Review of Alien Freshwater Vascular Plants in South-east Europe

Richard V. Lansdown[1], Paulina Anastasiu[2], Zoltán Barina[3], Ioannis Bazos[4], Halil Çakan[5], Danka Caković[6], Pinelopi Delipetrou[7], Vlado Matevski[8], Božena Mitić[9], Eszter Ruprecht[10], Gordana Tomović[11], Anita Tosheva[12], Gergely Király[13]

[1] 45 The Bridle, Stroud, Glos. GL5 4SQ, UK; E-mail: rlansdown@ardeola.demon.co.uk
[2] University of Bucharest, Department of Botany and Microbiology, 1-3 Intr. Portocalelor, 060101-Bucharest, Romania
[3] Hungarian Natural History Museum, Department of Botany, Könyves Kálmán krt. 40, 1087 Budapest, Hungary
[4] University of Athens, Department of Ecology and Systematics, Panepistimiopolis, Athens 15784, Greece
[5] Çukurova University, Department of Biology, 01330 Adana, Turkey
[6] University of Podgorica, Department of Biology, Cetinjski put b.b., 81000 Podgorica, Montenegro
[7] University of Athens, Department of Botany, Panepistimiopolis, Athens, 15784, Greece
[8] University of St. Cyril and Methodius, Institute of Biology, Blvd. Krste Petkov Misirkov b.b., 1000 Skopje, FYR Macedonia
[9] University of Zagreb, Department of Botany, Marulićev trg 9a, 10000 Zagreb, Croatia
[10] Babes-Bolyai University, Hungarian Department of Biology and Ecology, str. Republicii 42. 400015 Cluj-Napoca, Romania
[11] Institute of Botany and Botanical Garden, Faculty of Biology, Takovska 43, 11 000 Belgrade, Serbia
[12] Sofia University "St. Kliment Ohridski", Department of Botany, 8 Dragan Tzankov blvd., 1164 Sofia, Bulgaria
[13] University of West Hungary, Institute of Silviculture and Forest Protection, Ady E. u. 5, 9400 Sopron, Hungary

Abstract

Data on the current distribution and status of alien freshwater plants in the ESENIAS countries were compiled from the literature, herbarium records and the personal knowledge of regional specialists. The focus of this work was on plants which are able to grow with their roots permanently in water, rather than including the large numbers of marginal plants and species occurring in ephemeral wetlands. 45 alien aquatic plant species were recorded, of which only four were widespread and nine considered invasive. Most countries in the region support the same widespread alien freshwater plants as occur throughout Europe but there is a much greater representation of species originating in the tropics. Alien freshwater plants occurring in the ESENIAS countries mainly originate either from the horticultural trade or rice cultivation. There has been an almost exponential increase in the number of alien aquatic plant species in the region since the start of the 20th century. Although initiatives aimed at public awareness and legislative controls on sale of invasive taxa may help to reduce the rate of invasion, the most effective way to tackle the problem is through an industry-led quality standard, linked to biosecurity and good practice.

Keywords

Plant invasions, biogeographical pattern, donor regions, habitat affinity, residence time, temporal trends

Introduction

Alien freshwater plants with the ability for rapid vegetative reproduction or vegetative expansion have the potential for significant disruption of ecosystem services. They can compromise flood control measures, disrupt navigation, disrupt flow and cause stagnation of water, as well as potentially disrupting the production and harvesting of crops (Barrett and Seaman 1980; Mitchell and Gopal 1991; Richardson et al. 2000; Duncan et al. 2005; Zenetos et al. 2009). In addition to direct habitat loss and degradation, the most significant anthropogenic threat to biodiversity is the biological invasion of natural and semi-natural habitats (Zedler and Kercher 2004; Barrat-Segretain 2005; Erhard and Gross 2006; Hejda and Pyšek 2006; Téllez et al. 2008; Richardson 2009; Smith 2012). It has been shown that the largest numbers of alien plants occur in anthropogenic and disturbed habitats and that there is an increasing vulnerability of ecosystems to invasion as a consequence of habitat degradation and fragmentation (Chytrý et al. 2005; Arianoutsou et al. 2010; Nikolić et al. 2013). The cost of attempts to control alien species is growing throughout the world (Pimentel et al. 2000, 2005; Chu et al. 2006) and this is only likely to continue, as a consequence of the increasing ease of international travel and transport, combined with climate change.

In recent years, there has been a significant improvement in the availability of information on the spread of alien plants (e.g. Kühn and Klotz 2003; Lambdon et al. 2008). This has developed with a much needed increase in emphasis on the compilation of credible data-sets derived through the involvement of regional specialists, combined with greatly improved clarity of terminology (e.g. Pyšek et al. 2004). However there is still a need to gather reliable data from habitats which are typically under-recorded such as freshwater systems, as well as areas for which comprehensive data-sets have yet to be compiled such as the Balkans (Lambdon et al. 2008).

This article presents data on alien freshwater plants occurring in ESENIAS countries (Katsanevakis et al. 2013), compiled by botanists actively working in the relevant country.

