TRANSYLVANIAN REVIEW OF SYSTEMATICAL AND ECOLOGICAL RESEARCH

20.3

The Wetlands Diversity

Editors

Angela Curtean-Bănăduc & Doru Bănăduc

Sibiu – Romania
2018

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Department of Ecology and Environment Protection

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IN MEMORIAM

Great Union Day
(Romania, 1 December 1918)

On December 1, 1918, the *National Assembly of Romanians of Transylvania*, consisting of 1,228 elected representatives of the Romanians in Transylvania, Banat, Crişana and Maramureş, convened in Alba Iulia and decreed (by unanimous vote) "the unification of those Romanians and of all the territories inhabited by them with Romania".

On December 11, 1918, King Ferdinand signed the Law regarding the Union of Transylvania, Banat, Crişana, the Sătmar and Maramureş with the Old Kingdom of Romania, decreeing that "The lands named in the resolution of the Alba-Iulia National Assembly of the 18th of November 1918 are and remain forever united with the Kingdom of Romania".

The Great Union of 1918 was and remains the most sublime event in Romanian history. Its greatness resides in the fact that the fulfilment of the national unity is not the work of any politician, government or party; it is the historic deed of the whole Romanian nation, accomplished out of a powerful longing coming from the vivid awareness of the unity of the people and channelled by the political leaders for it to be led towards its aim with a remarkable political intelligence.

The Great Union was not the result of Romania participating in the war. Neither the supporters of the Entente, nor those of the Central Powers did take into account the Russian revolution or the disintegration of the Austro-Hungarian monarchy. Their reasoning followed the traditional formula of the power relations between states: the victory of the Entente would bring back to Romania Bucovina, Transylvania and the Banat, while the victory of the Central Powers would bring back Bessarabia; one victory excluded the other so that no one could see how all these provinces could join the borders of the Old Kingdom simultaneously.

It was not a military victory that laid the foundation of Romania, but the will of the Romanian nation to create for itself the territorial and institutional framework that is the national state.

A historic necessity - the nation has to live within a national state - proved to be more powerful than any government or party, guilty of selfishness or incompetence and, putting the nation into motion, gave it that huge drive to overcome all the adversities and make its dream come true: the national state.

Florin Constantiniu
A Sincere History of the Romanian People

The Editors

Transylvanian Review of Systematical and Ecological Research

20.3 The Wetlands Diversity ***2018***

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Preface

In a global environment in which the climate changes are observed from few decades no more only through scientific studies but also through day by day life experiences of average people which feel and understand allready the presence of the medium and long-term significant change in the “average weather” all over the world, the most comon key words which reflect the general concern are: heating, desertification, rationalisation and surviwing.

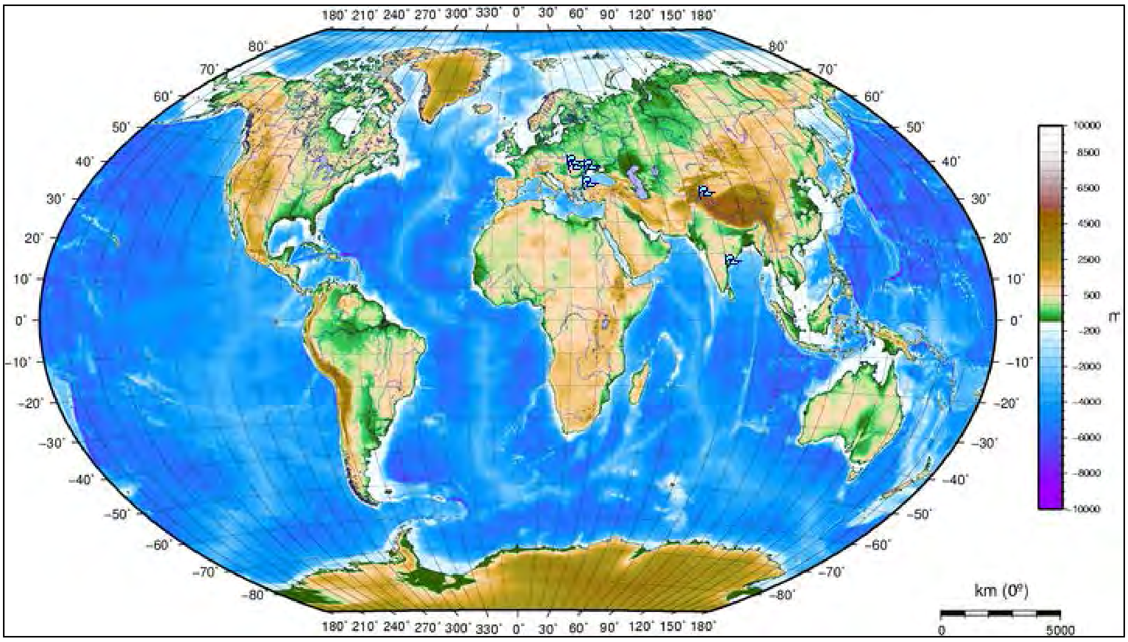
The causes, effects, trends and possibilities of human society to positively intervene to slow down this process or to adapt to it involve a huge variety of aproacess and efforts.

With the fact in mind that these aproaces and efforts shuld be based on genuine scientific understanding, the editors of the *Transylvanian Review of Systematical and Ecological Research* series launch three annual volumes dedicated to the wetlands, volumes resulted mainly as a results of the *Aquatic Biodiversity International Conference*, Sibiu/Romania, 2007-2017.

The therm wetland is used here in the acceptance of the Convention on Wetlands, signed in Ramsar, in 1971, for the conservation and wise use of wetlands and their resources. **Marine/Coastal Wetlands -** Permanent shallow marine waters in most cases less than six metres deep at low tide, includes sea bays and straits; Marine subtidal aquatic beds, includes kelp beds, sea-grass beds, tropical marine meadows; Coral reefs; Rocky marine shores, includes rocky offshore islands, sea cliffs; Sand, shingle or pebble shores, includes sand bars, spits and sandy islets, includes dune systems and humid dune slacks; Estuarine waters, permanent water of estuaries and estuarine systems of deltas; Intertidal mud, sand or salt flats; Intertidal marshes, includes salt marshes, salt meadows, saltings, raised salt marshes, includes tidal brackish and freshwater marshes; Intertidal forested wetlands, includes mangrove swamps, nipah swamps and tidal freshwater swamp forests; Coastal brackish/saline lagoons, brackish to saline lagoons with at least one relatively narrow connection to the sea; Coastal freshwater lagoons, includes freshwater delta lagoons; Karst and other subterranean hydrological systems, marine/coastal. **Inland Wetlands -** Permanent inland deltas; Permanent rivers/streams/creeks, includes waterfalls; Seasonal/intermittent/irregular rivers/streams/creeks; Permanent freshwater lakes (over eight ha), includes large oxbow lakes; Seasonal/intermittent freshwater lakes (over eight ha), includes floodplain lakes; Permanent saline/brackish/alkaline lakes; Seasonal/intermittent saline/brackish/alkaline lakes and flats; Permanent saline/brackish/alkaline marshes/pools; Seasonal/intermittent saline/brackish/alkaline marshes/pools; Permanent freshwater marshes/pools, ponds (below eight ha), marshes and swamps on inorganic soils, with emergent vegetation water-logged for at least most of the growing season; Seasonal/intermittent freshwater marshes/pools on inorganic soils, includes sloughs, potholes, seasonally flooded meadows, sedge marshes; Non-forested peatlands, includes shrub or open bogs, swamps, fens; Alpine wetlands, includes alpine meadows, temporary waters from snowmelt; Tundra wetlands, includes tundra pools, temporary waters from snowmelt; Shrub-dominated wetlands, shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils; Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils; Forested peatlands; peatswamp forests; Freshwater springs, oases; Geothermal wetlands; Karst and other subterranean hydrological systems, inland. **Human-made wetlands -** Aquaculture (e. g., fish/shrimp) ponds; Ponds; includes farm ponds, stock ponds, small tanks; (generally below eight ha); Irrigated land, includes irrigation channels and rice fields; Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture); Salt exploitation sites, salt pans, salines, etc.; Water storage areas, reservoirs/barrages/dams/impoundments (generally over eight ha); Excavations; gravel/brick/clay pits; borrow pits, mining pools; Wastewater treatment areas, sewage farms, settling ponds, oxidation basins, etc.; Canals and drainage channels, ditches; Karst and other subterranean hydrological systems, human-made.

The editors of the *Transylvanian Review of Systematical and Ecological Research* started and continue the annual sub-series (*Wetlands Diversity*) as an international scientific debate platform for the wetlands conservation, and not to take in the last moment, some last heavenly "images" of a perishing world …

This 20.2 volume included variated researches from diverse wetlands around the world.



The subject areas (⚐) for the published studies in this volume.

No doubt that this new data will develop knowledge and understanding of the ecological status of the wetlands and will continue to evolve.

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The Editors

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BIOINDICATION OF WATER PROPERTIES BY ALGAL COMMUNITIES IN THE PAMIR HIGH MOUNTAIN MINERAL AND THERMAL SPRINGS

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KEYWORDS: diatoms, thermal, mineral springs, Pamir, Tajikistan.

ABSTRACT

The bioindication methods have been implemented for the first time for the analyses of water properties in six mineral and thermal springs of Pamir. The studied environment was characterized as flow-alkaline, well oxygenated with low salinity, and low to middle organically polluted. Studied diatom communities preferred periphytonic and benthic habitats of temperate temperature waters. Bioindicator species preferred photosynthetic way of protein synthesis. In first time assessed the trophic level of each studied source show that all they have a state from oligotrophic to mesotrophic. Bioindication methods revealed the effectiveness of nature conservation system in Tajikistan and relevance of bioindication methods using in purpose of assessment and monitoring of water sources on the protected territories.

ZUSAMMENFASSUNG: Bioindikation von Wassereigenschaften durch Algengemeinschaften in den Pamir-Hochgebirgsmineral- und Thermalquellen.

Erstmals wurden für die Analyse der Gewässergüte in sechs Mineral- und Thermalquellen im Pamir Gebiet Bioindikationsmethoden eingesetzt. Die Umgebung der untersuchten Quellen wurde als schwach alkalisch, sauerstoffreich, salzarm und gering bis mittel-organisch eingestuft. Die untersuchten Kieselalgengemeinschaften bevorzugten periphytonische und benthische Habitate von Gewässern mit gemäßigter Temperatur. Die Bioindikator-Arten bevorzugten die photosynthetische Art der Proteinsynthese. Beim ersten Mal zeigte das trophische Niveau jeder untersuchten Quelle einen oligotrophen bis mesotrophen Zustand an. Die Bioindikationsmethoden verdeutlichen die Wirksamkeit des Naturschutzsystems in Tadschikistan sowie die Relevanz von Bioindikationsmethoden bei der Bewertung und Überwachung von Wasserquellen in den geschützten Gebieten.

REZUMAT: Bioindicarea proprietăților apei de către comunitățile de alge din izvoarele minerale și termale din munții Pamir.

Metoda bioindicatorilor a fost aplicată pentru prima dată pentru analiza proprietăților apei în șase izvoare minerale și termale din Pamir. Mediul surselor de apă studiate se caracterizează prin alcalinitate slabă, oxigenare bună, salinitate scăzută și poluare organică redusă până la moderată. Comunitățile de diatomee studiate preferă habitatele perifitice și bentonice ale apelor cu temperatură moderată. Speciile bioindicatoare sunt fotosintetizatoare. Pentru prima dată s-a evaluat nivelul trofic al fiecărei surse de apă studiate, constatându-se că acestea sunt de la oligotrofe până la mezotrofe. Metoda bioindicatorilor a evidențiat eficacitatea sistemului de conservare a naturii în Tadjikistan și relevanța folosirii acestei metode în scopul evaluării și monitorizării surselor de apă din ariile protejate.

INTRODUCTION

Mineral and thermal springs are widely distributed throughout the world but are most numerous in mountain areas in which there has been volcanic activity in late geologic time (Waring, 1965).

Mineral and thermal springs represent natural waters that are characteristic of the region. Biota in natural high mountain sources has been mostly studied from the middle period of 20th century (Winterbourn, 1969) when most attention was given to cyanobacteria, and only in last years to diatoms also (Fránková et al., 2009; Leira et al., 2017).

Algal species richness and occurrence up to now are studied not enough in mountain springs because their usually placed in hard-to-reach areas (Sisma-Ventura et al., 2010).

There are known many springs in Pamir with different water properties (Waring, 1965). The natural springs in Tajikistan are under protection (Bokhodjaev and Davlatmamadov, 1994) and can represent some natural environment as reference characteristics in the context of an increase in the anthropogenic load of the surrounding areas. But study of algal diversity in Pamir springs is in initial stage (Churshina, 1982; Barinova and Niyatbekov, 2017) although its algal species ecology can help to characterize the reference natural water properties in this important and interesting area of the world.

Freshwater algae are widely used in ecological assessment of water quality. It is very important to know about algal diversity in inland waters because most algal species can be used as environmental indicators. (Barinova et al., 2006; Sinitean and Kutaşi, 2012; Torrisi and Dell'uomo, 2012; Barinova and Niyatbekov, 2017)

Diversity of algae in Tajikistan has been studied sporadically during the last century. The uppermost part of Tajikistan territory is Pamir where large regional rivers as Panj and Gunt are started. This high mountain area is very rich in thermal and mineral waters. In these waters, for many centuries, a special community of algae with a specific species composition and degree of species resistance to peculiarly extreme environmental conditions was formed and developed. Therefore, Pamir is one of high altitude area in Eurasia with close relations to Hindu Cush, Altay, and Himalayas. Its territory has diverse aquatic habitats from clear freshwater large rivers, streams, lakes, to mineral and thermal springs which are occupied by diverse algal communities.

Our own study of diatoms in thermal and mineral springs was enriched by the regional diversity (Barinova and Niyatbekov, 2017) but we assume that the diversity study of this group of algae in Pamir is still far from complete. Nevertheless, it can help to characterize the high mountain aquatic habitats water quality by bio-indication methods.

Thus, the aim of our work was to reveal species-specific ecological preferences of diatom algae from studied mineral and thermal springs of Pamir to assess its water quality.

Pamir is very rich in thermal and mineral waters, which in a way are unique habitats characterized by a constantly and high temperature from 10°C to 86°C and various chemical compositions saturated with carbon dioxide and nitrogen gases such as hydrogen sulfide-siliceous, hydrocarbonate-sulphate-calcium-magnesium, chloride-sulfate-calcium-sodium, hydrocarbonate-sulfate-sodium and weak radon-chloride-sulfate (Churshina, 1982; Bokhodjaev and Davlatmamadov, 1994). In these waters, for many centuries, a special community of algae with a specific species composition was formed.

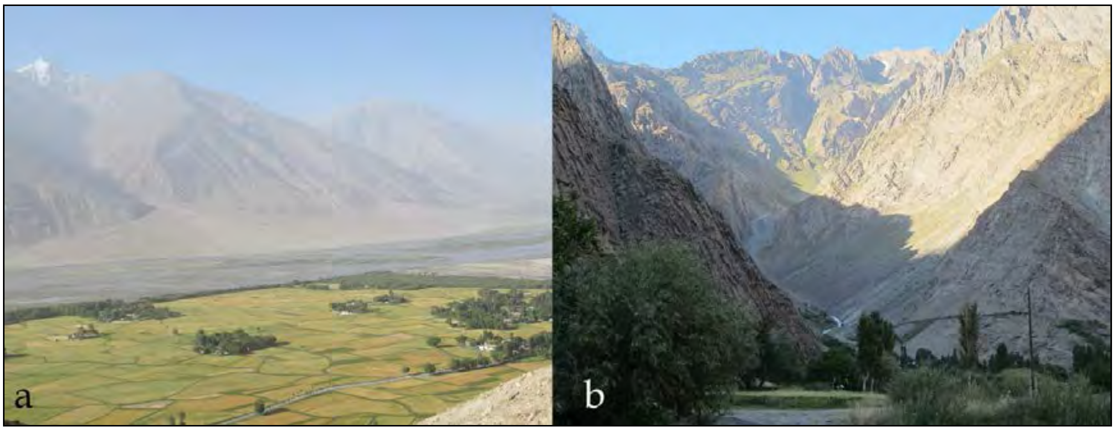

Figure 1: The Panj River, Ishkashim vicinity (a);
the Bartang Canyon (b).

Figure 2: The Yashilkul Lake and its vicinity (a);
the Yazgulam Canyon (b).

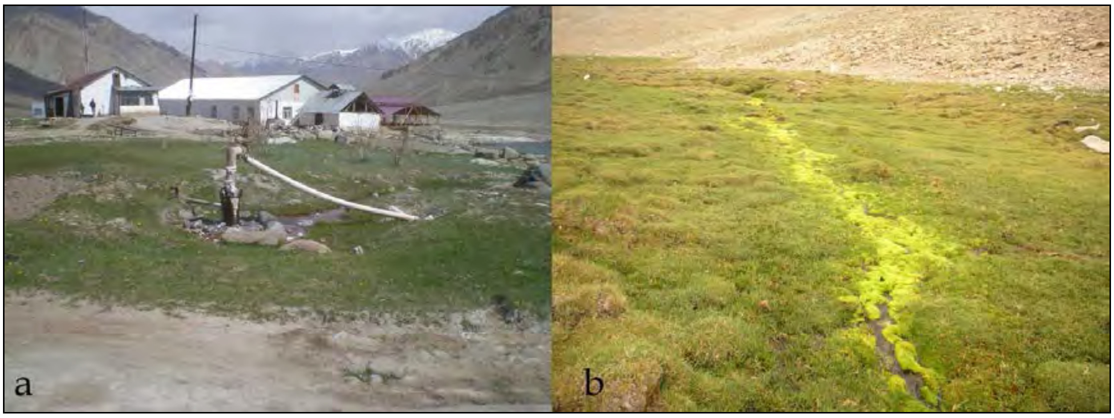

Figure 3: The Jelandy source near the Biological station (a);
the Jelandy source vicinity (b).

MATERIAL AND METHODS

The biological material for this study is represented by personal data (150 samples collected in the summer of 2000-2015 from Jelandy, Avadzh, Garm-Chashma, Sassykbulak, Sist and Barshor located at an altitude from 2,360 to 3,800 m a.s.l. (Figs. 1-3). Algal periphytonic samples were collected and processed from various places, springs, and griffins with a water temperature of 10°C to 86°C (Tab. 1).

Species ecology data come from database (Barinova et al., 2006) for nine ecological bioindication systems. A total list of revealed diatoms in Pamir mineral and hot springs was correlated with an ecological database in the Microsoft Access Program.

Table 1: Diatom indicator taxa and the major variables of habitats in the mineral water springs of Pamir with geographical coordinates.

Pamir region	East	West	West	East	West	West
Name of spring	Jelandy	Avadzh	Garm-Chashma	Sassykbulak	Sist	Barshor
No. of spring	1	2	3	4	5	6
No. of indicator taxa	92	48	18	14	9	18
Altitude, m a.s.l.	3,600	2,410	2,800	3,800	2,360	2,400
Temperature, °C	21-86	35	40-62	22	10-12	10-15
pH	7.8	7.1	7.1	7.4	5.8	6.4
North	37°34’ 30.84”	37°12’ 19.06”	37°12’ 11.06”	37°40’ 84.90”	37°10’ 18.26”	37°00’ 98.02”
East	72°34’ 41.93”	71°31’ 90.51”	71°32’ 11.18”	73°00’ 22.54”	71°30’ 19.87”	71°30’ 21.89”

RESULTS AND DISCUSSION

Data about studied communities from six sources are represented in table 1 with relation to the West or East Pamir regions. We calculated Pearson coefficients for species richness, water pH, temperature and altitude of source with wessa.net and find that only water pH and altitude have significant correlation 0.78 with $p < 0.03$.Alkaline sources are placed in highest altitude and acidic-water sources are in altitude about 2,400 m a.s.l. (Fig. 4). Water temperature in the studied sources is varied even in the same source, but uppermost localities have highest water temperature.

As a result of laboratory processing of 150 periphytonic samples from six thermal and mineral springs, the regional diversity was enriched by 134 diatom species (166 with infraspecific taxa) (Barinova and Niyatbekov, 2017). For the basic list of species, we revealed species-specific ecological properties that are represented in table 2. All found taxa were indicators of substrate preferences, oxygenation, water pH, chlorides concentration, organic pollution, nutrition type, and trophic level.

Species richness of diatoms in the studied source communities is varied in the broad range from 92 in Jelandy to 9 in Sist. Table 1 and figure 4 shows that highest diversity was found in the studied sources with alkaline water with highest temperature. Remarkably, the Jelandy source, where water is 7.8 pH and temperature varied in the range 21-86°C, it was revealed that maximal species richness was – 92 taxa.

Table 2: Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Achnanthes exigua Grunow in Cleve and Grunow	1	–	–	–	–	–	B	eterm	st-str	alf	i	sp	2.0	o-e	ate
Achnanthes gibberula Grunow	1	–	1	1	–	–	B	eterm	st-str	ind	mh	sx	0.3	o-m	–
Achnanthes Gibberula var. *interrupta* Poretzky and Anisimova	1	–	–	–	–	–	B	eterm	st-str	ind	mh	sx	0.3	o-m	–
Achnanthidium minutissimum (Kützing) Czarnecki	1	–	–	–	–	–	P-B	eterm	st-str	ind	i	es	0.95	o-e	ate
Achnanthidium thermal Rabenhorst	1	–	–	–	–	–	B	eterm	st-str	ind	mh	sx	0.3	o-m	–
Actinella punctata Lewis F. W.	1	–	–	–	–	–	B	–	–	acf	hb	–	1.0	ot	–
Amphora ovalis (Kützing) Kützing	1	–	1	–	–	–	B	temp	st-str	alf	i	sx	1.5	me	ate
Amphora ovalis var. *ediculus* (Kützing) Van Heurck	–	1	–	–	–	–	B	temp	st	alf	i	es	1.7	o-m	ate

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Amphora ovalis var. *lybica* (Ehrenberg) Cleve	–	1	–	–	–	–	B	temp	st	alf	i	es	1.5	o-m	–
Aneumastus minor Lange-Bertalot	1	–	–	–	–	–	P-B	–	–	alf	i	–	1.2	o-m	–
Aneumastus rostratus (Hustedt) Lange-Bertalot	–	–	–	1	–	–	P-B	–	–	alf	i	–	2.0	–	–
Aneumastus tuscula f. *intermedia* Kisselev	1	–	–	–	–	–	P-B	–	–	alf	i	–	0.9	o-e	–
Aulacoseira italica (Ehrenberg) Simonsen	1	1	–	–	–	–	P-B	cool	st-str	ind	i	es	1.45	me	–
Brachysira serians (Brébisson) Round and Mann D. G.	1	–	–	–	–	–	B	–	st-str	acf	hb	–	0.2	ot	ats
Caloneis bacillum (Grunow) Cleve	1	–	–	–	–	1	B	temp	st-str	ind	i	es	1.3	me	ats
Caloneis silicula (Ehrenberg) Cleve	1	–	–	–	–	–	B	–	st	ind	i	sp	1.3	o-m	ats
Caloneis silicula var. *kjellmaniana* Cleve	1	–	–	–	–	–	B	–	–	alb	i	–	–	–	–

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Cavinula lacustris (Gregory W.) Mann D. G. and Stickle in Round, Crawford and Mann	1	–	–	–	–	–	B	–	–	ind	i	–	1.0	o-m	ats
Cocconeis pediculus Ehrenberg	–	1	–	–	–	–	B	–	st-str	alf	i	sx	1.8	me	ate
Cocconeis placentula Ehrenberg	1	1	–	–	–	–	P-B	temp	st-str	alf	i	es	1.35	me	ate
Cocconeis placentula var. *rouxii* (Héribaud-Joseph and Brun) Cleve	1	–	–	–	–	–	B	–	–	alf	i	–	1.4	–	–
Cocconeis scutellum Ehrenberg	–	1	–	–	–	–	B	–	–	–	hl	–	–	–	–
Craticula cuspidata (Kützing) Mann	1	–	–	–	–	–	B	temp	st-str	alf	i	es	2.45	me	–
Craticula halophila (Grunow) Mann D. G. in Round, Crawford and Mann	–	1	–	–	–	–	B	–	st-str	alf	mh	es	3.0	e	ate

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Cymbella affinis Kützing	1	–	–	1	–	–	B	temp	st-str	alf	i	sx	1.1	ot	ats
Cymbella aspera (Ehrenberg) Cleve	1	–	–	–	–	–	B	–	st-str	neu	i	es	0.3	o-e	ats
Cymbella cistula (Ehrenberg) Kirchner O.	–	1	–	–	–	–	B	–	st-str	alf	i	sx	1.2	e	ats
Cymbella compacta Østrup	1	–	1	1	–	–	B	–	–	–	–	–	0.7	–	–
Cymbella cymbiformis Agardh C.	1	–	–	–	–	1	B	temp	str	ind	i	sx	2.0	o-m	ats
Cymbella falaisensis (Grunow) Krammer and Lange-Bertalot	–	–	–	–	1	–	B	–	str	–	hb	es	1.0	o-m	ats
Cymbella helvetica Kützing	–	1	–	–	–	–	B	–	str	ind	i	–	0.6	o-m	–
Cymbella helvetica var. *curta* Cleve	–	1	–	–	–	–	B	–	–	alf	i	–	–	–	–
Cymbella hustedtii Krasske	1	–	–	–	–	–	B	–	str	neu	i	–	1.0	o-m	ats

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Cymbella lanceolata (Agardh C.) Agardh C.	1	–	–	–	–	1	B	–	str	alf	i	sx	1.5	me	ats
Cymbella stuxbergii (Cleve) Cleve	1	–	–	–	–	–	B	–	–	neu	i	–	1.0	ot	–
Cymbella tartuensis Molder	–	1	–	–	1	–	B	–	–	ind	i	–	–	–	–
Cymbella tumida (Brébisson) van Heurck	–	1	–	1	–	–	B	temp	str	alf	i	sx	2.2	me	ats
Cymbella ventricosa Kützing	1	–	–	–	–	–	B	–	–	ind	i	es	1.4	–	–
Cymbella laevis Nägeli in Rabenhorst	1	–	–	1	–	–	B	cool	–	ind	i	sx	–	–	–
Cymbopleura naviculiformis (Auerswald ex Heiberg) Krammer	1	–	–	1	–	–	B	–	st-str	ind	i	es	1.2	o-m	ate
Cymbopleura reinhardtii (Grunow) Krammer K.	1	–	–	–	–	–	B	–	str	ind	i	sx	1.0	m	ats

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Denticula elegans Kützing	–	1	–	–	–	–	P-B, aer	–	–	alf	i	–	0.4	ot	–
Denticula thermalis Kützing	1	–	–	–	1	–	B	warm	–	alf	–	–	2.0	me	–
Diatoma anceps (Ehrenberg) Kirchner	1	–	–	1	–	–	P-B	cool	st-str	neu	hb	sx	0.6	ot	–
Diatoma mesodon Kützing	1	–	1	–	–	–	B	cool	st-str	neu	hb	sx	0.4	ot	ats
Diatoma vulgaris Bory	1	–	–	–	–	–	P-B	–	st-str	ind	i	sx	2.2	me	ate
Diatoma vulgaris var. *linearis* Grunow in van Heurck	1	–	–	–	–	–	B	–	str	alf	i	es	2.2	me	ate
Diatoma vulgaris var. *brevis* Grunow	1	–	–	–	–	–	P-B	–	st-str	alb	i	sx	2.2	me	ate
Didymospheni a geminata (Lyngbye) Schmidt M.	1	–	1	–	–	–	B	–	st-str	ind	i	sx	0.7	ot	–
Diploneis ovalis (Hilse) Cleve	1	–	–	–	–	–	B	–	str	alf	i	sp	0.9	o-m	ats

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Diploneis ovalis var. *oblongella* (Nägeli) Cleve	1	–	1	–	–	–	B	–	str	ind	i	sx	0.9	ot	ats
Ellerbeckia arenaria (Moore ex Ralfs) Crawford	–	1	–	–	–	–	P-B	cool	st-str	alf	i	–	0.6	ot	ats
Encyonema alpinum (Grunow) Mann D. G. in Round, Crawford R. M. and Mann D. G.	–	1	–	–	–	–	B	–	str	ind	hb	es	0.5	ot	ats
Encyonema elginense (Krammer) Mann D. G. in Round, Crawford and Mann	–	1	1	–	–	–	B	temp	st	acf	hb	sx	1.5	–	–
Encyonema pergracile Krammer	–	1	1	–	–	1	B	–	–	–	–	–	–	–	–
Encyonema prostratum (Berkeley) Kützing	–	1	–	–	–	–	P-B	–	str	alb	i	es	1.3	e	ats
Epithemia adnata (Kützing) Brébisson	1	1	–	–	–	–	B	temp	st	alb	i	sx	1.2	me	ats

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Epithemia adnata var. *porcellus* (Kützing) Ross R.	1	–	–	–	–	–	B	–	–	alf	i	–	2.0	me	–
Epithemia adnata var. *saxonica* (Kützing) Patrick R. M. in Patrick and Reimer	–	–	1	–	–	–	B	temp	–	alf	i	–	1.2	me	–
Epithemia argus (Ehrenberg) Kützing	1	–	–	–	–	–	P-B	–	st-str	ind	i	es	0.7	m	–
Epithemia argus var. *angusta* Tarnavschi	–	–	1	–	–	–	B	–	–	ind	i	–	–	–	–
Epithemia argus var. *longicornis* (Ehrenberg) Grunow	1	–	–	–	–	–	P-B	–	–	ind	i	–	–	–	–
Epithemia sorex Kützing	–	1	–	–	–	1	B	temp	st-str	alf	i	sx	1.1	me	ats
Epithemia turgida (Ehrenberg) Kützing	–	–	1	–	–	–	B	temp	st	alf	i	sx	0.9	me	ats
Epithemia turgida var. *capitata* Fricke	1	–	–	–	–	–	B	–	–	alf	i	–	–	–	–

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Epithemia turgida var. *granulata* (Ehrenberg) Brun	–	–	–	–	–	1	B	–	st	alf	i	–	0.9	o-m	ats
Eucocconeis flexella (Kützing) Meister	1	–	–	–	–	–	B	–	str	ind	mh	sx	0.2	ot	ats
Eunotia diodon Ehrenberg	1	–	–	–	–	–	B	cool	st	acf	i	–	0.2	ot	ats
Eunotia faba Ehrenberg	–	–	–	1	–	–	B	temp	st-str	acf	i	sx	1.1	o-m	ats
Fragilaria capucina var. *vaucheriae* (Kützing) Lange-Bertalot	–	1	–	–	–	–	P-B, Ep	–	st-str	alf	i	sx	1.95	e	ate
Fragilaria tenera (Smith W.) Lange-Bertalot	1	–	–	–	–	–	P-B	–	str	acf	hb	sx	2.3	o-m	ats
Fragilarifor-ma virescens (Ralfs) Williams D. M. and Round	1	–	–	–	–	–	P-B	–	st	ind	i	es	0.4	o-m	ats
Gomphoneis olivaceum (Hornemann) Dawson ex Ross and Sims	1	–	–	–	–	–	B	–	st-str	alf	i	es	1.45	e	ate

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Gomphonema angustatum (Kützing) Rabenhorst	–	1	–	–	–	–	B	–	st-str	ind	i	es	1.3	o-m	–
Gomphonema longiceps Ehrenberg	–	1	–	–	1	–	B	–	str	ind	i	es	0.4	–	–
Gomphonema longiceps var. *subclavatum* Grunow in Schneider	–	1	–	–	–	–	B	–	str	ind	i	es	1.4	–	–
Gomphonema productum (Grunow) Lange-Bertalot and Reichardt in Lange-Bertalot	1	–	–	–	–	–	B	–	str	ind	i	es	1.3	o-m	ate
Gomphonema ventricosum Gregory	–	1	–	–	–	–	B	cool	str	ind	i	–	0.3	ot	ats
Gomphonema gracile Ehrenberg	1	–	–	–	–	1	B	temp	st	alf	i	es	0.8	m	ats
Halamphora acutiuscula (Kützing) Levkov	-	1	–	–	–	–	P-B	warm	–	alf	mh	sp	2.0	–	–
Halamphora coffeaeformis (Agardh) Levkov	–	–	–	–	1	–	B	–	st-str	alf	mh	–	3.0	e	ate

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Halamphora subcapitata (Kisselew) Levkov	–	–	1	–	–	–	B	–	–	–	hl	–	1.0	–	–
Halamphora veneta (Kützing) Levkov	1	–	–	–	–	–	B	–	st-str	alf	i	es	2.6	e	ate
Hannaea arcus (Ehrenberg) Patrick R. M. in Patrick R. M. and Freese L. R.	1	1	1	–	–	–	B	temp	str	alf	i	es	0.3	o-m	ats
Humidophila perpusilla (Grunow) Lowe at al.	1	–	–	–	–	–	B	warm	str	ind	i	sp	0.7	o-m	ats
Kurtkrammeria aequalis (Smith W.) Bahls L.	1	–	–	–	–	–	P-B	–	–	ind	i	–	1.0	ot	–
Mastogloia smithii Thwaites	1	–	–	–	–	–	B	–	–	alf	mh	sx	1.3	me	–
Meridion circulare (Greville) Agardh	1	–	–	–	–	–	B	–	str	ind	i	es	1.1	o-m	ate
Meridion circulare var. *constrictum* (Ralfs) Brun	1	–	–	–	–	–	P-B	–	st-str	ind	hb	sx	1.1	o-e	ate

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Meridion lineare Williams	1	1	–	1	–	–	B	–	str	ind	i	es	1.1	o-m	ate
Navicula brasiliensis Grunow	–	1	–	–	–	–	B	–	–	–	–	–	–	–	–
Navicula cincta (Ehrenberg) Ralfs	1	–	–	–	–	–	B	warm	st-str	alf	hl	es	0.5	me	ate
Navicula cryptocephala Kützing	1	–	–	–	–	–	P-B	temp	st-str	ind	i	es	2.1	o-e	ate
Navicula cryptocephala var. *lata* Poretzky and Anisimova	1	–	–	–	–	–	B	–	–	–	i	–	–	–	–
Navicula dicephala Ehrenberg	1	–	–	–	–	–	B	–	–	ind	i	–	1.4	–	–
Navicula digitoradiata (Gregory) Ralfs in Prichard	–	–	–	1	–	–	B	–	–	alf	I	es	2.0	me	–
Navicula gothlandica Grunow	1	–	–	–	–	–	P-B	–	–	alf	hl	es	2.0	o-m	–
Navicula lacustris var. *paulseniana* (Petersen J. B.) Zabelina	–	–	–	–	–	1	B	–	–	–	i	–	–	–	–

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Navicula lanceolata (Agardh) Ehrenberg	–	1	–	–	–	–	B	–	st-str	alf	i	es	2.5	e	ate
Navicula lucidula Grunow	–	–	–	–	–	1	B	–	–	–	i	–	–	–	–
Navicula peregrina (Ehrenberg) Kützing	–	–	–	1	–	–	P-B	–	–	alf	mh	es	1.5	o-m	–
Navicula radiosa var. *tenella* (Brébisson) Cleve and Möller	–	–	–	1	–	–	P-B	–	–	ind	i	sx	1.3	o-m	–
Navicula rhynchoce-phala Ehrenberg	–	1	–	–	–	–	B	–	–	alf	hl	–	1.95	o-m	ate
Navicula rostellata Kützing	–	–	–	–	–	1	B	–	st-str	alf	i	es	2.2	e	ate
Navicula rotaeana (Rabenhorst) Grunow	–	1	–	–	–	–	P-B	–	st	ind	i	–	0.7	ot	–
Navicula scutum Schumann	–	–	–	–	1	–	B	–	–	–	–	–	–	–	–

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Navicula tripunctata (Müller O. F.) Bory in Bory de Saint-Vincent	–	1	–	–	–	–	P-B	–	st-str	ind	i	es	1.7	e	ate
Navicula tuscula f. *obtusa* (Hustedt) Proschkina-Lavrenko	–	–	–	–	–	1	P-B	–	–	alf	i	–	1.2	o-m	–
Navicula viridula (Kützing) Ehrenberg	–	–	1	–	–	–	B	–	st-str	alf	hl	es	2.2	me	ate
Neidiomorpha binodis (Ehrenberg) Cantonati M., Lange-Bertalot and Angeli N.	1	–	–	–	–	–	B	–	str	alf	i	–	1.0	me	ate
Neidium Affine (Ehrenberg) Pfizer	–	1	–	–	–	–	B	–	str	ind	i	–	0.7	ot	ats
Neidium affine var. *undulatum* (Grunow) Cleve	–	1	–	–	–	–	B	–	str	ind	i	–	0.7	ot	ats
Neidium productum (Smith W.) Cleve	–	1	–	–	–	–	P-B	temp	–	ind	i	sx	0.9	ot	ats
Nitzschia amphibian Grunow	1	–	–	–	–	–	P-B, S	temp	st-str	alf	i	sp	2.1	e	hne

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Nitzschia amphibia var. *thermalis* Grunow	1	–	–	–	–	–	B	–	–	–	–	–	–	–	–
Nitzschia dissipata (Kützing) Rabenhorst	1	–	–	–	–	–	B	–	st-str	alf	i	sx	1.7	me	ate
Nitzschia dubia Smith W.	1	–	–	–	–	–	P-B	–	st-str	alf	i	–	2.7	e	hne
Nitzschia fasciculate (Grunow) Grunow in Van Heurck	–	–	–	1	–	–	B	–	st	alf	hl	sx	1.1	–	–
Nitzschia gracilis Hantzsch	1	–	–	–	–	–	P-B	temp	st-str	ind	i	sp	1.8	m	–
Nitzschia gradifera Hustedt	–	–	–	–	1	–	B	–	–	–	hl	–	–	–	–
Nitzschia linearis (Agardh) Smith W.	1	–	–	–	–	–	B	temp	st-str	alf	i	es	1.7	me	ate
Nitzschia linearis var. *tenuis* (Smith W.) Grunow in Cleve and Grunow	–	–	–	–	–	1	B	–	str	alf	i	es	1.7	me	–

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Nitzschia sublinearis Hustedt	–	1	–	–	–	–	P-B	–	–	alf	i	es	3.0	me	–
Nitzschia subtilis (Kützing) Grunow in Cleve and Grunow	–	1	–	–	–	–	B	–	–	alf	i	es	1.7	o-m	–
Nitzschia thermalis (Ehrenberg) Auerswald in Rabenhorst	1	–	–	–	–	–	P	–	–	ind	i	es	2.8	–	–
Nitzschia thermalis var. *minor* Hilse	1	–	–	–	–	–	B	–	st-str	acf	–	–	1.0	–	–
Nitzschia vermicularis (Kützing) Hantzsch in Rabenhorst	–	–	1	–	–	–	P-B	–	str	alf	i	–	2.2	m	–
Parlibellus crucicula (Smith W.) Witkowski, Lange-Bertalot and Metzeltin	1	–	–	–	–	–	B	–	–	ind	mh	-	2.0	–	–
Pinnularia appendiculata (Agardh C.) Schaarschmidt	1	–	–	–	–	–	B	–	str	ind	i	es	0.3	o-m	ats
Pinnularia elegans (Smith W.) Krammer K.	1	–	–	–	–	–	B	–	–	alf	hl	–	2.0	m	–

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Pinnularia fonticola Hustedt	1	–	–	–	–	–	B	–	–	ind	i	–	–	–	–
Pinnularia gibbiformis Krammer K.	1	–	–	–	–	–	B	–	–	–	–	–	0.3	–	–
Pinnularia lata (Brébisson) Smith W.	1	–	–	–	–	–	P-B	–	str	acf	i	–	1.0	ot	–
Pinnularia microstauron (Ehrenberg) Cleve	–	1	–	–	–	–	P-B	temp	st-str	ind	i	sp	0.7	ot	ate
Pinnularia viridis Ehrenberg (Nitzsch)	–	–	–	–	–	1	P-B	temp	st-str	ind	i	es	0.3	o-e	ate
Placoneis amphibola (Cleve) Cox E. J.	–	–	–	–	–	1	B	cool	str	ind	i	–	1.0	o-m	ats
Placoneis exigua (Gregory) Mereschko-vsky	1	–	–	–	–	–	B	–	–	ind	i	es	1.4	o-m	–
Placoneis placentula (Ehrenberg) Mereschko-wsky	1	–	–	–	–	–	B	temp	st-str	alf	i	sx	1.5	e	ate

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot 1999	–	–	–	–	1	–	P-B	warm	st-str	alf	i	sx	1.6	e	ate
Rhopalodia gibba (Ehrenberg) Otto Müller	1	–	–	–	–	–	B	temp	–	alf	i	es	1.4	o-m	–
Rhopalodia gibba var. *mongolica* (Østrup) Proschkina-Lavrenko	–	1	–	–	–	–	B	temp	–	alf	i	es	1.4	–	–
Rhopalodia gibba var. *ventricosa* (Kützing) Mayer	1	–	–	–	–	–	B	temp	–	alf	i	es	1.4	–	–
Rhopalodia gibberula (Ehrenberg) Müller O.	1	–	–	–	–	–	B	temp	str	alf	mh	es	2.0	me	–
Rhopalodia gibberula var. *producta* (Grunow) Müller O.	–	1	–	–	–	–	B	–	str	alf	hl	–	–	–	–
Rhopalodia musculus (Kützing) Müller O.	1	–	–	–	–	–	P-B,S	–	str	alb	mh	–	1.0	–	–
Rhopalodia musculus var. *mirabilis* Fricke	1	–	–	–	–	–	B	–	–	alf	hl	–	2.0	me	–

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Rossithidium anastasiae (Kaczm.) Potapova	–	–	–	–	1	–	B	–	–	–	–	es	0.4	–	–
Sellaphora pupula (Kützing) Mereschko-wsky	–	1	–	–	–	–	B	eterm	st	ind	hl	sx	1.9	me	ate
Stauroneis acuta Smith W.	–	–	1	–	–	–	B	–	st-str	alf	i	–	1.0	o-m	–
Stauroneis anceps Ehrenberg	–	–	1	–	–	1	P-B	–	st-str	ind	i	sx	1.3	o-m	ate
Staurosira construens Ehrenberg	–	1	–	–	–	1	P-B	temp	st-str	alf	i	sx	1.3	me	ats
Stephanodiscus astraea (Ehrenberg) Grunow in Cleve and Grunow	–	–	1	–	–	1	P	temp	st	alb	i	es	1.5	me	–
Surirella angusta Kützing	–	1	–	–	–	1	P-B	–	st-str	alf	i	es	1.7	e	ate
Surirella angusta var. *constricta* Hustedt	1	–	–	–	–	–	B	–	–	–	i	–	–	–	–

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Surirella brebissonii Krammer and Lange-Bertalot	1	–	–	–	–	–	B	–	st-str	alf	i	–	1.7	–	–
Surirella linearis Smith W.	1	–	–	–	–	–	P-B	–	–	ind	i	es	0.5	o-m	–
Surirella linearis var. *helvetica* (Brun) Meister	–	1	–	–	–	–	B	–	–	neu	i	es	0.5	ot	–
Surirella minuta Brébisson ex Kützing	1	–	–	–	–	–	B	–	st-str	ind	i	es	1.8	me	–
Synedra montana Krasske ex Hustedt	–	1	–	–	–	–	B	–	–	–	–	–	–	–	–
Synedra rumpens Kützing	–	1	–	–	–	–	B	–	–	alf	i	es	1.55	–	–
Synedra goulardii Brébisson ex Cleve and Grunow	–	1	–	–	–	–	B	–	–	–	–	–	–	–	–
Tabularia fasciculata (Agardh C.) Williams D. M. and Round	1	–	–	–	–	–	P-B	–	st	ind	mh	es	2.5	e	ate
Tetracyclus rupestris (Kützing) Grunow in Van Heurck	1	–	–	–	–	–	P-B	cool	ae	acf	i	–	0.8	ot	–

Table 2 (continued): Diversity and ecology of diatom algae in the thermal and mineral water sources of Pamir with species autecology. Number of springs 1-6 as in table 1.

Taxa	1	2	3	4	5	6	Hab	T	Oxy	pH	Hal	D	Sap	Tro	Aut-Het
Ulnaria oxyrhynchus (Kützing) Aboal in Aboal, Alvarez Cobelas, Cambra and Ector	1	–	–	–	–	–	P-B	–	–	alf	i	es	2.4	o-m	–
Total:	92	48	18	14	9	18									

Note. Substrate preferences (Hab): P – planktonic, P-B – plankto-benthic, B – benthic, S – soil, Ep – epiphyte. Temperature preferences (T): temp – temperate temperature, eterm – eurythermic, warm – warm-water, cool – could water inhabitants. Oxygenation and streaming (Oxy): st – standing water, str – streaming water, st-str – low streaming water, ae – aerophiles. Halobity degree (Hal): i – oligohalobes-indifferent, hl – halophiles, hb – halophobes, mh – mesohalobes. Acidity degree (pH): alf – alkaliphiles, ind – indifferents; acf – acidophiles, alb – alkalibiontes. Organic pollution indicators according to Watanabe (D): sx – saproxenes, es – eurysaprobes, sp – saprophiles. Species-specific index of saprobity S (Sap). Nitrogen uptake metabolism (Aut-Het): ats – nitrogen-autotrophic taxa, tolerating very small concentrations of organically bound nitrogen; ate – nitrogen-autotrophic taxa, tolerating elevated concentrations of organically bound nitrogen; hne – facultatively nitrogen-heterotrophic taxa, needing periodically elevated concentrations of organically bound nitrogen. Trophic state (Tro): ot – oligotraphentic; o-m – oligo-mesotraphentic; m – mesotraphentic; me – meso-eutraphentic; e – eutraphentic; o-e – oligo-eutraphentic.

We analyzed bioindicator species representation in each studied source as well as distribution of specific groups over source communities and between them. The bioindication histograms are organized in order of water pH decreasing. Table 2 and figure 4 shows that benthic species prevail in all studied sources but Garm-Chashma and Barshor were slightly enriched by planktonic inhabitants because only two of these sources have some water mass (Barinova and Niyatbekov, 2017). Temperature species-indicators were represented as whole small taxa, but it also shows prevalence of temperate temperature water inhabitants, a number of which are increased with decreasing of water alkalinity. In figure 4, we have demonstrated that in the Sist community, the presence of warm-water species was high but it is not true because this community contains only nine taxa and we found only one temperature indicator which is related to warm-water group.

Enrichments of water with oxygen is a very important characteristic of aquatic ecosystem because without it cannot exist as a biotic part of the ecosystem. Bioindication groups were mostly related to slow moving or standing water that is in small water sources that we study. In the second place we studied, there were indicators of streaming waters that reflect output of water from the sources with small streams. Standing water indicators are slightly increased with decreasing water alkalinity but it can be more related to the water volume of the source. In the Sist we found only two groups related to water moving and oxygenation but it is difficult to assess because the species richness of diatom indicators is represented by nine taxa only.

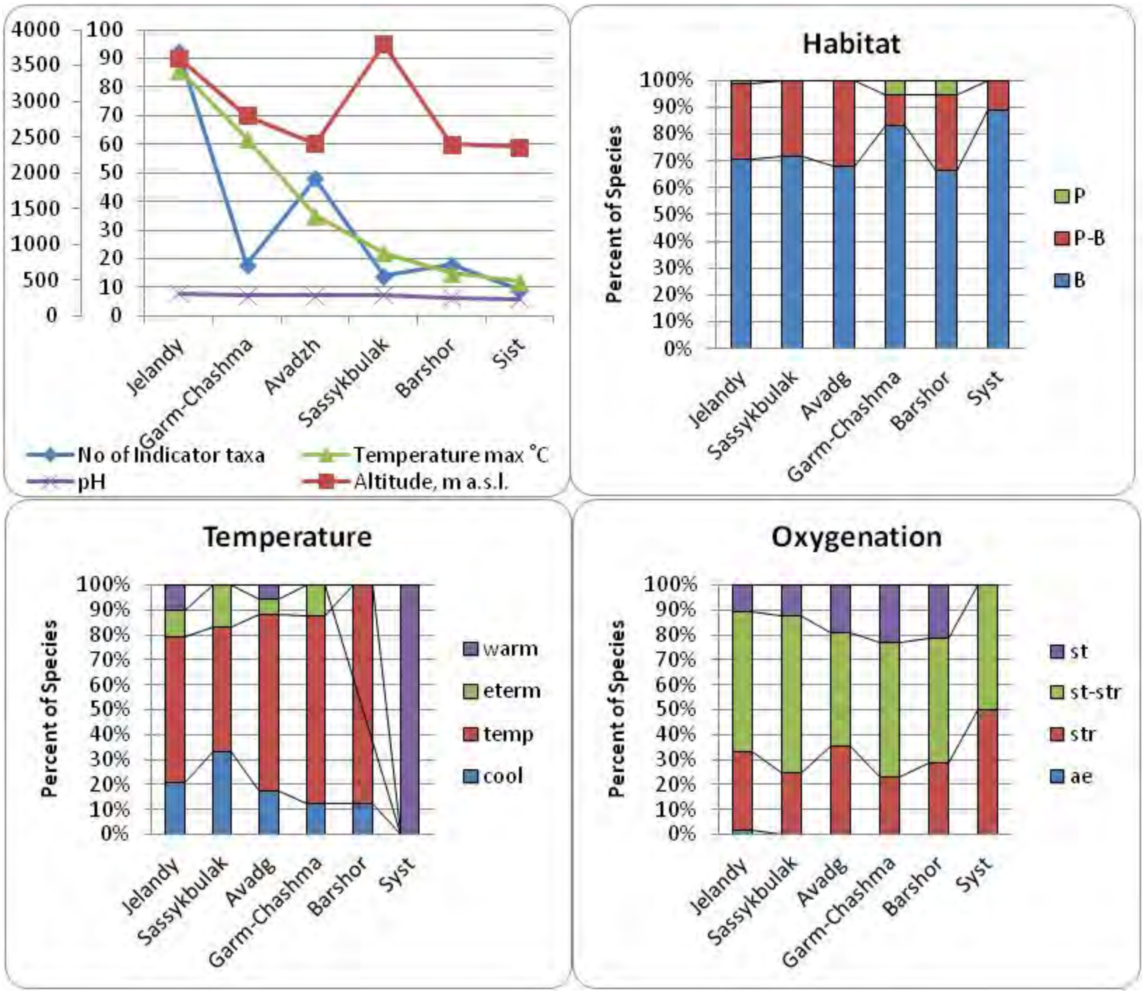

Figure 4: Water variables and indicator species of substrate preferences, temperature, and oxygenation distribution in the studied sources of Pamir.

Water pH bioindication shows (Fig. 5) prevailing alkalic waters over the studied sources although water pH is slightly decreased from 7.8 in Jelandy to 5.4 in Sist. As a whole, indicator groups of alkaliphiles and indifference take about 90% of indicator species in each source community. We assume that the community of each source has some buffered property for stabilizing source environment, and give the possibility to survive for species with broad ecological amplitude. The same situation can be seen in bioindication of water salinity. Figure 5 shows the prevalence of indifferent group and insufficient numbers of the low- and high-salinity indicator number.

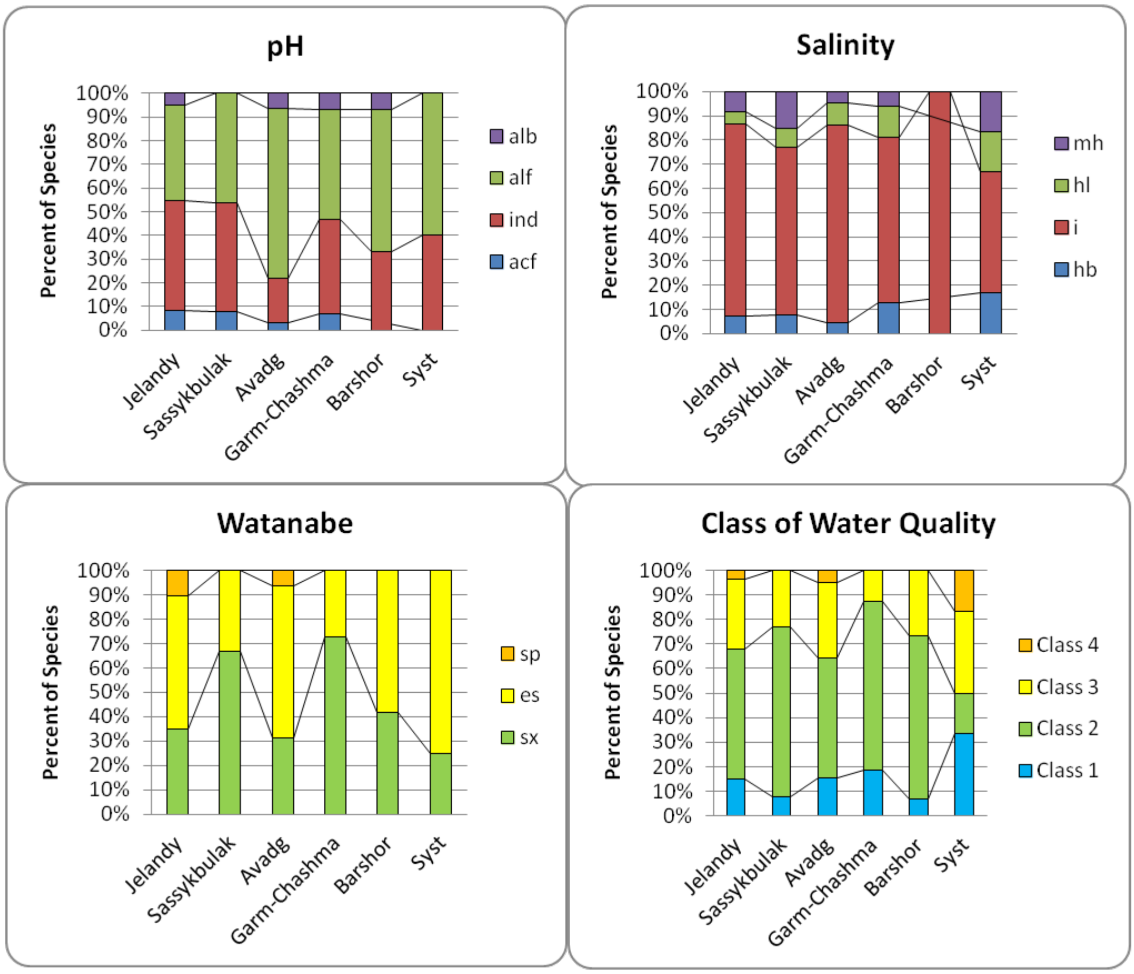

Figure 5: Indicator species of water pH, salinity, and organic pollution with Water Quality Classes distribution in the studied sources of Pamir.

Studied thermal and mineral springs are represented by natural protected areas, therefore, most important to reveal anthropogenic influence on its communities as criteria of protection effectiveness. Figure 5 represents bioindication results of organic pollution with the Watanabe system as well as with the Sládeček's system. The source communities are represented by all indicator groups of Watanabe's method but number of taxa of clear (sx) and middle polluted (es) indicators are prevalent. The colours of groups are the same as are used in the EU system. Classes 1 and 2 indicators in Sládeček system contain most parts of the community in each studied source. That means that water sources are organically clear. Even indicators of middle pollution Class 3 were not as large in number as Class 2. Only few species of Class 4 were found but indicators of polluted water Class 5 were not revealed at all. All this led us to conclude that studied sources are represented by natural unpolluted waters with natural undisturbed aquatic ecosystems.

The effectiveness of photosynthesis was determined in each of the sources with help of the nutrition type indicator species distribution. The photosynthetic diatoms are prevail (97%) in communities of all studied sources (Fig. 6). