European Network for Invasive Alien Species (ESENIAS) was established in 2011, with the support of the European Environment Agency, Ministry of Environment and Water of Bulgaria, Bulgarian Academy of Sciences and NOBANIS, in order to facilitate solving IAS issues in the Balkan countries. Consequently, 12 countries were involved in the ESENIAS activities: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Italy, Kosovo under UNSC Resolution 1244/99, FYR Macedonia, Montenegro, Romania, Serbia and Turkey. They are represented by nine governmental and 11 scientific organisations.

The aims of ESENIAS are: 1) exchange and sharing of IAS information via an Internet portal; 2) facilitate collaboration between institutions and IAS experts from East and South Europe; 3) conduct joint research activities (publications, projects); 4) develop and harmonise regional IAS policy; and 5) integrate to European and global IAS initiatives.

One of the main activities of ESENIAS has been promoting of awareness raising and capacity building initiatives on IAS within all countries in the region, by organisation of yearly workshops. Until now six workshops were organised: Zagreb 2010, Sofia 2011, Belgrade 2012, Çanakkale 2013, Antalya 2014, and Sofia 2015. The 7th ESENIAS Workshop with Scientific Conference 'Networking and Regional Cooperation Towards Invasive Alien Species Prevention and Management in Europe', which was held on 28-30 March 2017, in Sofia, Bulgaria, was a follow up of these activities.

In order to initiate the collection and analysis of IAS data in the ESENIAS region, several joint research projects have been undertaken. The largest project implemented by the ESENIAS countries is the **ESENIAS-TOOLS project: East and South European Network for Invasive Alien Species – A tool to support the management of alien species in Bulgaria** (2015-2017). This project is funded by the Financial Mechanism of the European Economic Area 2009-2014, under the Programme BG03 'Biodiversity and Ecosystem Services', and aims at networking and development of IAS tools in the frame of ESENIAS in order to support the management of alien species in Bulgaria and in the overall region. Eleven partners (environmental agencies, universities, research institutions) from eight countries (Bulgaria, Greece, Croatia, Serbia, Romania, Turkey, Iceland and FYR Macedonia) participate in the project. The project promoter is the Institute of Biodiversity and Ecosystem Research with the Bulgarian Academy of Sciences (IBER-BAS). The work on the project has been organised in 10 working groups and four bilateral case studies (Bulgaria – Italy, Iceland – Bulgaria, FYR Macedonia – Bulgaria, and Romania – Bulgaria), and included creation of a database structure and functionalities, field surveys, laboratory work, short and study visits, organisation and participation in workshops and training courses, data processing and analysis, preparation of IAS factsheets and publications. The main outcomes of the ESENIAS-TOOLS project and the partnership developed are: 1) adoption of joint standardised and harmonised methods for data collection, analysis, database use, dissemination and further outreach; 2) creation of a technical infrastructure for the network, including a geo-referenced database; 3) collection of data on alien species (marine, freshwater and terrestrial plants, fungi and animals) from the ESENIAS countries; 4) compilation of common lists of alien species and priority species for the ESENIAS region and for Bulgaria; 5) strengthening and extending the collaboration within the ESENIAS, e.g. three new member countries (Slovenia, Hungary and Ukraine) joined ESENIAS; and 6) exchanging and sharing of information, networking and development of cooperation with other organisations, institutions and networks.

Another important activity of ESENIAS has been the exchange and dissemination of IAS information and ESENIAS research results by the Internet portal (www.esenias.org), by participation in scientific forums, and by joint publications. The ESENIAS-TOOLS project and project results were presented at 15 scientific forums, organised within the project, and 32 other international scientific events, with a total of 205 communications (oral and poster presentations). The ESENIAS publications include two books of abstracts (Uludağ et al. 2014, Trichkova et al. 2017a), two volumes of the series ESENIAS Scientific Reports (Rat et al. 2016, Trichkova et al. 2017b) and many research articles. The ESENIAS-TOOLS contributions alone comprise 54 research articles, 86 abstracts and one PhD thesis (Cardeccia 2016).

