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Freshwater Molluscan Fauna in Danubian Drainage Ditches in Slovakia: High Species Richness and Conservation Value

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Abstract: In 2014–2016, we conducted a malacological survey at 49 drainage ditches in the Danubian Lowland, SW Slovakia. A total of 56 species (36 gastropods, 20 bivalves) have been found, which is 69% of the total species number of freshwater molluscan fauna in the country. Species richness varied from 5 to 35 snail species, with a median value of 12 species. The most frequent species (presence at more than 60% of the sites) were *Bithynia tentaculata* (89.8%), *Lymnaea stagnalis* (71.4%), *Planorbarius corneus* (67.3%), *Bithynia leachii* (65.3%) and *Anisus vortex* (61.2%). Twenty-one species (38% of the total species pool) are listed in the regional Red Data Book as one of the higher IUCN categories. Our results demonstrate that both main and side ditches make a unique contribution to aquatic biodiversity of the agricultural landscape.

Key words: Mollusca; Danube River; Slovakia; artificial water bodies.

Introduction

Contemporary European wetlands exist as isolated fragments of their former extent, with those that remain being largely surrounded by agricultural land (Verdonschot et al. 2011). Frequently, the only remaining aquatic habitat/refuges that exist in agricultural landscapes are ponds (e.g. Sayer et al. 2012) and drainage ditch networks. Agricultural drainage ditches are ubiquitous features in lowland agricultural landscapes, built primarily to facilitate land drainage, irrigate agricultural crops and alleviate flood risk (Hill et al. 2016). Drainage ditches and canals in both rural and urban areas may support biodiversity comparable to the one in streams and rivers in the same landscapes (Armitage et al. 2003, Stammler et al. 2008, Vermonden et al. 2009, Walker et al. 2010, Simon & Travis 2011), including on their retaining walls (Francis & Hoggart 2012). In peat-land areas they also support a wide biodiversity of aquatic plants and Coleoptera (Painter 1999, Cooper et al. 2005) and may have higher beta-diversity than ponds (Verdonschot et al. 2011). In European comparative studies, ditches were not as diverse as ponds, but sustained species not found in other freshwater bodies, including rare species of macroinvertebrates (Williams et al. 2003, Watson & Ormerod 2004, Davies et al. 2008a, 2008b) and plants (Goulder 2008). In the past, networks of ditches in the Danubian Lowland have served to divert water from fens and marshy areas to permit exploitation of the land for agriculture (Dorotovičová 2013). Though ditches are artificial habitats, in the Danubian Lowland they are considered to be relict habitats of the previous landscape that existed before the drainage (neorefugia *sensu* Nekola 1999). However, the potential importance of drainage ditch habitats in supporting aquatic biodiversity, the persistence of molluscan fauna in the Danubian Lowland has been poorly studied to date.

The aim of the study is to examine the species richness, diversity and conservation value of aquatic molluscan fauna in the rural drainage ditch system in the Slovak part of the Danubian Lowland.

Materials and Methods

Study area and sampling sites

The study area stretches between Bratislava City and Číčov Village in SW Slovakia (between 48.0219°N,

17.2047°E and 47.8741°N, 18.4631°E; Fig. 1). The studied 49 ditches (Fig. 1, Table 1) are part of the drainage and irrigation systems in South Slovakia. The major part of the ditch system is more than 50 years old, several ditches are more than 140 years old (Gyalokay 1960). The surveyed ditches are lowland flows running at the altitude of 103–113 m a.s.l. The average annual temperature is 10°C, the average summer temperatures in July reaches 20.2°C, whereas in January it is −1.5°C. The climate is dry continental, lowland climate and the average annual rainfall is 550 mm (Miklós & Hrnčiarová 2002). Natural open water bodies with corresponding flora have almost disappeared, been replaced by terrestrial habitats. Nevertheless, old fluvial landforms of former river paleo-channels play a substantial role in beta diversity of the region, since the last remnants of forest, shrub and semi-natural riparian vegetation habitats (e.g. *Phragmito-Magnocaricetea*, *Salicion cinereae*) preserved among intensively managed agricultural landscape are almost exclusively restricted along the ditches. The width of the studied channels ranged from 1 to 27 m (median = 5.0 m). Where there was a flow, it could be in either direction, but was erratic and often artificially induced.