Methods

The aim of the exercise was to establish which alien aquatic vascular plant species have been recorded in each ESENIAS country and their current status. The study of freshwater plants is extremely complicated, not least because there is no definition so far devised using which two botanists would reliably produce the same list of species. A variety of terms are widely employed to denote aquatic plants, such as "macrophyte" (e.g. Holmes et al. 1999; Chambers et al. 2008) literally "big plant", or "hydrophyte" literally "water plant" and usually used to distinguish aquatic plants from "helophytes" literally "marsh plants", but none of these carries an unambiguous definition. The main definitions in use are those devised by Cook (1996a) or Cook (1996b), however even these definitions include an element of ambiguity, for example "long periods" (Cook 1996a) and "several months" (Cook 1996b). For the purposes of this study, a simplistic definition was sought that would be likely to be consistently applied by different experts and which would include only the plants most strongly dependent upon water. The following definition was adopted: Vascular aquatic plants are interpreted as "vascular plants which can grow with their lower stem and roots permanently submerged".

Species names follow those considered to be accepted by the World Checklist of Selected Plant Families (WCSPF) (The Board of Trustees of the Royal Botanic Garden, Kew 2013) where possible or The Plant List as a secondary option (http: //www.theplantlist.org/).

There is considerable confusion over the taxonomy of certain aquatic plant groups. Three *Azolla* species have been reported from the region; *A. caroliniana* Willd., *A. filiculoides* Lam. and *A. mexicana* Cham. & Schltdl. The WCSPF has yet to treat the genus. Reid et al. (2006) support *A. caroliniana*, *A. filiculoides*, *A. mexicana* and *A. microphylla* Kaulf. as separate species. Hassler and Schmidt (2012) accept *A. caroliniana* and *A. filiculoides* and treat *A. mexicana* as a synonym of *A. microphylla* but do not treat *A. microphylla* as occurring in Europe. The Plant List treats *A. carolini-*

ana as a synonym of *A. filiculoides* and *A. mexicana* as a synonym of *A. microphylla* and this is the treatment followed here, but records of *A. microphylla* from the region are not accepted as they have not been subject to critical confirmation. A similar issue arises with *Paspalum distichum* L. and *P. paspalodes* (Michx.) Scribn., both taxa are reported from the region and there is confusion over the true identity of some material. Barkworth et al. (2007) and the WCSPF treat *P. paspalodes* as a synonym of *P. distichum* and this is the treatment followed here.

Terminology regarding the distinctions between different types of colonisation by alien plants, casuals, naturalised and invasive species follows Pyšek et al. (2004).

A comprehensive review of the literature from ESENIAS countries was supplemented by field data and records generated by the contributing authors. The alien flora of the region is complicated by uncertainty over the native or alien status of many taxa. In some cases, this is due to an extremely long association with man for ornament (e.g. Padgett 2007; Bosi et al. 2009a, 2009b) such as *Nuphar*, *Nymphaea* and *Nymphoides* species or for food (e.g. Tolar et al. 2011; Dénes et al. 2012; Łuczaj et al. 2012) such as *Alisma plantago-aquatica*, *Nasturtium officinale* and *Trapa natans*, in others because of a very long history of accidental transport, such as *Lemna* species. According to the main floras and chorological atlases (Soó 1964-1980; Davis 1965-1988; Meusel et al. 1965, 1978, 1992; Jalas and Suominen 1972, 1989; Hultén and Fries 1986) the following taxa are all considered to be native to the region and are not discussed further, even though the native distribution of these species is often obscured by planting: *Lemna gibba*, *L. minor*, *Ludwigia palustris*, *Najas minor*, *Nymphaea alba*, *Nymphoides peltata*, *Sagittaria sagittifolia*, *Salvinia natans*, *Stratiotes aloides*, *Trapa natans* and *Wolffia arrhiza*. The status of *Lemna turionifera* in the region is far from clear; it was originally thought to be alien in Europe (Wolff and Lang 1993; Wolff and Orschiedt 1993), however herbarium collections were found from Scandinavian countries in the 1800s suggesting that it might actually be native to northern Europe (Lansdown 2008; Sinkevičienė 2011). It is treated here as native to the Balkans, although it will probably never be possible to be certain of its status. *Vallisneria spiralis* is usually considered native to Mediterranean parts of the Balkans; however, occurrences in the Pannonian ecoregion are most likely alien (Soó 1964-1980). The native range of *Elatine ambigua* is uncertain (Cook 1985) and it is not considered further here. *Utricularia gibba* is considered native to the Iberian Peninsula, parts of North Africa and Israel (Taylor 1989) but had not been recorded from Greece at the time of publication. Although it is widely naturalised and popular with specialist horticulture, it is likely that it is native in Greece (Sarika-Hadjinikolaou et al. 1996; Sarika and Yannitsaros 2009) and it is not therefore considered further here. It is not actually possible to establish the native distribution of two of the alien aquatics in the region (Cook 1985); *Bergia capensis* and *Eclipta prostrata* are known to have originated in the tropics but their precise origins are obscured by anthropogenic dispersal.

The number of occurrences of each taxon was calculated for all Balkan countries as an estimate of the number of 10×10 km UTM grid squares with records (Table 1). Due to slight uncertainty in some data, these data are presented as a number of sites for the ESENIAS countries classed as 1-10, 11-100 or 100+.