DIAS Network

Another regional initiative is the **Danube Region Invasive Alien Species Network (DIAS)**. DIAS was established in 2014 in Sofia, Bulgaria, within the frame of the Priority Area 06 of the European Union Strategy for the Danube Region, and supported by the Bavarian State Ministry of Environment and Consumer Protection (Munich, Germany), the International Association of Danube Research (IAD), ESENIAS and the IBER-BAS. In the implementation of its mission, DIAS promotes an improved coordination among all actors in the thematic field of invasive alien species within the Danube Region. Politically independent, it brings together scientists, authorities and stakeholders and: 1) supports sharing of knowledge; 2) formulates a strategy and work plan to efficiently tackle the issue of IAS in the Danube Region; 3) considers and cooperates with existing European and global IAS networks and organisations; 4) develops individual but coordinated projects in the single regions; and 5) promotes the transfer of knowhow and expertise to actors on all administrative levels; in a transnational context in order to contribute to a sustainable and livable future of the Danube Region. It has been agreed

that the work of DIAS should develop in a flexible way to cover both the heterogenity of the region and the scientific complexity of the topic. The thematic structure foresees the connection and cooperation of experts in working groups and pool of experts. The regional structure foresees informal, decentral and interdisciplinary cooperation in the Lower, Middle and Upper Danube Region, as well as in the adjacent Black Sea Region. The network structure, work approaches and organisation were discussed at four DIAS meetings until now (Sofia 2014, Budapest 2015, Budapest, June 2016, and Sofia, November 2016).

Currently, the main focus of DIAS is the completion of the **DIAS strategy and work plan**, which follow the requirements of the EU Strategy for the Danube Region (EU 2010) and the IAS Regulation 1143/2014 (EU 2014), and consider the demands of the region. The strategy will provide the goals and objectives, but also possible measures and recommendations on seven key topics. Region specific requirements and relevant actors are defined as well. The seven key topics are: 1) IAS – Species and interactions/ impact in the DRB; 2) Pathways of introduction in the DRB; 3) Information system and knowledge dissemination; 4) Risk assessment, early warning, and prioritisation; 5) Early detection and rapid response; 6) Management of established IAS and restoration; and 7) Awareness raising and communication regarding IAS.

A few joint projects with the participation of countries in the Danube Region within the frame of DIAS have already been developed. The project '**Potential threats to environmental and economic sustainability in the Danube and Black Sea Region: Danube River as invasive alien species corridor'** has been conducted since 2012, by the IBER-BAS, and supported by the IAD, ESENIAS, and recently by DIAS. Another DIAS project was launched in 2016: **Pilot-study (data collection) on invasive alien species in the Danube Region with a smartphone application developed by the JRC (Danube-IASapp project)** (2016-2017). This project is implemented jointly by three countries in the Lower Danube Region: the IBER-BAS, Bulgaria, 'Ovidius' University of Constanta, Romania, and University of Belgrade, Institute for Biological Research 'Siniša Stanković', Serbia, and funded by the European Commission. The aim of this project is to test the practical use of the Invasive Alien Species in Europe app developed by the JRC, within the frame of DIAS, in order to complement environmental monitoring and early warning of invasive alien species in the Danube River Basin and the Danube Region.

The 7th ESENIAS Workshop and Scientific Conference

The 7th ESENIAS Workshop with Scientific Conference 'Networking and Regional Cooperation Towards Invasive Alien Species Prevention and Management in Europe' was held on 28-30 March 2017, in Sofia, Bulgaria. The conference was co-organised by the IBER-BAS, ESENIAS and DIAS. The conference was funded by the Financial Mechanism of the European Economic Area 2009-2014, Programme BG03 Biodiversity and Ecosystem Services (ESENIAS-TOOLS Project), and the National Science Fund of the Republic of Bulgaria. The aim of the conference was to provide a forum for presentation of multidisciplinary research activities on various topics related to invasive alien species, highlighting the importance of regional cooperation for finding solutions at national, regional and European level. Furthermore, the ESENIAS workshop and conference aimed at presentation of ESENIAS-TOOLS project results, establishment of cooperation in the area of invasive alien species between scientists within the ESENIAS and DIAS networks and development of cooperation with other networks, organisations and projects.

A total number of 150 participants from 20 countries took part in the conference. Of them 70 participants were from Bulgaria and 80 participants from other countries: Albania, Australia, Croatia, Czech Republic, France, Greece, Hungary, Iceland, Italy, Kosovo, Lithuania, FYR Macedonia, Montenegro, Romania, Serbia, Slovenia, Switzerland, Turkey, and Ukraine. The contributions included nine keynote presentations, 53 presentations and 64 posters. Totally 127 abstracts were published.

The contributions and discussions during the conference covered the following scientific topics:

1) Invasive alien species traits and trends – invasive alien species introductions and spread, biological and ecological characteristics; characteristics of recipient environment; invasive alien species and climate change;

2) Vectors and pathways for invasive alien species introductions – trade, transport, horticulture, aquaculture, agriculture, forestry, hunting, etc.;

3) The Danube River as invasive alien species corridor – priority species for the Danube Region, impact on threatened species, specificity of biological invasions in Lower, Middle and Upper Danube River sections;

4) Invasive alien species impact – environmental impact, impact on ecosystem services, socioeconomic

impact and impact on human health; pests and pathogens; and

5) Invasive alien species prevention and management – early detection and rapid eradication, surveillance systems; risk assessment and horizon scanning; control measures; restoration of damaged ecosystems; education, citizen science, strategies, policy and legislation; IAS networks and information systems, databases, data planning and management.