Sampling and sample processing

A 20-m stretch was surveyed in each ditch and molluscs were collected at four randomly located sampling points along one bank. The sample locations within each ditch were randomly selected at distances between 0.05 and 1.0 m from the bank. A sample consisted of a vigorous sweep over 1.0 m, parallel to the bank and included the sediment, vegetation and water surface, using a sieve net with 0.20 m diameter and 1 mm mesh (Watson & Ormerod 2004). The samples were preserved on site in 70 % methylated ethanol. In the laboratory, the samples were washed through a 0.5 mm mesh sieve and molluscs removed and identified by eye and under a light microscope (10×) using Glöer & Meier-Brook (2003). Specimens of *Stagnicola* sp. and *Gyraulus* sp. were killed with hot water, fixed in 70% ethanol and then dissected and identified using the morphology of copulatory organs (Glöer 2002). Voucher specimens for all species have been confirmed and the collections are stored at the Institute of Botany, Plant Science and Biodiversity Centre SAS, Bratislava, Slovakia.

Results

A total of 8255 individuals of 56 species (36 snails, 20 bivalves) were found from the 49 sites. This species number represents 69 % of the total species number of Slovak freshwater molluscan fauna. Species richness varied from 5 to 35 snail species with a median value of 12 species. If we divide channels by their size, main arterial ditches (width >5 m) and side ditches (width <5 m), a higher number of species were recorded in the main arterial ditches (5 to 35 species, median = 13.0), while side ditches harboured 6 to 22 species (median = 11.5). Average values (mean, median) did not differ significantly (t-test, p=0.661, computed by R software 2017).

The most frequent species (presence at >60% of the sites) were the snails *Bithynia tentaculata* (89.8%), *Lymnaea stagnalis* (71.4%), *Planorbarius corneus*

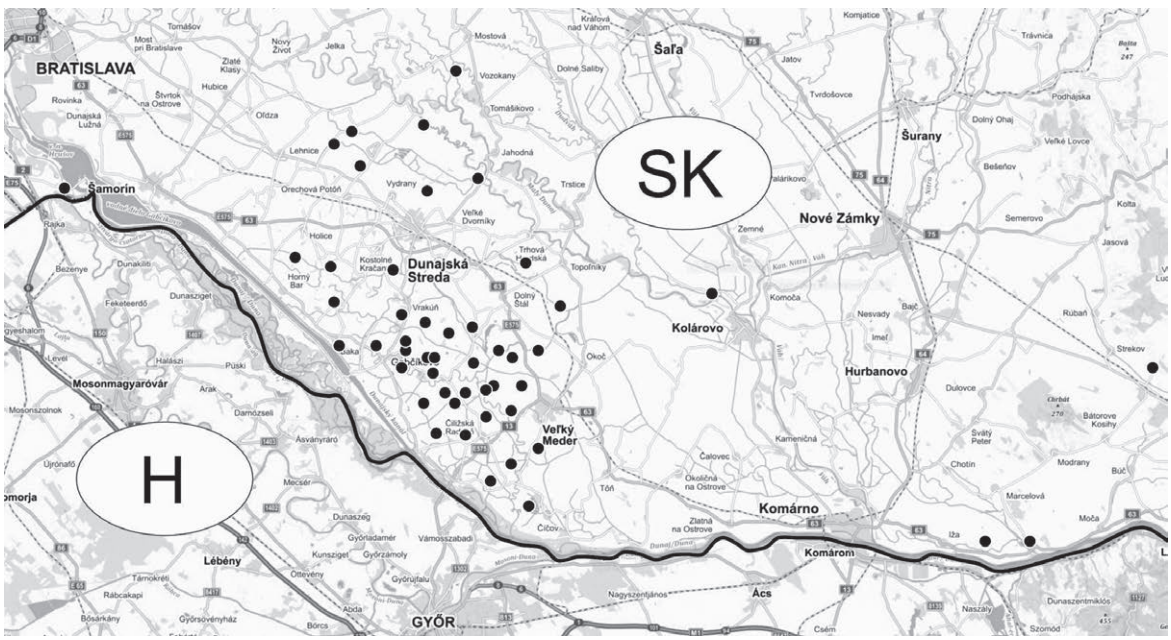

Fig. 1. Location of the study sites (black dots) in the Danubian Lowland, Slovakia.

Table 1. A list of the surveyed ditches indicating closest municipality and geographic coordinates.