Results and Discussion

The current distribution of alien freshwater plants in ESENIAS countries

A total of 45 alien freshwater plants (as defined in the methods) has been recorded from the ESENIAS countries (Table 1). The largest countries support the largest number of taxa (Table 2) except for Turkey and the effect of area must therefore be taken into account when comparing the level of invasion between countries (Lambdon et al. 2008). Only Greece and Romania, which have the largest surface area of the ESENIAS countries, support more than 20 species, Bulgaria and Turkey between 10 and 20 and the remainder fewer than ten. The most widespread

Table 1. A revised list of alien freshwater plants in ESENIAS countries.

Legend: AL – Albania, BIH – Bosnia and Herzegovina, BG – Bulgaria, CR – Croatia, GR – Greece, MK – FYR Macedonia, MO – Montenegro, RO – Romania, SR – Serbia (incl. Kosovo), TE – Turkey-in-Europe. Date of the first records concerned the Balkans entirely. No. of localities based on 10×10 km UTM grid squares. c = casual; n = naturalised, non-invasive; i – invasive; p = present, status unknown. * The species is native in other parts of the Balkans.

Family	Species	AL	BIH	BG	CR	GR	MK	MO	RO	SR	TE	First record	No. of localities	Origin
Acoraceae	*Acorus calamus* **L.**		**n**	**n**	**n**		**p**		**n**	**n**	**n**	**16th C**	**101-1000**	**Asia &North America**
Lythraceae	*Ammannia auriculata* **Willd.**			**n**		**p**					**c**	**1980**	**1-10**	**tropics & subtropics**
Lythraceae	*Ammannia baccifera* **L.**					**p**						**2001**	**1-10**	**India**
Lythraceae	*Ammannia coccinea* **Rothb.**					**n**						**1989**	**11-100**	**The Americas**
Lythraceae	*Ammannia senegalensis* **Lam.**					**p**						**2002**	**1-10**	**Africa**
Lythraceae	*Ammannia verticillata* **(Ard.)** Lam.			**n**			**p**	**p**	**c**	**p**		**1893**	**1-10**	**Asia**
Azollaceae	*Azolla filiculoides* **Lam.**	**n**		**n**	**n**	**i**	**p**		**i**	**i**	**n**	**1916**	**11-100**	**tropical America**
Plantaginaceae	*Bacopa rotundifolia* **Michx.**) Wettst.					**p**						**1988**	**1-10**	**North America**
Elatinaceae	*Bergia capensis* **L.**					**p**						**2001**	**1-10**	**unknown**
Cabombaceae	*Cabomba caroliniana* **A.**Gray								**n**	**p**		**1950**	**1-10**	**The Americas**
Pteridaceae	*Ceratopteris thalictroides* **(L.)** Brongn.								**i**			**1974**	**1-10**	**tropics & subtropics**
Compositae	*Cotula coronopifolia* **L.**					**p**						**1966**	**11-100**	**South Africa**
Pontederiaceae	*Eichhornia crassipes* **(Mart.)** Solms								**c**			**2010**	**1-10**	**C & S America**
Compositae	*Eclipta prostrata* **(L.)** L.	**p**		**n**		**p**		**p**	**n**		**n**	**1998**	**11-100**	**unknown**
Hydrocharitaceae	*Egeria densa* **Planch.**										**p**	**1984**	**1-10**	**South America**
Hydrocharitaceae	*Elodea canadensis* **Michx.**	**n**	**i**	**i**	**i**		**p**	**c**	**i**	**i**	**p**	**1894**	**101-1000**	**North America**
Hydrocharitaceae	*Elodea nuttallii* **(Planch.)** H.St.John			**i**	**i**				**i**	**i**		**1993**	**11-100**	**North America**
Pontederiaceae	*Heteranthera limosa* **(Sw.)** Willd.					**p**	**p**					**2001**	**1-10**	**The Americas**
Pontederiaceae	*Heteranthera reniformis* **Ruiz & Pav.**					**p**						**2002**	**1-10**	**The Americas**
Pontederiaceae	*Heteranthera rotundifolia* **(Kunth) Griseb.**			**n**		**p**						**2002**	**1-10**	**The Americas**
Araceae	*Lemna aequinoctialis* **Welw.**					**p**						**<2005**	**1-10**	**tropics & subtropics**
Araceae	*Lemna minuta* **Kunth in F.**W.H. von Humboldt	**n**				**n**			**i**			**1988**	**1-10**	**The Americas**
Poaceae	*Leptochloa fusca* **(L.)** Kunth.					**p**						**2002**	**1-10**	**tropics & subtropics**
Onagraceae	*Ludwigia grandiflora* **Michx.**) Greuter & Burdet					**p**						**2002**	**1-10**	**The Americas**
Onagraceae	*Ludwigia peploides* **(Kunth) P.**H.Raven					**p**						**2001**	**1-10**	**S & C America**
Phrymaceae	*Mimulus guttatus* **Fisch.** ex DC.			**n**				**p**	**c**			**1893**	**1-10**	**North America**
Pontederiaceae	*Monochoria korsakowii* **Regel & Maack**								**c**			**1989**	**1-10**	**Asia**
Hydrocharitaceae	*Najas chinensis* **N.**Z.Wang					**p**						**2001**	**1-10**	**Asia**

