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Distribution of the Non-native Bryozoan *Pectinatella magnifica* (Leidy, 1851) in the Danube River

Katarina Zorić[1], József Szekeres[2], Béla Csányi[2], Stoimir Kolarević[3], Vanja Marković[1], Momir Paunović[1*]

[1] Institute for Biological Research „Siniša Stanković", University of Belgrade, 142 Bulevar despota Stefana, 1 1060 Belgrade, Serbia;
[2] Danube Research Institute, Centre for Ecological Research, MTA (Hung. Acad. Sci.), 14 Jávorka Sándor u. Street., Göd H-2131, Hungary;
[3] Faculty of Biology, University of Belgrade, 3 Studentski trg Street., 11000 Belgrade, Serbia;
E-mails: katarinas@ibiss.bg.ac.rs, szekeres.jozsef@okologia.mta.hu, csanyi.bela@okologia.mta.hu, stoimirk@bio.bg.ac.rs, vanjam@ibiss.bg.ac.rs, mpaunovi@ibiss.bg.ac.rs

Abstract: The non-native freshwater magnificent bryozoan *Pectinatella magnifica* (Leidy, 1851) was firstly recorded in the summer of 2011 from the Danube River (side arm Ráckevei-Soroksári Duna downstream from Budapest). Despite intensive research along the length of the Danube River between Budapest and Belgrade in 2001-2013, it has not been detected to expand its range. Recently, the species has distributed rapidly in the 900-km-long downstream stretch of the Danube River. The species was found at ten sites, between river kilometres 1586 (Hungary, downstream from Budapest) and 685 (the Romanian-Bulgarian stretch of the Danube River). The highest colony abundance was recorded from the Iron Gate (Đerdap) sector that is influenced by the backwater effect of the Iron Gate dams. Our findings reveal the capacity of this bryozoan to spread extremely rapidly and to invade successfully stretches of rivers that are exposed to hydromorphological pressures.

Key words: *Pectinatella magnifica*, Danube River, non-native species, spread, abundance, hydromorphological alterations

Introduction

The consequences of biological invasions can be diverse, interconnected and complex. Invaders can alter fundamental ecological properties, such as the dominant species in a community, the productivity and nutrient cycling, and thereby can modify the structure and functioning of the ecosystem (Mack *et al.* 2000). The anthropogenic impact on the distribution of plants and animals is considered to be one of the major threats to biodiversity (Cohen 1998, Hopkins 2001, Grigorovich 2003). Aquatic ecosystems are not an exception when this aspect of disturbance is considered. The ballast waters of ships, deliberate fish stocking and aquaculture are potential means of introduction of non-native species. The constructions of artificial channels that connect previously geographically isolated river basins facilitate the intensive dispersal of species and greatly contribute to the spread of non-native taxa (Leuven *et al.* 2009). This scenario has occurred at different sections along the Danube River. The river belongs to the Southern Invasion Corridor that links the Black Sea Basin with the North Sea Basin via the Danube and Main-Rhine Canal (reopened in 1992). This corridor is one of the four principal routes for entry of invasive non-native aquatic organisms into Europe (Panov *et al.* 2009). This complex system of interconnected river basins and artificial channels (the Danube Delta, the Danube River, the Main-Danube Canal, the Main River, the Rhine River) facilitates the spread of non-native taxa in both downstream and upstream directions throughout the Danube River Basin. The Danube River and its main tributaries are also exposed to aquatic invasions (*e.g.* the rivers Sava (Paunović *et al.* 2008, Žganec *et al.* 2009), Tisa (Tomović *et al.* 2013) and Velika Morava (Tomović *et al.* 2012, Zoric *et al.* 2013)).

Despite intensive research, it is still not possible to assess the real consequences of aquatic invasions and to provide effective solutions for proper management, especially in the case of large and complex systems such as the Danube River. A certain amount of progress has been achieved in evaluating the pressures of biological invasions on particular aquatic assessment units (Olenin *et al.* 2007, Arbačiauskas *et al.* 2008, Panov *et al.* 2009, Tricarico *et al.* 2010). However, considerable efforts still need to be undertaken in order to fully understand invasion processes.