Scientific Outcomes

The current supplement of *Acta Zoologica Bulgarica* is the **3rd volume of the series ESENIAS Scientific Reports**, which presents results of the 7th ESENIAS Workshop with Scientific Conference. It comprises 41 contributions: 28 research articles, seven review articles and six short communications, covering all conference scientific topics.

Alien species trends in the ESENIAS countries: Introduction and establishment success

The number of alien species in the ESENIAS countries has been constantly increasing. Here, twelve new alien species are reported: three plants, one fungus, and one animal species from Bulgaria, one freshwater invertebrate from Kosovo, two terrestrial invertebrates from the FYR Macedonia, and four marine species from the Turkish coast.

Ammannia coccinea Rottb. (Lythraceae), a plant species native to North America, is reported for the first time from Bulgaria (Vladimirov et al. 2017a). The report is based on records from rice fields in the Thracian Lowland floristic region, in 2016, and a review of herbarium materials of *Ammannia* spp. since 1980. A morphological description and distinguishing characters of the species are specified and its invasiveness and spreading potential are discussed. Another species *Oenothera laciniata* Hill (Onagraceae) is reported for the first time for the Bulgarian flora from the Black Sea Coast floristic region (Petrova & Barzov 2017). It was found in the inland sand dunes habitats in 2014 and 2016. The authors provide a brief morphological description of the species, comment on its distinguishing characters, and present data about its phenology, distribution and populations. The invasive alien plant species of EU concern, *Heracleum sosnowskyi* Manden. (Apiaceae), was newly recorded in Bulgaria, in a residential area in Sofia City, in 2017 (Vladimirov et al. 2017b). A morphological description of the species based on the material from the Bulgarian locality is given. The pathways of introduction and the invasive potential of the species are discussed, and control measures recommended. The alien fungus *Mycena seynii* Quél. was recorded for the first time in a planted stand of *Pinus pinaster* Aiton and *Pinus halepensis* Mill., both non-native plants in Bulgaria (Assyov 2017). The author provides a detailed description and illustrations of the finding and makes a comparison with materials from different localities in Greece. The distribution of this fungus in Europe is summarised and briefly discussed, with emphasis on cases of introduction along with the exotic pine trees. The first records of the Chinese mitten crab *Eriocheir sinensis* H. Milne Edwards, 1853 (Varunidae), is reported from Bulgaria (Trichkova et al. 2017c). The species was caught in two localities in the Bulgarian stretch of the Danube River: upstream of the town of Tutrakan and near the village of Botevo. The authors present morphological characters of the species and make a review of its distribution in the Danube River. The possible pathways of introduction of *E. sinensis* into the Bulgarian stretch of the Danube River are discussed. The first record of the freshwater jellyfish *Craspedacusta sowerbii* Lankester, 1880 (Hydrozoa) in Gazivode Lake on the Ibar River, northern Kosovo, in 2016, is also presented here (Jaksic et al. 2017). Furthermore, the Japanese wax scale *Ceroplastes japonicus* Green, 1921 (Hemiptera) was detected on leaves, twigs, branches and fruits of persimmon (*Diospyros kaki* L.) in the regions of Valandovo and Dojran, in the southern part of the FYR Macedonia, in 2016 (Lazarevska et al. 2017). The Geranium Bronze, *Cacyreus marshalli* Butler, 1898 (Lepidoptera) was another alien species newly recorded in the FYR Macedonia (St. Naum Monastery), one female ovipositing on *Pelargonium* sp., in 2017 (Langourov & Simov 2017). Öztürk et al. (2017) report the first records of *Varicopeza pauxilla* (A. Adams, 1855) (Gastropoda) from the Mediterranean Sea, other two gastropod species *Leucotina natalensis* E. A. Smith, 1910, and *Pyrunculus fourierii* (Audouin, 1826) from the Turkish coast of the Aegean Sea, and one bivalve species *Arcuatula senhousia* (Benson in Cantor, 1842) from the Sea of Marmara.