Family	Species	AL	BIH	BG	CR	GR	MK	MO	RO	SR	TE	First record	No. of localities	Origin
Hydrocharitaceae	*Najas gracillima* **(A.**Braun ex Engelm.) Magnus					**p**						**1985-88**	**1-10**	**Asia, North America**
Hydrocharitaceae	*Najas graminea* **Delile**	**c?**		**n**	**c**	**p**			**c**		**n**	**1933**	**1-10**	**tropics & subtropics**
Nelumbonaceae	*Nelumbo nucifera* **Gaertn.**								**i**			**1931**	**1-10**	**Asia, Australasia**
Nymphaeaceae	*Nymphaea lotus* **L.**								**n**			**1797**	**1-10**	**tropics & subtropics**
Poaceae	*Oryza sativa* **L.**			**c**		**c**	**p**				**n**	**1891**	**11-100**	**China**
Poaceae	*Paspalum distichum* **L.**	**n**	**n**	**i**	**i**	**i**	**p**	**i**	**i**	**i**	**i**	**1959**	**101-1000**	**The Americas**
Poaceae	*Paspalum dilatatum* **Poir.** in J.B.A.M.de Lamarck		**n**		**i**	**i**		**i?**			**c**	**1963-66**	**11-100**	**South America**
Poaceae	*Paspalum thunbergii* **Kunth ex Steud.**										**c**	**?**	**1-10**	**Eastern Asia**
Poaceae	*Paspalum vaginatum* **Sw.**					**p**						**2005-2007**	**1-10**	**The Americas**
Polygonaceae	*Persicaria hydropiperoides* **(Michx.)** Small					**n**						**2005-2007**	**1-10**	**The Americas**
Polygonaceae	*Persicaria senegalensis* **(Meisn.)** Soják					**n**						**<1989**	**1-10**	**Africa**
Araceae	*Pistia stratiotes* **L.**								**c**	**c**		**2005**	**1-10**	**tropics & subtropics**
Lythraceae	*Rotala ramosior* **(L.)** Koehne					**p**	**p**					**2002**	**1-10**	**The Americas**
Alismataceae	*Sagittaria latifolia* **Willd.**			**n**					**n**			**1931**	**1-10**	**The Americas**
Alismataceae	*Sagittaria subulata* **(L.)** Buchenau								**n**			**1973**	**1-10**	**The Americas**
Alismataceae	*Sagittaria trifolia* **L.**								**n**		**c**	**1993**	**1-10**	**E & SE Asia**
Hydrocharitaceae	*Vallisneria spiralis* **L.***								**n**	**p**	**p**	**1949**	**1-10**	**tropics & subtropics**

species are *Paspalum distichum* in all ten countries, *Elodea canadensis* in nine, *Azolla filiculoides* in eight and *Acorus calamus* in seven. This agrees strongly with the findings of Lambdon et al. (2008) that, of the 150 most widespread alien plant species recorded in Europe, which occur in more than 25 European countries, only five (with *Mimulus guttatus* in addition to the species listed above) are aquatics. Equally in agreement with Lambdon et al. (2008), most species have been recorded from only one country (Fig. 1) with only four species occurring in more than five countries.

Few taxa are actually considered to be invasive in the region: *Paspalum distichum* is considered invasive in seven countries, *Elodea canadensis* and *Paspalum dilatatum* in five, *Elodea nuttallii* in four, *Azolla filiculoides* and *Paspalum dilatatum* in three, and *Ceratopteris thalictroides*, *Lemna minuta* and *Nelumbo nucifera* are all considered invasive in one each. It is surprising that *A. calamus*, the most widespread alien freshwater species in the region, which occurs at the largest number of sites, is not considered invasive in any of the countries in the region.

The three families most strongly represented among the alien freshwater plants of the ESENIAS countries are the Poaceae, Hydrocharitaceae and the Lythraceae, each with six species, followed by the Pontederiaceae with five species and then the Alismataceae with three. The abundance of the Hydrocharitaceae agrees with the findings of Hussner (2012), but otherwise the data show strong differences, possibly because of the warmer more Mediterranean

Table 2. Number of alien freshwater plants in the ESENIAS countries.

