Amorpha fruticosa invasibility of different habitats in lower Danube

Hristo P. Pedashenko, Iva I. Apostolova & Kiril V. Vassilev

Department of Plant and Fungal Diversity and Resources, Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Acad. Georgi Bonchev St., bl. 23, 1113 Sofia, Bulgaria, e-mail: hristo_pedashenko@yahoo.com

Received: June 26, 2012 ▹ Accepted: August 28, 2012

Abstract. Danube River plays a role of major corridor for plant invasions. Downstream is expected to be more strongly affected by such invasions. There were scarce data about alien plants dispersion by habitats in Bulgarian part of Danube. Sampling sites were selected on the river banks and on several islands and *Amorpha fruticosa* cover together with number of alien plants were sampled. Four habitat types were recognized. Most affected by indigo bush were poplar plantations while natural forests due to their closed structure and biodiversity remain less influenced.

Key words: aliens, river bank, vegetation

Introduction

Intensive studies of alien plants in the recent years reveal that the different habitats become affected to varying degree by invasions. It is well known that the more disturbed is a habitat the more likely it becomes invaded by aliens (Chytrý & al. 2005; 2008; Walter & al. 2005; Carranza & al. 2011). Land-use change is another factor which also facilitates invasions (Chytrý & al. 2012). River floodplains are among the most threatened habitats (Pyšek & Prach 1994; Hood & Naiman 2000; Schnitzeler & al. 2007). Rivers transport vegetative matter and seeds from upstream which can rapidly develop in the highly fertile riparian zones. In this respect, the river systems could be considered as transport corridors for invasive plants propagules (Gallé & al. 1995).

Danube is one of the most important routes for spreading of such species. Its long distance, fluctuating water level and long time anthropogenic presence facilitate the invasions. Danube shapes the northern Bulgarian border with length of 470 km. So far there was shortage of information about presence and abundance of alien plants along the Bulgarian part of the river as well as about the extent of indigo bush colonization. Recently, studies on alien flora were intensified in the framework of a project conducted during 2009–2012 and new data was collected (Biology, ecology and control of the alien invasive species of Bulgarian flora, funded by NSF (DO 02-194/2008)).

First written data about *Amorpha* invasion in Bulgaria exist since the beginning of 20th century (Dimitrov 1923). The author has reported the species *Amorpha canescens* Pursh. Later on *A. fruticosa* L. has been mentioned as a "widespread shrub on the wet places close to rivers and also very successfully cultivated" (Dimitrov 1926, 1928).

Szentesi (1999) claims that indigo bush has been known in Hungarian part of Danube from 20-30ies of the past century. It might be expected that during the same time the species has been introduced in the lower river flow. First data about *A. fruticosa* presence in Bulgarian part of Danube has been published by Stoyanov (1948). The author has reported that the species has been broadly distributed and well adapted in communities dominated by *Salix alba, Populus alba*, *P. nigra*, *Quercus robur* and *Ulmus effusus* on the river banks and on the islands, where indigo bush has grown in small patches or as single individuals. Stoyanov (1948) has mentioned also that ten years earlier the beekeepers in the town of Lom have noticed the positive role of indigo bush for honey production. This information means that the presence of the shrub along the Bulgarian part of Danube could be related to even earlier period and might be referred to the time of distribution in western countries.

Considering the state of current knowledge, our purpose was to identify the invasibility of different habitat types by *A. fruticosa* along Bulgarian part of Danube River and how this is related to nature conservation.

Methods

Study area

The study was conducted along the narrow 260 km strip between the Danube River and the dike starting from the village of Baykal (N 43.713122°, E 24.411736°) and reaching the town of Silistra (N 44.116758°, E 27.176919°). Additionally 8 islands were also visited. The area is characterized by temperate continental climate with cold winter and warm summer and the highest values of temperature amplitudes (24 °C) in the country (Velev 2002). The minimum of the river water level is in October unlike the two maximums: (1) in March – as a result of snow melting in the Danube catchment area and (2) in June – caused by the precipitation maximum in the entire watershed. The amplitude between maximum and minimum water level is between 9 and 11 m, when it is higher in narrower parts and lower in wide sections of the river (Yordanova & Chubrieva 2002). Soils are mainly Calcaric Fluvisols characterized by shallow groundwater, subjected to periodic flooding and deposition of alluvium (Ninov 2002).