The freshwater species *Pectinatella magnifica* (Leidy, 1851) (Bryozoa: Phylactolaemata: Plumatellida) is a non-native taxon exhibiting considerable long-distance spread, well away from its natural distribution range. This taxon is native to the eastern part of North America (from Ontario in Canada to Florida in the United States of America). However, nowadays it can be found in other parts of the USA (Balounová *et al.* 2013). Its presence has been reported from several European countries, including Germany (Kraepelin 1887, Grabow 2005), France (Rodriguez, Vergon 2002, Devin *et al.* 2005, Notteghem 2009), Czech Republic (Opravilova 2005, 2006, Balounová *et al.* 2011), Poland (Balounová *et al.* 2013), Austria (Bauer *et al.* 2010), Romania (Lacourt 1968), Hungary (Szekeres *et al.* 2013) and from Asia Minor (Lacourt 1968). It is believed that the species was introduced to Europe in the 19th century. First it was reported in Hamburg in 1883 (Bernauer, Jansen 2006).

The magnificent bryozoan is a colonial organism with ciliated tentacles that are attached to a large gelatinous mass (Pennak 1989, Wood 2010). The typical size of the colonies is between 10 and 20 cm, while the diameter of large colonies can be up to two meters. It feeds on diatoms, green algae, cyanobacteria, non-photosynthetic bacteria, dinoflagellates, rotifers, protozoa, small nematodes and microscopic crustaceans (Callaghan, Karlson 2002). As in all bryozoan species, the life cycle of *P. magnifica* includes both sexual and asexual reproduction. During favourable temperature conditions (in temperate climate zone between May and June (Rodriguez, Vergon, 2002)), *P. magnifica* reproduces sexually. Asexual reproduction includes simple bulking and formation of new individuals, but also formation of statoblasts that enable survival during unfavourable conditions, at lower temperature and during periods of draught. *Pectinatella magnifica* is a thermophilous species. The details of its life cycle, including literature reviews, are given in Rodriguez, Vergon (2002).

The objective of this work is to present the current distribution of *P. magnifica* along the Danube River based on the 2013 Survey and to point out the fast dispersal of this species between 2011 and 2013.

Materials and Methods

Sampling was performed during August-September 2013, within the Joint Danube Survey 3 (JDS3) International Expedition (a research program organised by the International Commission for the Protection of the Danube River, in cooperation with the European Commission) and the Serbian National Research Program. A total of 68 sampling sites were inspected along the 2 500 km stretch of the Danube River.

Sampling was done using benthic FBA hand nets (500 µm mesh size), benthological dredge (500 µm mesh size) and by free diving. Potential finding sites of *P. magnifica*, herein referred to as characteristic habitats, *i.e.* areas with reduced flow that are covered by aquatic vascular plants and woody debris (see text below for descriptions of the major habitats), were visually inspected, either from a boat, or during free diving. Littoral zones were examined at

Table 1. Assessment criteria for the abundance of colonies of *Pectinatella magnifica* per 100 m river (using surveys of characteristic habitats along both river banks)

Abundance criterion	Code	Description
Few	1	Single or few colonies
Many/locally	2	Many colonies. Up to one colony per m^2 of the characteristic habitat.
Mass occurrence/locally	3	Mass occurrence. More than one colony per m^2.

Note: Characteristic habitats are areas with constantly reduced water flow (backwater effect in the area of Iron Gate Reservoir, average flow velocity 0.099 m/s (JDS 3 database 2014)), covered with aquatic vascular plants and woody debris.

both riverbanks at each sampling site along a length of about 100 m.

Due to the specific colonial life of *P. magnifica*, the relative abundance/aerial coverage of the colonies was assessed using the criteria presented in Table 1.

The overall evaluation of hydromorphological status was taken from Kraier, Schwarz 2008.

Results and Discussion

The freshwater bryozoan *P. magnifica* (Fig. 1) was recorded at nine sites along the Danube River, between river kilometres (Rkm) 1586 (Hungary, downstream Budapest) and Rkm 685 (Romanian-Bulgarian stretch of the Danube River; Table 2, Fig. 2). During the same period, the species was recorded at one additional site during the realisation of the Serbian National Research Program (Rkm 1163, Site 3, Viљnjica, downstream from Belgrade).

The colonies were found on aquatic macrophytes and woody debris submerged in the water (Fig. 1b), mostly along the shore in shallow parts of the river (0.5-1.5 m deep). The recorded colonies were formed near the surface of the water, up to a depth of 30 cm, except for one record: a colony collected from a deeper part of the river with a benthological dredge (site 2, downstream from Novi Sad, at a depth of 2.5-3 m). The riverbed at the sites where the magnificent bryozoan was recorded consisted predominantly of silt-clay and very fine sand substrate (mineral substrate classification according to Verdonschot (1999): grains not visibly perceptible; <0.125 mm). The bank area at the sites was characterised by dense associations of aquatic vascular macrophytes and macro algae. The size of the colonies ranged from 3 cm up to 35 cm in diameter. The abundance in the invaded stretch (assessed as described in Table 1), ranged from a single or few colonies within the characteristic habitats (Abundance Code 1), to mass occurrence of colonies (Abundance Code 3) (Table 2, Fig. 2).

The majority of the sites where the organisms were observed were located in areas with altered flow regimes, in the stretch influenced by the Iron Gate Dams (sites 2-9). Overall, the hydromorphological status was evaluated as poor (Table 2). Only two sites, situated outside this sector (1 and 10), with hydrological regime affected to a lesser extent, had lower level of hydromorphological alterations.

Since the initial detection of the magnificent bryozoan in the Rackeve-Soroksar Danube River side arm in 2011 (Szekeres *et al.* 2013), it rapidly colonised a 900-km-long stretch of the Danube River. The organism is already a well-established inhabitant of the entire length of the Rackeve-Soroksar Danube River arm (Szekeres *et al.* 2013), and our data has confirmed the frequent appearance of extensive colonies of *P. magnifica* in the most downstream stretch of the side arm, immediately upstream from the lock.

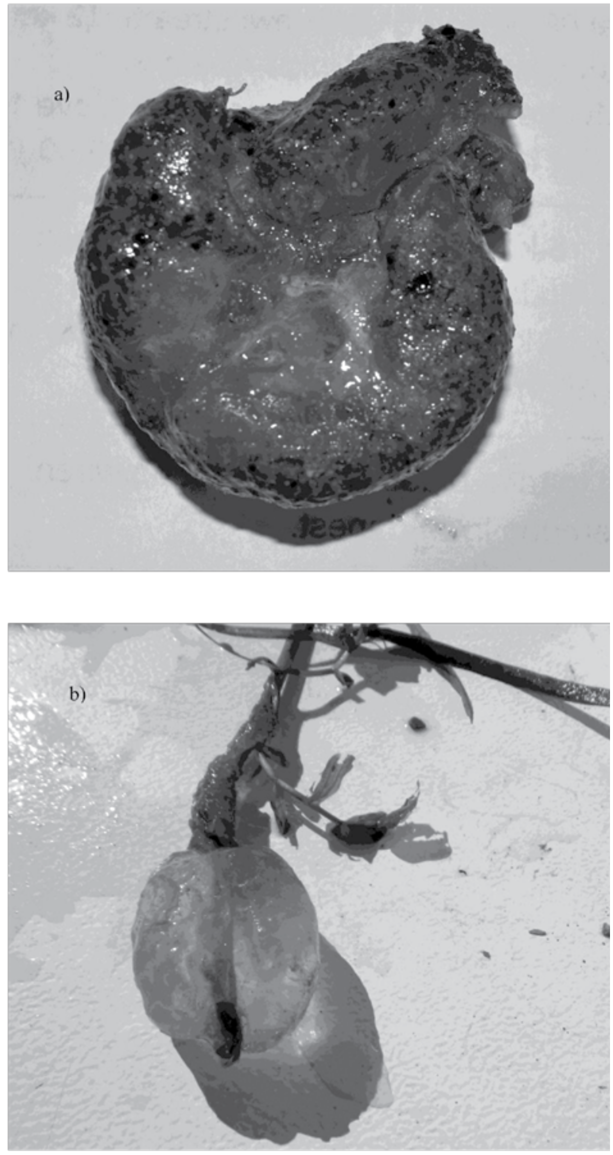

Fig. 1. The freshwater bryozoan *Pectinatella magnifica* (Leidy, 1851). Photos by József Szekeres, colonies collected at: a) Site 1 – Rackeve-Soroksar Danube River Arm and b) Site 9 - Vrbica/Simijan

The most frequent occurrence of the magnificent bryozoan was recorded in stretches with altered flow regimes. Out of 18 points surveyed in the area of backwater effect, downstream from Novi Sad-Vrbica/Simijan, *P. magnifica* was recorded at eight sights, thus the frequency of occurrence was F=44.44%, while in the Iron Gate F=50%. Due to damming in the Iron Gate sector (Đerdap area), a

Table 2. Distribution and abundance of the magnificent bryozoan *Pectinatella magnifica*

Site code	Site Name and Date	Rkm	Latitude	Longitude	Hydromorphological status	Abundance
1	Rackeve-Soroksar Danube River Arm 28/8/2013	confluence on 1586	47°1.998′	18° 58.668′	moderate	3
2	Downstream from Novi Sad 2/9/2013	1252	45°15.522′	19° 53.226′	poor	1
3	Višnjica 6/9/2013	1163	44° 49.62′	20° 32.832′	poor	2
4	Downstream from Velika Morava 7/9/2013	1097	44° 42.846′	21° 2.94′	poor	1
5	Banatska Palanka/Baziaš 8/9/2013	1071	44° 48.576′	21° 22.464′	poor	1
6	Iron Gate Reservoir (Golubac/ Koronin) 9/9/2013	1040	44° 39.696′	21° 41.754′	poor	1
7	Iron Gate Reservoir (Golubac/ Koronin) 9/9/2013	1041	44° 39.906′	21° 41.706′	poor	1
8	Tekija/Oršova 9/9/2013	954	44° 41.058′	22° 24.456′	poor	1
9	Vrbica/Simijan 10/9/2013	926	44° 36.144′	22 °41.526′	poor	3
10	Downstream from Kozloduy 14/9/2013	685	43° 46.092′	23° 49.812′	good	1

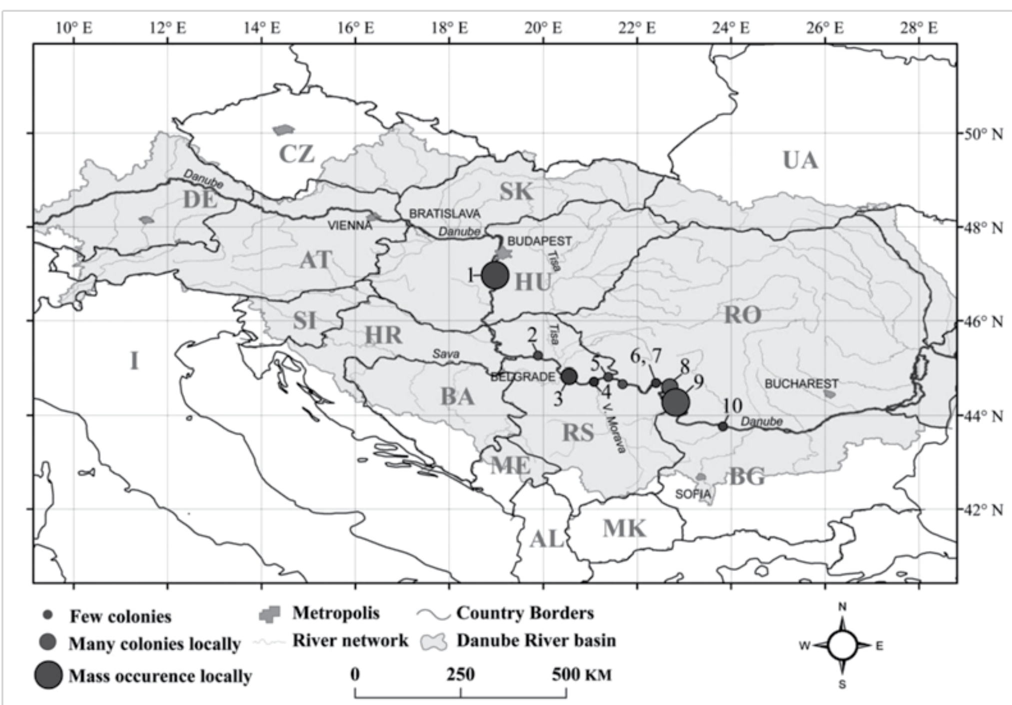

Fig. 2. Map showing the sites along the River Danube with records of *Pectinatella magnifica*. For abundance criteria, see Table 1

Table 3. Autecological characteristics of *Pectinatella magnifica* that are potentially responsible for its successful invasiveness

Feature	Description and explanation	Consequences	Sources
Significant abundance	Aerial coverage of colonies; occurrence of large number of individual zooids in colonies; large colonies containing more than two million zooids.	Occurrence of large numbers of individuals provides for a high reproductive potential.	Callaghan, Karlson 2002; Szekeres *et al.* 2013; this study
Feeding plasticity	*Pectinatella magnifica* feeds on diatoms, green algae, cyanobacteria, non-photosynthetic bacteria, dinoflagellate, rotifers, protozoa, small nematodes and microscopic crustaceans.	Increased ability to survive and reproduce in a wide variety of aquatic ecosystems.	Callaghan, Karlson 2002
Habitat preference	Found in lentic areas, such as lowland rivers, side arms with reduced water flow and other sites with slow-moving or stagnant waters; often found in artificial habitats and altered water bodies; altered physical features of habitats, such as altered flow regimes, could provide favourable conditions for invasions.	Increased pressure on aquatic habitats, altered hydrological regimes, as well as formation of artificial water bodies, such as fish ponds, can accelerate the invasion rate.	Balounová *et al.* 2011; Szekeres *et al.* 2013; this study
Adaptation to growth in fertile water	A significant proportion of water bodies within the Danube River Basin is affected by organic and nutrient pollution. This could produce conditions that favour massive appearance in certain ecosystems in the river basin.	Increased invasiveness and survival in nutrient-rich water bodies.	Dendy 1963; DRBMP 2009
Fertility	The species reproduces sexually and asexually.	Increased reproductive capacity; increased spread rate.	Rodriguez, Vergon 2002
Life cycle characteristics	Under unfavourable conditions, the colonies produce statoblasts, which can survive these conditions and spread to other aquatic ecosystems, carried either by the water current, or by zoochoria (fish or birds).	Improved survival under unfavourable conditions; increased rate of spreading.	Rodriguez, Vergon 2002

significant stretch of the Danube River is characterised by altered flow regimes (reduced water current). Consequently the general characteristics of the environment are modified, such as more intensive sedimentation, increased occurrence of habitats with soft sediments, more intensive coverage by aquatic vegetation, as well as changed oxygen and nutrient regimes. The presence of the Iron Gate dams which are located along the section of the Danube River shared by Romania and Serbia (Iron Gate 1 at Rkm 943 and Iron Gate 2 at Rkm 862.8) affect the flow regime for about 393 kilometres upstream to Novi Sad (Rkm 1255). The complex relations between flow and sediment regime within the Iron Gate stretch are discussed in detail by Babić Mladenović (2007).

Since its introduction to Europe in the 19th century, *P. magnifica* has invaded many parts of Europe (Kraepelin 1887, Lacourt 1968, Rodriguez, Vergon 2002, Devin *et al.* 2005, Grabow 2005, Opravilova 2005, 2006, Notteghem 2009, Bauer *et al.* 2010, Balounova *et al.* 2011) and Asia Minor (Lacourt 1968). The species has also spread in North America, and is now found in Canada (Benson, Cannister 2014), Texas (Neck, Fullington 1983) and in 18 lakes in the Pacific Northwest, including the states of Idaho, Oregon and Washington (Marsh, Wood 2002). Based on our results, as well as on recent studies of other authors (Opravilova 2005, 2006, Devin *et al.* 2005, Grabow 2005, Notteghem 2009, Bauer *et al.* 2010, Balounová *et al.* 2011, Szekeres *et al.* 2013) we can speculate that this species is becoming increasingly common in areas outside its range.

The possible reasons for this species' invasiveness are related to its autecological characteristics and changes of its freshwater habitats. Characteristics of the species that could be responsible for the invasive success of the magnificent bryozoan are listed in Table 3.

Our results suggest that the changes in habitats and reduced flow regimes provided favourable conditions for invasion by *P. magnifica*. Aside from habitats that are typical for this species (reservoirs) fish ponds and other aquatic habitats with altered hydrological conditions are also potentially suitable recipient ecosystems for the magnificent bryozoan. Aquaculture (Seo 1998, Notteghem 1999) and zoochory (dispersal of statoblasts by birds, Oda 1974) are likely vectors for the spread of this invasive species.

The effect of the magnificent bryozoan on native ecosystems is still unknown. Mass occurrence of *P. magnifica* is suggested to improve water quality during the initial period of colonisation of new habitats. Wood (2010) described increased transparency of water due to removal of suspended particles as a result of the feeding of individual zooids as a long-term effect of colonisation. This in turn establishes conditions for increased algal production, which can severely affect the functionality of the aquatic ecosystem. With regard to a more direct impact on humans, mass occurrence of the magnificent bryozoan has been reported to clog the drainage systems and water pipes in North America, and to cause unpleasant smell when large colonies remain in dried out areas after water level drawdown (Wood 2010).

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