Some of the alien species introduced to the ESENIAS countries for the purposes of horticulture, forestry or aquaculture have already established in the wild. Petrova & Gerasimova (2017) report on a naturalised population of the European larch *Larix decidua* Mill. (Pinaceae) in the Rhodope Mountains, Bulgaria. The parent individuals were planted as ornamental trees in the yard of a border observation post about 40 years ago. A successful seed reproduction was observed with a progeny of different ages (one – app. 20 years), the oldest ones used to produce strobili and seeds for 3-6 years. Petrova et al. (2017) present

data on the naturalisation of another representative of the family Pinaceae, the Maritime Pine *Pinus pinaster* Aiton, both in the Northern and Southern Black Sea Coast floristic subregions in Bulgaria. A large scale of local spread, high invasion success and impact on natural vegetation in the coastal dune habitats, which are parts of protected areas, are reported. Another study provides evidence on the first established, self-sustaining population of *Oncorhynchus mykiss* (Walbaum, 1792) (Salmonidae) in Greece, which is the southernmost population reported for Europe (Stoumboudi et al. 2017). This population was found in an upland section of a spring-fed stream (Kissano Stream), near the village of Spili, in Southern Crete, in 2012. According to the authors, it originated from a single introduction of rainbow trout juveniles in the mid-1980s, and since then the population has been maintained by self-reproduction.

Lists of alien species in some taxonomic groups were compiled and presented here. Öztürk et al. (2017) document a total of 125 alien mollusc species for the Turkish coast. The species belong to 59 families, with the domination of Gastropoda, with 40 families. The family Pyramidellidae is the richest in species with 13 alien species, followed by Veneridae with eight alien species. In her study, Povž (2017) reports 20 fish species that have been introduced to the inland waters of Slovenia, either intentionally or unintentionally, since 1891, beginning with the introduction of the rainbow trout, *O. mykiss.* The author summarises the information on the introduction of all alien fish species, with specifying the year of introduction to Slovenia, the pattern of spread, the degree of acclimatisation, and the area of recent distribution.

Alien species trends in the ESENIAS countries: Range expansion

Most of the alien species quickly spread after their establishment in natural environments. Many new localities of alien species in the ESENIAS and neighbouring countries are reported in the current supplement. The freshwater jellyfish *C. sowerbii* was recorded first in Bulgaria in 1991. A study on its current distribution, based on field survey data from the period 2007-2016 and other available sources, shows that the species occurred in nine reservoirs, four of them belonging to the Aegean Sea Basin and five reservoirs within the Danube River Basin (Kozuharov et al. 2017). Arslan et al. (2017) report on the finding of some non-indigenous and translocated Ponto-Caspian Gastropoda species in Lake Sapanca (Turkey), and make notes on the Ponto-Caspian Clitellata species in the lake. The presence of these species in different parts of Turkey suggests that the main routes of migration might be the rivers flowing into the Black Sea. The North American oak lace bug, *Corythucha arcuata* (Say, 1832) (Hemiptera), was introduced to Russia in 2015 and was initially found in the city park of Krasnodar. Extensive sampling efforts combined with comparison of satellite images of the oak forests revealed the spread pattern of this invasive alien pest in the north-western Caucasus during 2015 and 2016 (Neimorovets et al. 2017**)**. New data on the distribution of the species in Russia are presented. In the same year 2015, *C. arcuata* was newly recorded also for western Romania. Chireceanu et al. (2017) present data on its first finding in the southern part of this country. In 2016, numerous eggs, nymphs and adults of the species were detected on leaves of the oaks *Quercus cerris* L. and *Q. robur* L. in the urban area of the city of Bucharest and in the area of the village of Moara Domnească, Ilfov County. Langourov & Simov (2017) report two new localities of *C. marshalli*: one in Bulgaria (the West Rhodope Mountains) from 2014, and one in Greece (Ormos Panagias, Halkidiki Peninsula) from 2016. Using published data, a map with the distribution of this species in the Balkan Peninsula and Turkey was prepared and it showed that most of the recorded localities were along the coast (including the islands), with prevalence at the Adriatic costal area. Data on the current distribution of the Western corn rootworm *Diabrotica virgifera virgifera* LeConte, 1868 (Coleoptera) in Romania are given by Manole et al. (2017). In 1996, the species was first observed in Nădlac, Romania, near the border with Hungary. For about 20 years it has spread in 21 counties. The trends of invasion of the species in Romania are discussed. New localities of the Rose-ringed Parakeet *Psittacula krameri* (Scopoli, 1769) (Psittacidae) in Bulgaria are reported by Grozdanov et al. (2017). The birds were observed in the period 2003-2017, inside or around big cities (Sofia, Varna, and Ruse).

Vectors and pathways of introduction and spread of alien species in the ESENIAS countries

Some of the newly recorded or established alien plants reported here were introduced for ornamental purposes in Bulgaria and subsequently spread in the wild: *L. decidua* (Petrova & Gerasimova 2017), *Solidago canadensis* L. and *S. gigantea* Aiton (Yankova-Tsvetkova et al. 2017), others escaped from plantations: *P. pinaster* (Petrova et al. 2017), or were introduced unintentionally: *A. coccinea* (Vladimirov et al. 2017a), *O. laciniata* (Petrova & Barzov 2017), and probably *H. sosnowskyi*

(Vladimirov et al. 2017b). It was supposed that the alien fungus *Mycena seynii* was introduced in Bulgaria with the cultivation of the non-native conifers *P. pinaster* and *P. halepensis* in afforested areas (Assyov 2017).