Natural vegetation adjacent to the water was represented by *Salix alba, S. fragilis* and *Populus nigra* communities. Riparian forests, dominated by *Ulmus minor* and *Fraxinus oxycarpa*, were developed at areas more remote from the river (Bondev 1991). The natural vegetation has been much disturbed by human activities and large areas of natural forests was converted to poplar plantations.

Data sampling and analyses

Data was collected in 2011 during periods of low water level. Systematically 48 sampling sites were selected aiming to cover the habitat diversity. Half of the study areas (n = 25) were situated in islands and the rest (n = 23) were on the river banks. Transects started form the water and ended at the dyke resulting in different transect length. Data was collected in overall number of 105 plots situated in each habitat type falling along transects. The plot size was set to 16m^2 in grasslands and 100 m^2 in forests. Plot position and the distance from the water were recorded by Etrex Vista GPS receiver. In each plot invasive species were registered and their particular cover together with the total vegetation cover was estimated in percentages.

Habitat type was determined using Interpretation Manual of European Union habitats (Eur 27, 2007) and Kavrakova & al. (2009).

Significance of parametric differences among habitat types, as well as the number of invasive species on islands and on the mainland, was tested by t-test. Spearman Rank test was used for detecting correlations between variables. The analyses were performed in Statistica 8 (Statsoft, Inc.).

Results

Four habitat types were recognized within the studied area. Three of them are listed in Habitat Directive (92/43 EEC): 3270 Rivers and muddy banks with *Chenopodium rubri* p.p. and *Bidention* p.p vegetation (H1), 92A0 *Salix alba* and *Populus alba* galleries (H2) and 91F0 Riparian mixed forests of *Quercus robur, Ulmus laevis* and *Ulmus minor, Fraxinus excelsior* or *Fraxinus angustifolia* along the great rivers (*Ulmenion minoris*) (H3). We identified all other sites as "man made habitat" (H0). It included the poplar plantations of different ages which occupy significant areas along the river.

The following alien plants were registered during field sampling: *Portulaca oleracea* L., *Bidens frondosa* L., *Erigeron annus* (L.) Pers., *Xanthium italicum* Moretti, *Echinocystis lobata* (Michx) Torr. & A. Gray and *Amorpha fruticosa* L.

Indigo bush was registered in 70 % of the sample plots, where its total cover ranges between one and 88 %. The shrub is at very low quantity on the banks close to the water, and increases its presence to the inland territories (Fig. 3a).

Quantity of indigo bush was always very low in the muddy river banks (H1). Slightly higher is the species presence in *Salix alba* forests (H2) and decreases in *Ulmenion minoris* (H3). Differences in *A. fruticosa* cover were statistically significant for the values in H1 and H3 (Fig. 1a, 1e). Cover of *A. fruticosa* as well as the number of invasive species in plots were higher in man-made habitats (H0) in comparison with natural habitats (H1, H2 and H3) (Fig. 1a,1b).

Despite the lack of significant difference in the number of invasive species between habitat types, the average number and cover of aliens for type H0 is the highest (Fig. 1b).

We registered higher number of invasive plants on the main land as compared to the islands (Fig. 2). In addition, cover of *A. fruticosa* is higher on the mainland than on islands but results are not significant.