Site No.	Municipality	Coordinates (°N, °E)	Site No.	Municipality	Coordinates (°N, °E)
1	Čičov	47.77251, 17.75289	26	Trstená na Ostrove	47.92809, 17.48803
2	Medveďov	47.80893, 17.65208	27	Jurová	47.92946, 17.54505
3	Čiližská Radvaň	47.81350, 17.70941	28	Padáň	47.92952, 17.66159
4	Medveďov	47.81467, 17.66528	29	Jurová	47.92998, 17.53740
5	Čiližská Radvaň	47.82762, 17.69501	30	Jurová	47.94977, 17.50305
6	Baloň	47.82848, 17.65384	31	Kynceľove Kračany	47.95734, 17.55631
7	Ňárad	47.84008, 17.60887	32	Amadeho Kračany	47.95742, 17.57550
8	Čiližská Radvaň	47.84189, 17.68346	33	Kľúčiarove Kračany	47.95595, 17.52789
9	Čiližská Radvaň	47.85470, 17.69665	34	Dolný Bar	47.96150, 17.66331
10	Čiližská Radvaň	47.83620, 17.72055	35	Kolárovo	47.94662, 17.96587
11	Čiližská Radvaň	47.85693, 17.67422	36	Kútniky	47.97206, 17.67018
12	Gabčíkovo	47.87167, 17.61758	37	Ohrady	47.97669, 17.71180
13	Gabčíkovo	47.87196, 17.61849	38	Bratislava – Čunovo	48.02188, 17.20476
14	Pataš	47.87322, 17.67088	39	Blahová	48.06956, 17.53093
15	Veľký Meder	47.87909, 17.75726	40	Blahová	48.07254, 17.54044
16	Pataš	47.88041, 17.64258	41	Čiernavoda	48.12812, 17.65523
17	Pataš	47.89277, 17.62782	42	Dunajský Klátov	48.03136, 17.68523
18	Gabčíkovo	47.90000, 17.62821	43	Orechová Potôň	48.06151, 17.57932
19	Veľký Meder	47.90020, 17.74118	44	Jahodná	48.06214, 17.66410
20	Pataš	47.90086, 17.64666	45	Orechová Potôň	48.04677, 17.56418
21	Gabčíkovo	47.90426, 17.55231	46	Patince	47.74873, 18.31389
22	Baka	47.91021, 17.55449	47	Patince	47.74661, 18.26101
23	Baka	47.91219, 17.56095	48	Veľké Kosihy	47.74891, 17.87550
24	Jánošíkovo na Ostrove	47.91300, 17.76672	49	Nová Vieska	47.87405, 18.46312
25	Padáň	47.91408, 17.68148			

(67.3%), *B. leachii* (65.3%) and *Anisus vortex* (61.2%) (Table 2). Twenty-one species (38% of the total species pool) are listed in the regional Red Data Book (Šteffek & Vavrová 2006) under one of the higher IUCN (2001) categories: critically endangered (CR) – 6 species, endangered (EN) – 9 species and vulnerable (VU) – 6 species (for details, see Table 2).

The most abundant species were *B. tentaculata*, *B. leachii*, *A. vortex* and *Valvata cristata*. The total abundance of *Aplexa hypnorum* was also high but this figure might be distorted by the species being extremely abundant at locality no. 30 (Table 2).

Discussion

Ditches support greater number of nationally uncommon, rare and very rare species (Armitage et al. 2003, Davies et al. 2008a, 2008b, Hill et al. 2016). In addition, Verdonschot et al. (2011), state that at a regional scale drainage ditch invertebrate taxon composition was more varied compared to that of small lakes, indicating a relatively high beta-richness. In a later work, Verdonschot (2012) found 46 species (35 snails, 11 bivalves) from Dutch ditches; Painter (1999) recorded 28 molluscan species in 17 sites in the Wicken Fen, UK; Killeen (1998, cited by Watson 2002) states 35 species (24 snails, 11 bivalves) from the ditches in the UK. This study showed that drainage ditches in the Slovak part of the Danubian Lowland could be a significant habitat type for indigenous freshwater molluscan fauna. Comparing species richness of agricultural drainage ditches and semi-natural ponds in the Danubian Lowland and other parts of Europe, the ditches in the Danube River Basin are characterised by higher species richness and conservation value.

The vegetation cover typical for the ecologically demanding snail species indicated that they all occurred in the middle to later stages of succession but our expectation of higher species richness in the

Table 2. List of recorded Mollusca in the Danubian ditch system, SW Slovakia (species are arranged alphabetically). Explanatory notes: IUCN – criterion according IUCN (2001), Ta – total abundance, F [%] – frequency of the species.