Country	Area (km²)	No. alien aquatics	No. alien aquatics by 10 km²
Turkey-in-Europe	**23,764**	**13**	**5**.47
Montenegro	**13,810**	**6**	**4**.34
FY Macedonia	**25,710**	**8**	**3**.11
Albania	**28,750**	**6**	**2**.09
Greece	**132,000**	**27**	**2**.05
Croatia	**56,590**	**7**	**1**.24
Bulgaria	**111,000**	**13**	**1**.17
Serbia	**88,360**	**9**	**1**.02
Romania	**238,400**	**21**	**0**.88
Bosnia and Herzegovina	**51,200**	**4**	**0**.78

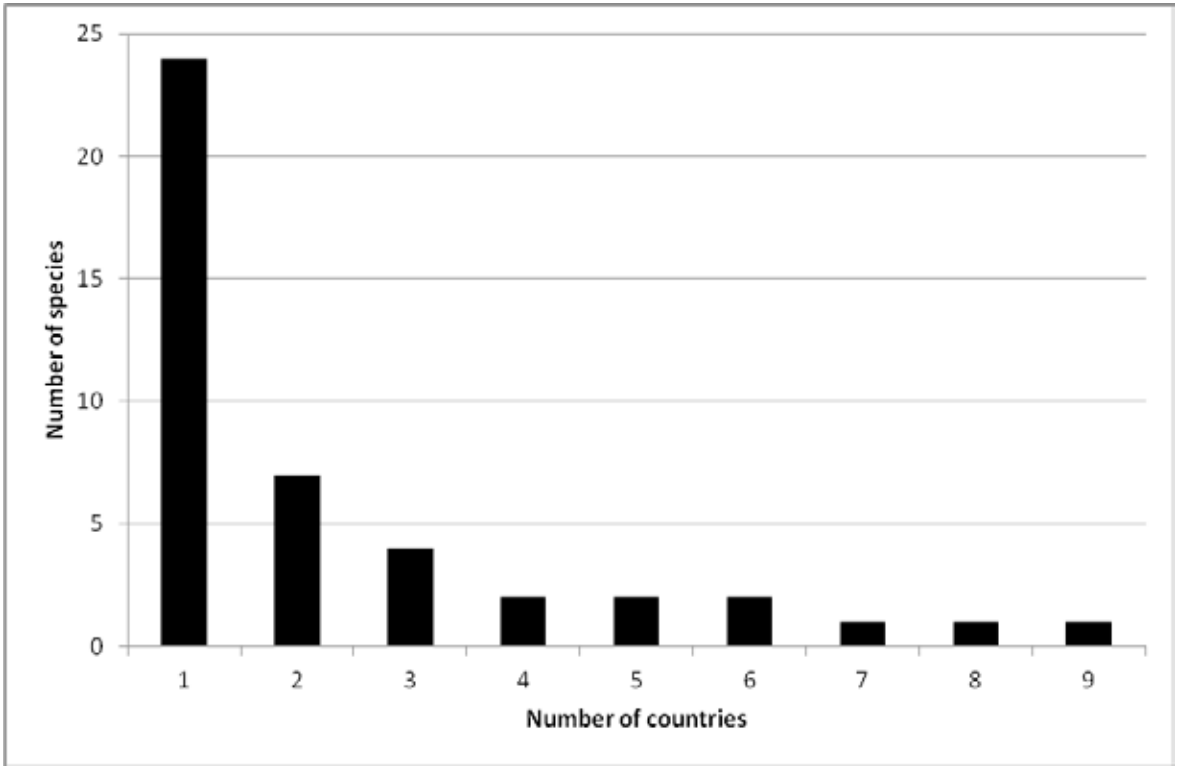

Fig. 1. Number of ESENIAS countries in which alien freshwater vascular plants occur.

Paspalum distichum, originating from ricer fields and now found in all ten ESENIAS countries

climate of the ESENIAS countries but also probably because of the influence of rice cultivation as a source of aliens in the ESENIAS region.

Summary accounts of the status of alien freshwater plants by country (based on data presented in Tables 1 and 2):

Albania

Only a few alien freshwater plants have been recorded from Albania, including the ubiquitous *Azolla filiculoides* and *Paspalum distichum*. All the other taxa are also among the most widely introduced of all alien aquatics in Europe; *Elodea canadensis*, *Lemna minuta* and *Najas graminea* (Vangjeli et al. 2000; Desfayes 2004). It is most likely that all of these taxa arrived from within the region, rather than representing new colonisation within the country. It is notable that *A. filiculoides*, *E. canadensis* and *L. minuta* were not recorded before 2000, in spite of the fact that *A. filiculoides* was recorded in the Balkans in 1916 and *E. canadensis* in 1894. It is possible that Albania has been sheltered somewhat by its relative isolation in the past but that this has changed as international travel and trade have become freer.

Bosnia and Herzegovina

The only species recorded from Bosnia and Herzegovina are those which are widespread throughout the region as a whole. *Acorus calamus* was recorded in 1892, while *Elodea canadensis*, *Paspalum dilatatum* and *P. distichum* were not recorded until 2010, although all are now considered to be widespread. Available data suggest that the only species which has been established for any time is *Acorus calamus* and that all the other species are relatively recent introductions.

Bulgaria

Bulgaria supports a wide range of alien aquatic plant species, including many that are widespread throughout Europe such as *Acorus calamus*, *Azolla filiculoides*, *Elodea canadensis*, *E. nuttallii*, *Mimulus guttatus*, *Najas graminea* and *Sagittaria latifolia*, as well as *Paspalum distichum* which is more characteristic of the alien flora of the Balkans (Assyov et al. 2012; Petrova et al. 2012). Most of these species were recorded before the 1980s; but during the last two decades the following species; *Eclipta prostrata*, *Elodea nuttallii* and *Heteranthera rotundifolia* have been recorded new to Bulgaria (Češmedžiev and Stojchev 2005; Tsonev 2007; Georgiev et al. 2011).