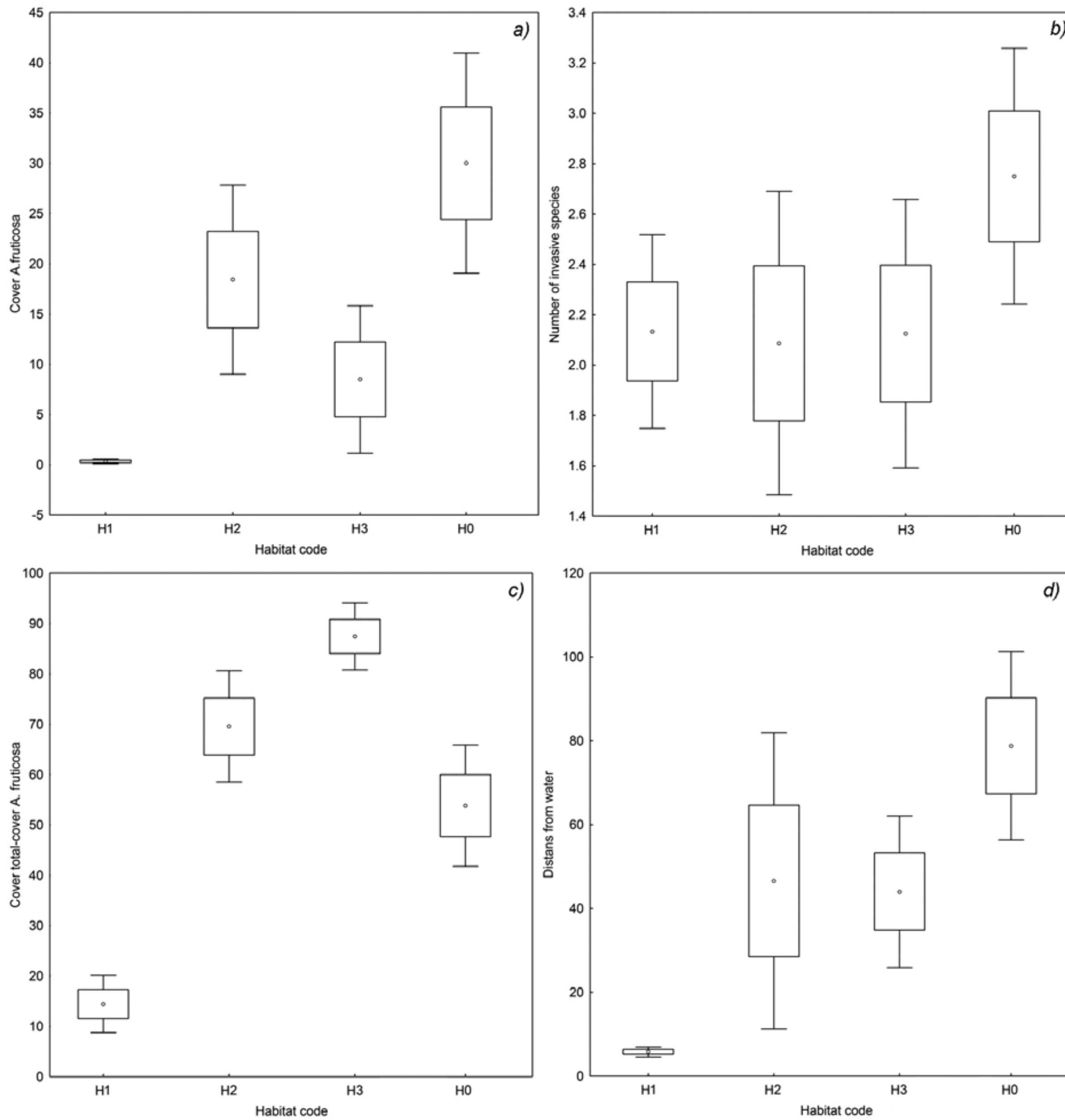
The total cover of vegetation without *A. fruticosa* portion is lower in H0 than H2 and H3 (Fig. 1c). Distance between plots and the river was the shortest for H1 and the longest for H0 whereas mean values of this parameter for H2 and H3 are almost equal Fig. 1d. There was also positive correlation between total cover of vegetation without *A. fruticosa* portion and the cover of *A. fruticosa* on one hand, and the distance from water on the other, unlike the number of invasive species which were equal regardless of distance to the river (Fig. 3a). Correlation between the cover of *A. fruticosa* and the number of invasive species was also not found (Fig. 3b).

Discussion

The proper identification of habitat types in the current study required a revision of the understanding of riparian forests along Danube in Bulgaria. Kavrakova & al. (2009) pointed the habitat 91E0 Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*) as representative for the willow galleries. We consider this interpretation not correct because this habitat is characteristic for "arborescent galleries of tall *Salix alba, S. fragilis* and *Populus nigra*, along medio-European lowland, hill or sub-montane rivers" (Eur 27, 2007). Before the accession of Bulgaria and Romania to the EU this habitat type has been the only opportunity for interpretation of our Danubian riparian forests (see Interpretation Manual Eur 25, 2003). When both countries became EU members, the subtype "Lower Danube willow galleries"(Pallearctic hab. code 44.1621, Devillers & Devillers-Terschuren 1996) was included in habitat 92A0 and published in the last edition of the Interpretation Manual of European Union habitats (Eur 27, 2007). This allows us to relate our forests to this habitat type. This way the forests on both sides of Danube will be equally assigned to one and the same habitat.

Differences for *A. fruticosa* coverage between identified habitat types could be explained by the frequency and nature of disturbances. Floods play a role of a natural disturbance that keeps lower cover values closer to the river (Fig. 3a) and in areas with regular floods (Sanchez-Perez & al. 1999). Dikes are located at varying distances from the river which range from 120 to 380 m. Thus, the closest areas to the water (habitat type H1) are subjected to regular flooding (several times a year) whereas others are flooded annually (habitat type H2) or once every few years (habitat type H3) depending on the relief (Fig. 1d). Regular floods (at least twice a year) in habitat type H1 act as a disturbance to which vegetation has adopted. Bare ground is quickly covered by native annuals after water retraction. Obviously *A. fruticosa* does not bear the changes in water level and could not survive under temporary high water table (Fig. 1a, 1e). Habitat type H3, subjected to the least disturbances, seems also unsuitable for *A. fruticosa* probably because of its distance from water, stable structure and close canopy.

Anthropogenic disturbances in natural habitats along the river are relatively recent events. Urbanization, construction of facilities for navigation and shipping take place on many locations but are mostly adjacent to the towns. Soil digging and waste disposal were not significant as disturbance practices. Poplar plantations between river and dike are the most widespread human activity which results in development of new vegetation types (H0).



e)

	Habitat	M	SD	H0 t	H0 df	H0 p	H1 t	H1 df	H1 p	H2 t	H2 df	H2 p	H3 t	H3 df	H3 p	M	SD	
Cover A. fruticosa	H0	30.03	33.56				1.83	64	0.07	1.63	57	0.11	1.38	49	0.17	2.75	1.56	Num. invas. sp.
	H1	0.33	0.66	4.84	64	<0.001				0.13	51	0.90	0.00	43	1.00	2.13	1.07	
	H2	18.43	23.5	1.45	57	0.15	-4.31	51	<0.001				-0.10	36	0.92	2.09	1.47	
	H3	9.00	15.35	2.32	49	<0.05	-3.1	43	<0.01	1.4	36	0.17				2.13	1.13	
Cov. tot-A.frut	H0	53.83	30.00				5.81	64	<0.001	1.59	57	0.12	1.74	49	0.09	78.81	68.72	Dist. to water
	H1	14.43	15.80	5.43	64	<0.001				-2.59	51	<0.05	-5.96	43	<0.001	5.80	3.36	
	H2	69.56	27.06	-1.76	57	0.08	-9.30	51	<0.001				0.02	36	0.98	46.61	86.52	
	H3	86.60	13.61	-3.33	49	<0.01	-15.09	43	<0.001	-2.25	36	<0.05				46.07	37.15	

Fig. 1. Box and Whiskers diagrams of variables dependent on the habitat type. ∘ is the mean value, ☐ is the mean ± SE and I is the mean ± 1.96*SE, H0 – habitats not included in Directive 92/43, H1 – habitat 3270 Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation, H2 – habitat 92A0 *Salix alba* and *Populus alba* galleries, H3 – habitat 91F0 Riparian mixed forests of *Quercus robur*, *Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (*Ulmenion minoris*); **a**, Cover of *A. fruticosa*; **b**, number of invasive species; **c**, cover total minus cover of *A. fruticosa*; **d**, distance of plots from water; **e**, T-test comparisons between variables in different habitats. M – median, SD standard deviation, t – t-value, df – degree of freedom, p – p-value. Significant values are marked in gray.

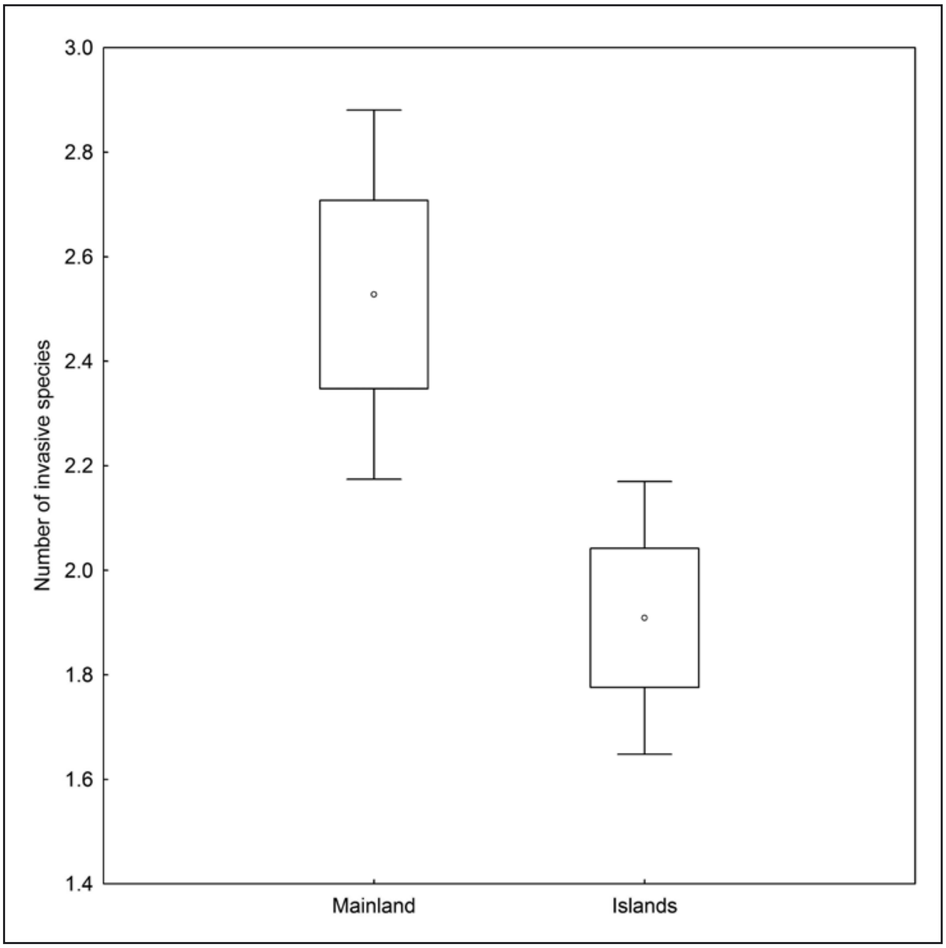


Fig. 2. Box and Whiskers diagram showing the significant difference in number of invasive species on the mainland (M=2.53, SD=1.53) and on islands (M=1.91, SD=0.77); t(103)= 2.20, p=0.03).

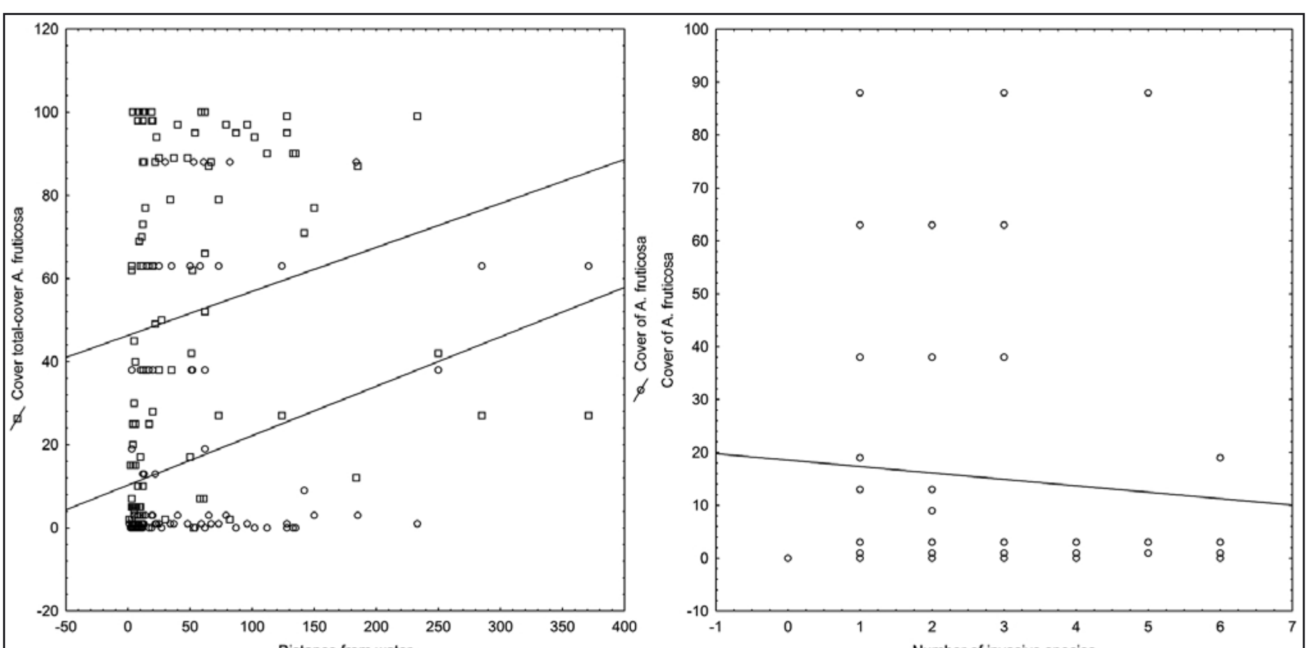


Fig. 3. Spearman's Rank-Order Correlation scatterplot of the cover of *A. fruticosa* against: **a**, distance from water ($r_s(103)=0.35$, $p<0.05$), the variable total cover without cover of *A. fruticosa* is also added ($r_s(103)=0.42$, $p<0.05$); **b**, number of invasive species ($r_s(103)=-0.03$, $p>0.05$).

In practice the poplar plantations are managed by regular replanting (Tsanov 1992). Prior to plantation the ground is ploughed and old logs are removed. This procedure allows the root fragmentation and the shrub abundance increases. New planted poplar trees are 3–4 years old and do not compete with the shrub layer for light. Aforementioned land-use type is similar in biofuel plantations as well as in crops which is known to be with the highest percentage level of invasion by alien plants among main land-use categories (Chytrý & al. 2012). Significant differences for *A. fruticosa* coverage between H0 and H3 (Fig.1a) show how more favorable are conditions for indigo bush in disturbed habitats (Schnitzler & al. 2007) than in stable ones which are by definition rich in biodiversity and structured by at least two layers. Annual floods occurring in habitat type H2 prevent development of constant undercover and most of the time the ground is free of vegetation. Indigo bush is a perennial plant which needs longer period of stable conditions in order to develop than annual plants, which dominate in regularly flooded habitats (H1), and become established permanently (H2). In the same time, only the water level rising provides seeds of *A fruticosa* which integrate into the seed bank, allowing rapid invasion of gaps (Schnitzler & al. 2007). A higher value of *A. fruticosa* abundance in H2 is related to its ability to compete local shrubs, especially species of *Salix*. Similar phenomenon was observed also along Dnipro River (Protopopova & al. 2006). Closer to the river dike floods are sparse events and vegetation there has higher cover resulting in lower presence of indigo bush.

Graphs of *A. fruticosa* coverage and of total cover without *A. fruticosa* (Fig. 1a and 1c) are mirrored to each other besides for habitat type H1 where regular floods support very low vegetation cover values. This shows that proportion of *A. fruticosa* in man-made habitats is higher than in naturally disturbed ones.

Despite the lack of significant difference in the number of invasive species between habitat types the mean value for type H0 is the highest (Fig. 1b) because of the high anthropogenic influence and disturbance rate. Similar explanation could be given for the significant difference in the number of invasive species on islands and on the mainland (Fig. 2). Lower values are logical for islands which are less accessible, and as a consequence less anthropogenically influenced. Visited islands are mostly covered by natural *Salix*, *Fraxinus* and *Populus* dominated forests. Total area of disturbed places is much less than on the mainland.

According to Chytrý & al. (2012) policies favoring sustainable development and environmental protection will not be able to stop or reduce the ongoing process of plant invasions. Current practice shows that bush removal is a difficult task and probably will not have complete success. Limiting the spread of shrubs can be achieved through restoration of riparian forests at places of existing poplar plantations.

Chytrý & al. (2012) predict decrease in the level of invasion in eastern Europe and some parts of southern Europe due to the abandonment of arable land (Reginster & al. 2010). Maintenance of Natura 2000 SCI zones provides opportunity for restoration at least some of the natural riparian habitats along Danube River and thus limit further indigo bush colonization.

Acknowledgements. This study was financially supported by National Science Foundation – DO 02-194/2008 (Biology, ecology and control of the alien invasive species of Bulgarian flora).

References

Bondev, I. 1991. The vegetation of Bulgaria. Map M 1:600 000 with explanatory text. Sofia Univ. Press, Sofia (in Bulgarian).

Carranza, M., Ricotta, C., Carboni, M. & Acosta, A. 2011. Habitat selection by invasive alien plants: a bootstrap approach. – Preslia, **83**: 529-536.

Chytrý, M., Jarošík, V., Pyšek, P., Hájek,O., Knollová, I., Tichý, L. & Danihelka, J. 2008. Separating habitat invasibility by alien plants from the actual level of invasion. – Ecology, **89**: 1541-1553.

Chytrý, M., Pyšek, P., Tichý, L., Knollová, I. & Danihelka, J. 2005. Invasions by alien plants in the Czech Republic: a quantitative assessment across habitats. – Preslia, **77**: 339-354.

Chytrý, M., Wold, J., Pyšek, P., Jarošík, V., Dendoncker, N., Reginster, I., Pino J., Maskell, L. C., Vila, M., Pergl, J., Kühn, I., Spangenberg, J.H. & Settele, J. 2012. Projecting trends in plant invasions in Europe under different scenarios of future land-use change. – Global Ecol. Biogeogr., **21**(1): 5-87.

Devillers, P. & Devilliers-Terschuren, J. 1996. A classification of Palaearctic habitats. – Nature and Environm., **78**. Strasbourg: Council of Europe Publishing.

Dimitrov, T. 1923. Alien woody plants in Bulgaria. (Materials for their study). – Svedenia po zemedelieto, **4**(3-4): 19-28 (in Bulgarian).

Dimitrov, T. 1926. Alien forest and park tree plants in Bulgaria (Materials for their study, and introduction). – Spisanie na zemedelskite izpitatelni institui v Bulgaria, **4**(1-2): 1-101.

Dimitrov, T. & Stefanov, B. 1928. Exotic forest plants and their propagation in Bulgaria. – Durjavna pechatnitsa, Sofia.(in Bulgarian).

Gallé, L., Margóczy, K., Kovács, E., Gyrffy, Gy., Körmöczy, L. & Németh, L. 1995. River valleys: are they ecological corridors? – Tiscia, **29**: 53-58.

Hood, W.G. & Naiman, R.J. 2000. Vulnerability of riparian zones to invasion by exotic vascular plants. – Pl. Ecolol., **148**: 105-114

Eur 25. 2003. Interpretation Manual of European Union Habitats. European Commission DG Environment. Natura and biodiversity.

Eur 27. 2007. Interpretation Manual of European Union Habitats. European Commission DG Environment. Natura and biodiversity.

Kavrakova, V., Dimova, D., Dimitrov, M., Tsonev, R., Belev, T. & Rakovska, K. 2009. Manual for Identification of Habitats of European Importance in Bulgaria. WWF-DCP, Green Balkans, Sofia (in Bulgarian).

Ninov, N. 2002. Soils. – In: **Kopralev, I.** (ed.), Geography of Bulgaria. Physical Geography. Socio-Economic Geography. Pp. 277-316. ForCom, Sofia (in Bulgarian).

Protopopova, V.V., Shevera, M.V. & Mosyakin, S.L. 2006. Deliberate and unintentional introduction of invasive weeds: A case study of the alien flora of Ukraine. – Euphytica, **148**: 17-33.

Pyšek, P. & Prach, K. 1994. How important are rivers for supporting plant invasions? – In: **de Waal, L.C. & al.** (eds), Ecology and management of invasive riverside plants. Pp. 19-26. John Wiley & Sons, New York.

Reginster, I., Rounsevell, M., Butler, A. & Dedoncker, N. 2010. Land use change scenarios for Europe. In: **Settele, J., Penev, L., Georgiev, T., Grabaum, R., Grobelnik, V., Hammen, V., Klotz, S., Kotarac, M. & Kühn, I.** (eds). Atlas of Biodiversity Risk. Pp. 100-105. Pensoft, Sofia & Moscow.

Sanchez-Perez, J.M., Tremolieres, M., Takatert, N., Ackerer, P., Eichhorn, A. & Maire, G. 1999. Quantification of nitrate removal by a flooded alluvial zone in the Ill floodplain (Eastern France). – Hydrobiologia, **410:** 185-193.

Schnitzler, A., Haleb, W.B. & Alsum, M.E. 2007. Examining native and exotic species diversity in European riparian forests. – Biol. Conservation, **138**, 146-156.

Stoyanov, N. 1948. Vegetation of our Danube Islands and its Economic Importance. Bulg. Acad. Sci. Publishing House, Sofia (in Bulgarian).

Szentesi, A. 1999. Predispersal seed predation of the introduced False Indigo, *Amorpha fruticosa* L. in Hungary. – Acta Zool. Acad. Sci. Hung., **45**(2): 125-141.

Tsanov, Ts. 1992. Flood-plain Forests along Bulgarian Part of Danube. Bulg. Acad. Sci. Publishing House, Sofia (in Bulgarian).

Velev, S. 2002. Climatic regioning. – In: **Kopralev, I.** (ed.), Geography of Bulgaria. Physical Geography. Socio-Economic Geography. Pp. 155-156. ForCom, Sofia (in Bulgarian).

Walter, J. M. 1979. Architectural profiles of flood forests in Alsace. In: **Cramer, J.** (ed.), Struktur and Dynamik von Walder. Pp. 187-234. Vaduz.

Yordanova, M. & Chubrieva, M. 2002. Hydrology of Bulgarian section of Danube River. In: **Kopralev, I.** (ed.), Geography of Bulgaria. Physical Geography. Socio-Economic Geography. Pp. 247-250. ForCom, Sofia (in Bulgarian).