Species	IUCN	Ta	F [%]	Sites with species presence
Acroloxus lacustris (L., 1758)		95	34.7	1, 2, 4, 6, 9, 12-15, 19, 21, 24, 36, 41, 44, 47, 49
Ancylus fluviatilis Müll., 1774		2	2.0	38
Anisus spirorbis (L., 1758)	VU	14	8.2	8, 14, 34, 35
Anisus vortex (L., 1758)		454	61.2	1, 5-8, 10-12, 14, 16-23, 26-29, 32, 34, 35, 37, 38, 41, 42, 44, 45
Anisus vorticulus (Troschel, 1834)	CR	120	32.7	1, 3, 5-7, 11-16, 18, 19, 35, 38, 49
Anodonta anatina (L., 1758)		49	30.6	5, 11, 19, 25, 27, 29, 32, 34, 38-43, 45
Anodonta cygnea (L., 1758)	VU	2	2.0	38
Aplexa hypnorum (L., 1758)	VU	381	4.1	1, 30
Bathyomphalus contortus (L., 1758)		333	40.8	1, 3, 5, 6, 8, 11, 12, 14, 16-21, 23, 25, 28, 32, 34, 41
Bithynia leachii (Sheppard, 1823)	EN	519	65.3	1-7, 9-14, 16-19, 21, 23-25, 27, 29, 32-35, 37, 38, 41, 42, 47
Bithynia tentaculata (L., 1758)		1975	89.8	2-12, 14-27, 29, 30, 32-34, 36-49
Bithynia transsilvanica Bielz, 1853	CR	114	10.2	1, 8, 17, 22, 23
Borysthenia naticina Menke, 1845	EN	4	2.0	41
Corbicula fluminea (Müll., 1774)		45	16.3	17, 21, 22, 25, 40, 41, 43, 45
Dreissena polymorpha (Pallas, 1771)		8	6.1	21, 38, 47
Ferrissia fragilis (Tryon, 1863)		17	12.2	10, 11, 15, 21, 24, 46
Galba truncatula Müll., 1774		40	26.5	1, 2, 4, 12, 15, 17, 19, 22, 27, 31, 34, 38, 49
Gyraulus albus (Müll., 1774)		312	57.1	3, 5-7, 9-11, 15, 18, 19, 21, 22, 25-27, 29, 34-36, 38, 40-43, 45-47, 49
Gyraulus crista (L., 1758)		68	22.4	8, 12, 14, 18, 20, 24, 28, 32, 35, 47, 49
Gyraulus laevis (Alder, 1838)	VU	5	4.1	38, 49
Gyraulus parvus (Say, 1817)		2	2.0	21
Hippeutis complanatus (L., 1758)		292	53.1	1, 2, 4-6, 8, 11-15, 17-20, 24, 27-29, 31, 33-35, 38, 41, 49
Lymnaea stagnalis (L., 1758)		221	71.4	1-5, 7-18, 20-24, 27, 32-34, 38, 40, 41, 43-45, 47-49
Musculium lacustre (Müll., 1774)		45	12.2	19, 20, 22, 34, 38, 41
Physa acuta Draparnaud, 1805		234	40.8	5, 6, 8, 11, 19, 21, 22, 25, 26, 31, 34, 38-41, 43-47
Physa fontinalis (L., 1758)	VU	49	20.4	1, 7, 12, 13, 16, 22, 23, 41, 47, 49
Pisidium amnicum (Müll., 1774)	EN	1	2.0	41
Pisidium casertanum (Poli, 1791)		136	34.7	2, 4, 16, 20-23, 25, 27, 28, 31, 34, 38, 39, 41, 45, 49
Pisidium henslowanum (Sheppard, 1823)		20	10.2	19, 27, 38, 41, 45
Pisidium milium Held, 1836	VU	116	30.6	2, 4, 5, 11, 15, 16, 19, 21, 23, 25, 27, 30, 31, 38, 41
Pisidium moitessierianum Paladilhe, 1866	CR	1	2.0	41
Pisidium obtusale (Lamarck, 1818)		8	2.0	49
Pisidium personatum Malm, 1855		5	4.1	27, 49
Pisidium pseudosphaerium Favre, 1927	CR	18	6.1	14, 16, 17
Pisidium subtruncatum Malm, 1856		121	28.6	8, 19, 21, 27, 30, 34, 38-43, 45, 49
Planorbarius corneus (L., 1758)		301	67.3	1-3, 5, 8-20, 22-24, 27, 29, 30, 32-36, 38, 41, 44, 48, 49
Planorbis carinatus (Müll., 1774)	EN	24	12.2	5, 7, 11, 15, 19, 27
Planorbis planorbis (L., 1758)		315	44.9	1, 2, 9, 14, 16-18, 20, 22, 23, 29, 30, 32-35, 37-39, 41, 42, 49
Potamopyrgus antipodarum (Gray, 1843)		215	18.4	19, 21, 22, 25, 31, 34, 38, 39, 42
Pseudanodonta complanata (Rossm., 1835)	CR	5	8.2	19, 40, 43, 45

Table 2. Continuation.