Povž (2017) analyses and lists the pathways of introduction and the pattern of spread in the country of the 20 alien freshwater fish species found in Slovenia. The most frequently used pathway was intentional introduction and release in nature for the purposes of recreational fishing (the primary pathway for nine fish species). It was followed by the introduction for aquaculture purposes and subsequent escape from aquaculture facilities (primary pathway for five fish species). The other pathways include: introduction as ornamental fish (two species) and for mosquito control (one species), one accidental introduction and two unaided (natural) dispersals upstream or downstream of rivers (Povž 2017). Deliberate introductions are reported also for *O. mykiss* in the Kissano Stream in Greece (Stoumboudi et al. 2017), and most probably for the translocated marine fish sand smelt *Atherina boyeri* Risso, 1810 (Atherinidae) in Hirfanlı Reservoir, in Central Anatolia, Turkey (Gençoğlu et al. 2017). Similar to Slovenia, the Eastern Mosquitofish *Gambusia holbrooki* Girard, 1859 (Poeciliidae) was introduced in Turkey as a malaria/ mosquito control agent (Yoğurtçuoğlu & Ekmekçi 2017). Innal & Giannetto (2017) assume that the studied population of redbelly tilapia *Coptodon zillii* (Gervais, 1848) (Cichlidae) in the Pınarbaşı Spring Creek, Burdur, Turkey, most likely originated from aquarium industry ponds located in the area of Burdur. Human activities mostly related to aquaculture are considered as the most probable pathway of introduction and spread of *C. sowerbii* in Bulgarian waters (Kozuharov et al. 2017).

The Danube River is recognised as part of the South European Invasion corridor; it links the Black and North Sea basins via the Danube–Main–Rhine waterway (Galil et al. 2007, Leuven et al. 2009, Panov et al. 2009). This complex waterway facilitates an intensive dispersal of previously geographically isolated species in both northwest and southeast directions throughout the Danube River Basin (Sommerwerk et al. 2009). Although, for most of the alien taxa the pathways and vectors of introduction in the Danube River are not known, it is assumed that many Ponto-Caspian, and Asiatic species expand their range in Europe, using this corridor by either natural dispersal, or by waterway transport, escape from aquaculture or deliberate introductions (Bij de Vaate et al. 2002, Copp et al. 2005, Hulme et al. 2009, Paunović et al. 2015). Such examples from the reviewed studies are: *E. sinensis* (Trichkova et al. 2017c), *Perccottus glenii* Dybowski, 1877 (Odontobutidae) (Skorić et al. 2017), and the Ponto-Caspian gobiid species (Lenhardt et al. 2017). Through the Danube River tributaries and with human aid these species further spread into inland water bodies (reservoirs, lakes), e.g. the invasive mussels *Dreissena polymorpha* (Pallas, 1771) and *Dreissena rostriformis bugensis* Andrusov, 1897, as well as the Ponto-Caspian Amphipoda species in Bulgaria (Beshkova et al. 2017, Kalcheva et al. 2017, Kenderov 2017). An unusual record is presented here: a zebra mussel specimen *D. polymorpha* attached to the chitin cover of a killer shrimp *Dikerogammarus villosus* (Sowinsky, 1894) (Kenderov 2017). The author comments that this is a rarely observed interspecies relationship (phoresis) between the two species, and assumes that in this way the zebra mussel obtains some opportunity for passive migration and probably this is one additional vector of its spread.

The most probable pathways for the introduction and spread of the alien arthropod species in the ESENIAS countries reviewed here are unintentional introductions associated with activities related to horticulture and urban vegetation (Ciceoi et al. 2017a, Hrnčić et al. 2017, Langourov & Simov 2017), agriculture (Ciceoi et al. 2017b, Lazarevska et al. 2017, Manole et al. 2017, Radonjić & Hrnčić 2017, Toshova et al. 2017a, b), and forestry (Chireceanu et al. 2017, Neimorovets et al. 2017).

Invasive alien species traits

Several contributions in the supplement deal with specific traits, such as: morphological characters, embryology, life history and feeding, of alien, translocated and invasive alien species in the ESENIAS region and other European countries.

Ognjanova-Rumenova et al. (2017) analyse the morphology of the freshwater diatom Didymo, *Didymosphenia geminata* (Lyngbye) M. Schmidt, from the River Elliðaár catchment, southwestern Iceland, where the species is considered invasive, by scanning electron microscopy, and give details on its nomenclatural history. An embryological study of two invasive alien plant species in Bulgaria: *Solidago canadensis* L. and *S. gigantea* Aiton (Asteraceae), reveals that both species can reproduce sexually and form viable seeds in the studied naturalised localities in Bulgaria (Yankova-Tsvetkova et al. 2017). Thus, the long-distance dispersal of the species is achieved by seeds, whereas, the local spread – by vegetative propagation, which facilitates the invasion of the species in the country. Ivanova et al. (2017) present data on the population status of six alien marine

species in Varna Bay, the Bulgarian Black Sea coast, in the period 2015-2016. The high abundance of two alien copepod species *Acartia tonsa* Dana, 1849, and *Oithona davisae* Ferrari F. D. and Orsi, 1984, showed that they became an important component of the plankton community structure in Varna Bay. Two ctenophore species *Mnemiopsis leidyi* A. Agassiz, 1865, and *Beroe ovata* Bruguière, 1789, also had stable and abundant populations in the Bulgarian Black Sea coastal area. The rapa whelk *Rapana venosa* (Valenciennes, 1846) dominated in the benthic community, represented by different size classes at different depths. Only the redlip mullet *Liza haematocheila* Temminck & Schlegel, 1845 (Mugilidae) showed a trend of permanent decrease along the Bulgarian Black Sea coast from 2009 to 2016 (Ivanova et al. 2017).

Another four studies focus exclusively on biological and ecological traits of alien and translocated fish species. Skorić et al. (2017) present data on the weight-length relationship of the invasive alien Amur sleeper *P. glenii* in the Danube River drainage canal, in Serbia (2015-2016). The results showed the dynamic of a recently established population. Data on the age structure and length-weight relationship of the alien redbelly tilapia *C. zillii* in the Pınarbaşı Spring Creek, Burdur, Turkey, are presented by Innal & Giannetto (2017). The study revealed a well-structured population with five different age classes: the presence of juveniles indicated that the population was well acclimatised and probably it was able to reproduce naturally in the warm water of the Pınarbaşı Springs Creek. Yoğurtçuoğlu & Ekmekçi (2017) report on variations in life history and feeding ecology of the alien Eastern mosquitofish *G. holbrooki* in Acıgöl, a groundwater-dependent wetland in Turkey. Two age groups in males and three in females were determined. The reproduction period was from April to September. The overall ratio of fertilised eggs and the absolute and relative fecundity varied at sites under different ecological conditions. Two trophic positions and significant temporal and ontogenetic differences in feeding were determined at different sites. Gençoğlu et al. (2017) present results on feeding ecology of the translocated marine fish sand smelt *A. boyeri* in the freshwater Hirfanlı Reservoir, in Central Anatolia, Turkey. The studied fish species fed mainly on larger zooplankton, but used also fish eggs and juvenile fish, including its own juveniles. It showed a dietary overlap among size classes and adaptation to temporal diet availability. The trophic niche breadth was the highest in summer (Gençoğlu et al. 2017).

Some biological traits of alien arthropod species are also reported here. Based on observations of two last instar caterpillars of *C. marshalli*, collected in Ormos Panagias, Halkidiki, Greece, under laboratory conditions, Langourov & Simov (2017) revealed that the species fed on *Pelargonium zonale* (L.) L'Hér. ex Aiton, with preference to flowers, and later transferred to the stem where they pupated. The period and temperature of development from chrysalis to imago and the duration of the complete life cycle are specified. Manole et al. (2017) report on duration of the life cycle stages in *D. v. virgifera* under climatic conditions in western Romania and the new alternative hosts used by the species. The study focused on the adult feeding behaviour on wild plant species (mostly weeds and aromatic plants), which were distributed in the maize crops or in the close surroundings. Beside the preferred host *Zea mays* L., the authors list 46 new alternative host species from 11 plant families. Of them, 37 species were registered as new food resources for the adults of *D. v. virgifera* in Europe and in Romania.

Invasive alien species impact in the ESENIAS countries

The main focus of some of the contributions in the current supplement is the impact of alien species in their new environments.

Yoğurtçuoğlu & Ekmekçi (2017) mention the potential impact that *G. holbrooki* may pose on the critically endangered native fish species *Aphanius transgrediens* (Ermin, 1946), in Acıgöl wetland in Turkey. Even though there was no evidence for competition, *Aphanius* scales were observed in the stomach of *G. holbrooki*, which indicated its aggressive pressure on the native species population. The results of Gençoğlu et al. (2017) suggested that the sand smelt *A. boyeri* may have a remarkable impact on zooplankton communities, and can be a strong competitor among planktivorous fish species, due to its selective predation on cladoceran groups, in the Hirfanlı Reservoir in Central Anatolia, Turkey.

Two studies deal with relationships of plankton communities in Bulgarian reservoirs with environmental factors and presence of the invasive zebra mussel *D. polymorpha*. Kalcheva et al. (2017) report that annual, seasonal and spatial changes in the total number, biomass, morphotypes and size structure of bacterioplankton demonstrated greater variability in the reservoirs infested by the mussels than in the non-infested reservoir. The quantities of *D. polymorpha* showed slightly negative correlations with the total number and biomass of bacterioplankton, and positive correlations with the quantities of rods, larger and attached bacteria, probably because of more organics by excreta of *D. polymorpha*. Beshkova et al. (2017)

also found out that the presence of *D. polymorpha* was one of the major factors that explained the variations in the physicochemical parameters and phytoplankton divisions, abundance and diversity between infested and non-infested reservoirs. The authors confirmed the clearance effect of *D. polymorpha* on the phytoplankton: statistically significant lower phytoplankton numerical abundance, biomass, and species diversity, as well as an increase in water transparency in the infested reservoirs.

The authors of the next four contributions present reviews of alien pests and their impact on horticulture and vegetation in urban environments, as well as on agriculture. As a result of monitoring of pests associated with ornamental plants in public parks, green areas and private gardens in the city of Bucharest, during the period 2012-2016, Ciceoi et al. (2017a) compiled a list of 52 species of pests of urban vegetation, specifying their locations and host plants. Eighteen of these species are alien to Romania, of them 12 are considered invasive. The authors give more detailed information about the impact of six most destructive species: *Cydalima perspectalis* (Walker, 1859), *Palpita vitrealis* (Rossi, 1794), *Cameraria ohridella* Deschka & Dimic, 1986, *Phyllonorycter platani* (Staudinger, 1870), *Corythucha ciliata* (Say, 1832), and *Unaspis euonymi* (Comstock, 1881), as well as a single case of interception for a mite not present in Europe: *Schizotetranychus celarius* (Banks, 1917). Hrnčić et al. (2017) present and review the impact of 15 alien horticultural pests on urban landscape in the southern part of Montenegro, recorded in the period 2003-2016. Most of the alien species established successfully and among them, *Metcalfa pruinosa* Say, 1830, *Bemisia tabaci* Gennadius, 1889, *Acizzia jamatonica* (Kuwayama, 1908), *Epichoristodes acerbella* (Walker, 1864), *Rhynchophorus ferrugineus* (Olivier, 1790), and *C. perspectalis,* were widely spread. All detected species caused negative alterations in the ornamental plants, which resulted in disruption of their health and aesthetic appearance. The most serious damages were caused by *R. ferrugineus*, which destroyed specifically the Canary Island date palm *Phoenix canariensis* Chabaud along the entire Montenegro seacoast. Another review presents 15 new alien species recorded as a result of ten-year (2006-2016) monitoring of pests that attack agricultural crops in Montenegro (Radonjić & Hrnčić 2017). Among them, *Frankliniella occidentalis* (Pergande, 1895), *Liriomyza bryoniae* (Kaltenbach, 1858), *Aphis illinoisensis* (Shimer, 1866), *Tuta absoluta* (Meyrick, 1917), and *Drosophila suzukii* (Matsumura, 1931) showed the highest rate of spread and successful establishment in large areas since their first detection. The highest environmental and economic impact was detected in *F. occidentalis*, *Aleurocanthus spiniferus* (Quaintance, 1903), and *Scaphoideus titanus* (Ball, 1932); in *Bemisia tabaci* (Gennadius, 1889) as potential virus vectors; in *D. suzukii* because of its high rate of spread and many available host plants (cultivated and wild); as well as in *T. absoluta* in the first years of its invasion. Ciceoi et al. (2017b) assessed the damages on maize crops by the invasive stink bugs *Halyomorpha halys* (Stål, 1855) and *Nezara viridula* (Linnaeus, 1758) (Hemiptera) in southern Romania, in 2016. The authors studied the feeding preferences of the stink bugs on six maize hybrids and estimated the qualitative and quantitative variations in the dried maize kernels under the attacks of the stink bugs. The results showed that the large stink bug populations reduced the maize yields, by attacking the kernels, and affected the quality of the crops, by reducing the starch and protein content.

Invasive alien species prevention and management

Grădilă (2017) presents data on management of some noxious Dicotyledonous weeds in winter rape (*Brassica napus* L.) crops in southern Romania, in 2015 and 2016. They were treated by integrating agro-technical measures and products for plants protection. The effects of both methods are presented and discussed. Fătu & Andrei (2017) conducted a laboratory test on virulence of the entomopathogenic fungus *Beauveria bassiana* (Bals.) Vuill. against the invasive sawfly *Aproceros leucopoda* Takeuki, 1939 (Hymenoptera), which is an important defoliator pest of elm trees (*Ulmus glabra* Huds) in Romania. Three different isolates, with different origins regarding the insect host, were tested and the results demonstrated that the larvae and pupae of *A. leucopoda* were susceptible to *B. bassiana* isolates under laboratory conditions.

Lenhardt et al. (2017) compared the efficiency of two different methods for fish sampling (electrofishing and beach seining) and assessed the influence of the twilight period on the catch of invasive Ponto-Caspian gobiids (Gobiidae) at four locations in the inshore parts of the Danube River in Serbia. Totally, 539 specimens of five gobiid species: *Neogobius fluviatilis* (Pallas, 1814), *Neogobius melanostomus* (Pallas, 1814), *Babka gymnotrachelus* (Kessler, 1857), *Ponticola kessleri* (Günther, 1861), and *Proterorhinus semilunaris* (Pallas, 1814), were caught. The authors conclude that beach seining was the better and more efficient method than electrofishing for monitoring of the Ponto-Caspian gobiids in shallow coastal sandy-muddy-gravel habitats in large rivers, and that the favorable period

was at the sunset. Toshova et al. (2017a) tested the trapping efficiency of different coloured sticky traps (CSALOMON®, Hungary) in maize crops in Bulgaria in 2014. A total of 11 species belonging to three Coleoptera families, Coccinellidae, Chrysomelidae, and Elateridae, were recorded, among them the alien species *Harmonia axyridis* Pallas, 1773, which was the most abundant in the traps, and the adults of *D. v. virgifera*. The authors conclude that the coloured sticky traps are useful tool to study the occurrence, relative abundance, seasonal appearance and activity, as well as the colour preference of different Coleoptera species. Furthermore, in 2015 and 2016, Toshova et al. (2017b) tested the potential of KLP+ traps baited with dual (pheromone and floral) lures (CSALOMON®, Hungary) as a new tool for detection and monitoring of *D. v. virgifera*. The traps showed very high efficiency at different population densities of the pest. The authors give some recommendations for their use for the monitoring purposes.

Recently, citizen science based monitoring and surveillance has been increasingly being used in the area of invasive alien species. Ciceoi et al. (2017c) analysed the Romanian citizen-generated data activities on invasive alien species on the EASIN, GBIF and iNaturalist web platforms and the citizen feedback on *Halyomorpha halys* alert leaflets and public presentations. The authors also initiated a questionnaire for reporting on invasive alien species, addressed to students and teachers of the University of Agronomic Sciences and Veterinary Medicine in Bucharest. The report rates on web platforms, e-mail and phones were low, while the questionnaire received higher percentage of answers from teachers and researchers than students. The authors conclude that good communication skills, personal involvement, face-to-face discussions and explanations of goals and advantages can contribute to the involvement of volunteers. The most appropriate tools should guarantee privacy, e.g. web platforms, smartphone apps, and require no supplementary costs.

As more and more citizen scientists are playing a vital role in reporting invasive alien species, taxonomic networks are essential in ensuring quality control of such data. National experts and networks, focusing on invasive alien species, are important data providers for a higher level of networks and EU databases. In the frame of the ESENIAS-TOOLS project, efforts were made to compile a list of experts working on marine alien species in the ESENIAS countries, which can serve as a foundation towards establishing a scientific network in this area (Karachle et al. 2017). The authors identified 242 scholars working in the marine waters of the area, with the majority being employed in universities and research centres. The highest numbers were recorded in Italy and Greece. Ecology, biology and biodiversity were the most often addressed subject areas, followed by impacts and pathways of alien species introduction. As far as taxonomic/ eco-functional groups are concerned, fish, phytobenthos, Mollusca and Crustacea were those taxa attracting mostly the interest of experts. The authors conclude that the list should be constantly updated and revised, in order to be used by authorities, scholars and citizen scientists.

Conclusions

The presented initiatives and results demonstrate the strong necessity of cooperation and coordinated actions related to invasive alien species at regional level. With their continuous activities, ESENIAS and DIAS networks are good examples of such cooperation between scientists, policy makers, managers and the public. The wide international participation in the 7th ESENIAS Workshop with Scientific Conference (150 participants from 20 countries, nine keynote presentations, 53 presentations and 64 posters) have demonstrated the big interest of the scientific community and stakeholders in the region in this topic. Furthermore, the participants provided important scientific contributions (127 published abstracts and 41 contributions in the current supplement). Therefore, despite numerous challenges, the efforts in this direction should continue, in order to achieve effective transboundary cooperation and information sharing, and effective prevention, early detection and management related to the invasive alien species in East and South Europe and the Danube Region.

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