Croatia

Only very few alien aquatic species have been recorded in Croatia; *Acorus calamus* and *Elodea canadensis* have been established for more than a century (Nikolić 2013), whilst *Azolla filiculoides* was first recorded in 1978 (Trinajstić and Pavletić 1978). Only three aquatic species are considered invasive in Croatia: *Elodea canadensis*, *Paspalum dilatatum* and

Ceratopteris thalictroides, a species which is "bulked-up" for subsequent sale to the horticultural trade in water bodies arising from thermal springs

P. distichum (Boršić et al. 2008). *Elodea nuttallii* was recently discovered (Király and Mesterházy 2013; Kočić et al. 2013) and is considered likely to become invasive.

Greece

Greece supports more alien aquatic plants than any other country in the region and more than most European countries, however in relation to its surface area; it has fewer species than FYR Macedonia, Montenegro and Albania. The large number of species present may be explained by the fact that compared to the other Balkan countries; Greece has a higher degree of urbanisation, industrialisation and tertiary sector (tourism) development as well as a longer history of human influence; it is also true that the alien flora of Greece has been studied more intensively and systematically since the 1970s. Notably, 13 of the alien freshwater plants are confined to ricefields, while only eight of the 27 species recorded from Greece are known from more than five 10 km squares. Only *P. distichum* can truly be considered widespread, occurring in more than 80 10 km squares. However, records of *Azolla filiculoides* and *Cotula coronopifolia* have been increasing as more rivers and wetlands are studied for the first time. A high proportion of the species occurring in Greece are of tropical origin.

FYR Macedonia

For its size FYR Macedonia supports the third largest number of alien freshwater vascular plant species of the ESENIAS countries. The species recorded fall into two groups, those which are widespread throughout Europe such as *Acorus calamus*, *Azolla*

filiculoides and *Elodea canadensis* and rice field weeds such as *Ammannia verticillata*, *Heteranthera limosa* and *Oryza sativa*.

Montenegro

For its size, Montenegro supports the second largest number of alien species in the region; these include species of tropical origin, but apparently the taxa most widespread both in the region and in Europe: *Acorus calamus* and *Elodea canadensis* are absent. Two species are considered to be invasive in Montenegro; *Paspalum dilatatum* and *P. distichum* (Stešević and Petrović 2010).

Romania

Romania supports a wide range of alien aquatic plants, including *Cabomba caroliniana*, *Ceratopteris thalictroides*, *Nymphaea lotus* and *Sagittaria subulata,* which are known only from thermal springs and have not been recorded elsewhere in the region. *Monochoria korsakowii* and *Nelumbo nucifera* are also known from thermal lakes but the former also grows in rice fields in the Danube Delta, whilst the latter is known from non-thermal lakes. Apart from these species, Romania supports most of the alien species which are widespread in the Balkans, including *Acorus calamus* (first recorded in 1780), *Azolla filiculoides* (since 1916), *Elodea nuttallii* (since 1993), *Lemna minuta* (since 1998) and *Paspalum distichum* (since 1992) (Anastasiu and Negrean 2009). As a peculiarity, *Nymphaea lotus* is known from the thermal lakes near Oradea and is considered by some (e.g. Ciocârlan 2009) as a preglacial relic, however its status is disputed by other authors (e.g. Lukács at al. 2006). In contrast, the invasive alien *Azolla filiculoides* is included in the Romanian Red List of vascular plants (Dihoru and Negrean 2009).

Serbia (incl. Kosovo)

According to the most recent publication (Lazarević et al. 2012), *Elodea canadensis*, *E. nuttallii* and *Paspalum distichum* are considered to be invasive throughout Serbia, while *Azolla filiculoides* is considered only locally invasive. *Oryza sativa* was sporadically cultivated until World War II. *Mimulus guttatus* has been treated as an ornamental plant and *Pistia stratiotes* only as a casual, whilst *Acorus calamus* is considered to have been introduced before the first World War (Vrbičanin et al. 2004). *Paspalum disti-*

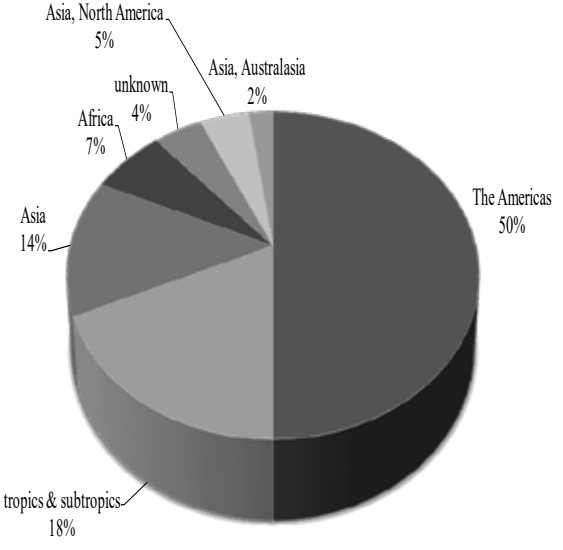

Fig. 2. Origins of alien freshwater vascular plants in the ESENIAS countries.

Elodea canadensis, recorded from nine ESENIAS countries, originating from the horticultural trade but probably at least partly dispersed between countries within the region

chum was first recorded in 1996 (Blaženčić et al. 2000), and since then it has been spreading along the banks of the rivers Sava and Danube. Most recently, *Cabomba caroliniana* was recorded for the first time in Serbia, where it is considered potentially invasive, especially in the Vojvodina region (Vukov *et al*. 2013).

Turkey-in-Europe

For its size, Turkey-in-Europe supports the largest number of alien freshwater plants in the region. Most of the species recorded from Turkey-in-Europe almost certainly spread from rice fields and most of those are shared with Greece. Obvious exceptions to this are *Egeria densa* and *Elodea canadensis*, *E. densa* has not been recorded elsewhere in the Balkans (Davis 1965-1988) but does occur in southern Turkey in Hatay Province (RVL authors obs.) and may have spread to Turkey-in-Europe within the country. *E. canadensis* could have arrived from neighbouring Bulgaria or could have colonised by direct introduction.

Colonisation and spread of alien freshwater plants in ESENIAS countries

The first alien freshwater plant to be recorded in the region was *Acorus calamus*, first recorded in the 18th century (Bondev and Popov 1971) (but maybe already present in the 1600s; Máthé 1959), as was *Nymphaea lotus*. *A. calamus* was an early colonist over a wide area, with the first record from the 16th century in Turkey, from Italy before 1500 (D. Saiani pers. comm.) and it is considered an ancient colonist to

Georgia (I. Machutadze pers. comm.). The available data suggest that three species entered the region as aliens in the 19th century; *Elodea canadensis*, *Oryza sativa* and *Mimulus guttatus*, five in the first fifty years of the 20th century, 16 in the second fifty years of the 20th century and 17 in the first 12 years of the 21st century. This agrees with the findings of Lambdon et al. (2008) who note that there has been an exponential increase in the number of alien arrivals in Europe. What is certain, is that the increase in the number of alien aquatic plant species in the region, the rate of which is increasing, will not end in the foreseeable future. Not only will there be more species colonising the region, but more species will become invasive. The invasibility of wetlands has been proved to be higher than that of other habitats both at Mediterranean and at European level (Chytrý et al. 2008, Arianoutsou et al. 2010).

Most of the alien aquatic plants occurring in the region originated in the tropics, with only a few from temperate regions (Figure 2). 22 species (50%) originated in the Americas of which two; *Egeria densa* and *Paspalum dilatatum* originate from South America, seven from North America and the remainder mainly from tropical America, including Central America and the Caribbean. This contrasts with the findings of Hussner (2012) based on a literature study, who found that most alien aquatic plant species in Europe as a whole originate in North America. It is likely that the proportion of species occurring in the Balkans which originate in the tropics is related in part to dispersal in association with rice cultivation, which is mainly tropical or sub-tropical and in part to the higher numbers of taxa of temperate origin in northern Europe. Eight species (18%) recorded in the ESENIAS countries originate in Asia, *Oryza sativa* from the Far East, *Ammannia baccifera* from India, *Sagittaria trifolia* from East and South-east Asia and others more widespread in the region. Two species, *Ammannia senegalensis* and *Persicaria senegalensis* originated in tropical Africa and *Cotula coronopifolia* from South Africa whilst most of the remainder are considered to be native throughout the tropics and sub-tropics.

It is likely that many of the species which have recently become established in the region will not yet have had an opportunity to disperse more widely but will spread rapidly once this opportunity arises. This is particularly true of *Ludwigia peploides* which is increasingly causing significant problems in Europe (Dandelot et al. 2005, Gassmann et al. 2006). It is also highly likely that some taxa will be in the phase that seems typical of alien plants in which they do not spread naturally and may even be difficult to propagate outside for many years before suddenly becoming invasive, as was the case with *Cabomba caroliniana* and *Hydrocotyle ranunculoides* in northern Europe (Newman and Dawson 1999, Hussner and Lösch 2007, Király et al. 2007).

Most alien freshwater plants occurring in the region entered either as rice field contaminants or through the ornamental or horticultural trade, either planted into ponds from which they spread into the wild or as aquarists discards. Of the alien freshwater plants recorded in the region, the *Ammannia* species, *Bergia capensis*, *Eclipta prostrata*, *Leptochloa fusca*, the *Paspalum* species, the *Persicaria* species and of course *Oryza sativa* are likely to have entered the region from rice cultivation. *Ammannia coccinea*, *Eclipta prostrata*, *Heteranthera limosa*, *H. reniformis*, *Ludwigia grandiflora*, *L. peploides*, *Paspalum distichum* and *P. dilatatum* also occur in rice fields in the Camargue (Marnotte et al. 2006), while the *Ammannia* and *Heteranthera* species also occur in rice fields in Italy (Ferrero et al. 1999). The remainder are likely to have originated either from horticulture or by spreading from elsewhere within the region. Zenetos et al. (2009) consider that the most serious impact caused by invasive alien freshwater plants comes from those which have escaped from aquariums, water gardens or rice fields. In fact, Lambdon et al. (2008) state that ornamentals constitute the highest and most diverse group of plants entering Europe and elsewhere. It is likely that some, probably including the *Elodea* species, will have spread from within Europe which is a common phenomenon (Simpson 1984, Király et al. 2007) and subsequently spread in the Balkans, although Zenetos

Azolla filiculoides, one of the most widespread and invasive vascular plants in the region, recorded from eight of the ten ESENIAS countries

et al. (2009) suggest that the relatively small size and geographical isolation of most river basins in southern and western Greece may inhibit the internal spread of some taxa. It is very difficult to demonstrate the primary source of colonisation of an area, and even more difficult to demonstrate a secondary source. However, the replacement of *Elodea canadensis* by *E. nuttallii* in natural water bodies in Europe (Barrat-Segretain 2001, Preston et al. 2002) is taking place in parts of the Balkans (e.g. Romania), supporting the idea that spread within the region may be a significant source of colonisation.

It is highly likely that species which are already established elsewhere in Europe such as *Eichhornia crassipes*, *Hydrocotyle ranunculoides*, *Lagarosiphon major*, *Myriophyllum aquaticum*, *Pontederia cordata* and *Saururus cernuus* will colonise the Balkans carried on boats and by animals between countries. Within the region, it is very likely that species will consolidate their range. Species known for their invasive potential elsewhere in the world but currently found in only one or two Balkan countries, such as *Cabomba caroliniana*, *Egeria densa*, *Ludwigia grandiflora*, *L. peploides*, *Mimulus guttatus*, *Paspalum vaginatum* and *Pistia stratiotes* are also likely to spread throughout the region.

Another potential source of new alien freshwater plants in the region is the "bulking-up" of plants for the horticultural trade by planting them into thermal springs and the canals which flow from these. This is a fairly common practice in Hungary and probably also occurs in Romania, Serbia and other areas. Although the plants which are grown in these habitats are typically taxa not known to survive through the winter elsewhere in Europe, such as *Bacopa monnieri* (e.g. Raus 2003) and a range of *Nymphaea* species

(e.g. Poczai et al. 2011), they include species which are becoming invasive in Europe such as *Cabomba caroliniana* and *Egeria densa*. The species cultivated in these springs and canals are likely to eventually spread into the wider countryside (Mesterházy et al. 2009).

The future of alien freshwater plants in the ESENIAS countries

There is a current trend for legislation against the introduction of alien aquatic plants by banning the sale of named taxa in certain states. Whilst this may to some extent remove known problem taxa from horticulture but only if it is accompanied by measures to control the use of nomenclatural ambiguity as a loophole, it will not stop or even slow down the introduction of new species to the region. The main initiatives employed to attempt to control alien freshwater plants are either legislative or target public awareness, such as the "Be plantwise" campaign in the UK (e.g. https: //secure.fera.defra.gov.uk/nonnativespecies/beplantwise/). These methods are also generally recommended by those involved in documenting alien plants (e.g. Hussner 2012). However, these initiatives will not significantly affect the two main pathways of entry of new taxa to the ESENIAS countries; rice fields and the horticultural trade. In addition, legislative control of the trade in aquatic plants can be seen as provoking an arms race, where the trade seeks to identify plants which will thrive in areas where they are sold, whereas these are precisely the types of plant which are prone to invasiveness. There is no obvious means of controlling the spread of aliens in rice field systems that is not already being attempted. However there is potentially a very power-

Acorus calamus, the most widespread and longest established alien vascular plant in the region but not considered invasive

ful means of influencing horticultural trade in aquatic plants. What is needed is a collaborative approach between governments, the horticultural trade and botanists involved in conservation, to identify taxa which lack the propensity for invasiveness or taxa native to different regions which can be brought into the horticultural trade within those regions.

The horticultural industry is enormous and aquatic plants represent a significant proportion of this trade. At present, the trade is seen as to blame for many invasions and its reputation is suffering. Initiatives aimed at raising public awareness, even when they involve members of the horticultural trade do little to enhance the reputation of the industry. What is needed, both to restore faith in the industry and to achieve very real influence over the trade in aquatic plants, is an industry-led kite mark as an indicator of adherence to a good code of practice. This kite mark must include elements of the following but it must be designed by members of the industry or it will not be taken up:

- Nurseries raising plants within their native range so that escape from nurseries ceases to be a source of introduction and to reduce pressure on native populations of rare species.
- Credible and effective biosecurity; in particular there must be controls on stowaways in plants sold (Smith 2012).
- Accuracy of labelling, including cessation of sale of taxa labelled for example simply as "oxygenating plants", to allow control of known problem taxa(Smith 2012).
- Collaborative research, involving the support of the botanical community, into alternatives to known aliens, but also development of ideas for sale of taxa native to the area in which they are sold. This idea has already begun in the UK with collaboration between garden centres which deal only in taxa native to the region in which they operate and the Millennium Seed Bank, who develop methods of propagating the target species (R. Probert pers. comm.).

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