Species	IUCN	Ta	F [%]	Sites with species presence
Radix ampla (Hartmann, 1821)	VU	2	2.0	22
Radix auricularia (L., 1758)		99	22.4	6, 19, 26, 34, 38, 39, 41, 46-49
Radix balthica (L., 1758)		224	46.9	2-9, 11, 15, 18, 19, 34, 36, 38-41, 43, 45, 46, 48, 49
Segmentina nitida (Müll., 1774)	VU	99	28.6	1, 5, 11-14, 16, 17, 28, 35, 37, 41, 47, 49
Sphaerium corneum (L., 1758)		103	26.5	1, 8, 19, 23, 27, 32, 34, 36, 38, 39, 41, 42, 49
Sphaerium rivicola (Lamarck, 1818)	EN	7	2.0	41
Sphaerium solidum (Normand, 1844)		2	2.0	36
Stagnicola corvus (Gmelin, 1786)		10	12.2	1, 3, 12, 24, 37, 49
Stagnicola turricula (Held, 1836)		78	36.7	1, 7, 12, 14, 17, 19, 25, 27, 30, 34, 38-41, 43-45, 49
Unio crassus Philipsson, 1788	EN	3	4.1	41, 42
Unio pictorum (L., 1758)		30	20.4	5, 11, 19, 25, 27, 40-43, 45
Valvata cristata Müll., 1774		377	59.2	1-5, 7-9, 11-14, 17-22, 24-27, 29-31, 33, 37, 41, 49
Valvata macrostoma Mörch, 1864	CR	3	6.1	30, 36, 41
Valvata piscinalis (Müll., 1774)		326	36.7	1, 5, 7, 10, 11, 19, 21, 22, 25, 27, 32, 34, 38, 40, 41, 43, 45, 46
Viviparus acerosus (Bourg., 1862)	VU	116	28.6	5, 11, 19, 23, 25, 27, 29, 34, 36, 39-41, 43, 45
Viviparus contectus (Millet, 1813)		90	49.0	2-4, 8-10, 12-17, 19, 20, 22-24, 26, 27, 30, 34, 37, 41, 49

side ditches in the later stages of succession has not been confirmed (see Results). However, several rare species, which did not occur in the main ditches, were present in the side ditches (*Aplexa hypnorum*, *Bithynia transsilvanica* and *Pisidium pseudosphaerium*). The reason for the low species richness could be the higher eutrophication of the old side ditches (Watson & Ormerod 2004). Eutrophication in ditches usually results in an increase in phytoplankton and floating plants such as duckweed (*Lemna* spp). In extreme cases this causes a decline in aquatic plant diversity or even complete loss of submerged aquatic plants with the regression of emergent vegetation (Mason & Bryant 1975, Moss 2009, Janse & van Puijenbroek 1998). The effects that changing vegetation structure may have on freshwater snails are not well understood. It is believed that most freshwater snails graze on epiphytic algae and organic detritus (Underwood & Thomas 1990) and, therefore, eutrophication might be beneficial through increasing their food source (Jones et al. 2000, 2002). Alternatively, eutrophication, by causing an increase in phytoplankton or floating plant biomass, often leads to higher concentrations of organic matter in ditches and contributes to increased deoxygenation in the lower ditch layers (Marshall 1981, Janse & van Puijenbroek 1998). Indeed, eutrophication has been defined by Codd & Bell (1985) as the development of a water body into a state in which the aerobic microbial decomposition of organic matter consumes more oxygen than is introduced into the environment at the substrate layer in which few macroinvertebrates could survive (Moss 1988, Marklund et al. 2001). A third potential detrimental effect of eutrophication is the direct toxicity effect of elevated concentrations of nitrate, nitrite or, more specifically, ammonia (Watson & Ormerod 2004).

As an artificial habitat, ditches need continuous maintenance. Without periodic mechanical desilting, the vegetation and sediment would gradually accumulate, causing the ditch to dry out and revert to a terrestrial habitat (Kirby 1992, Painter 2000). Given the need to maintain drainage ditches to support agriculture and flood defence measures, we advocate the application of principles from "reconciliation ecology" (*sensu* Hill et al. 2016) to inform the future management and conservation of drainage ditches in the Slovak part of the Danubian Lowland.

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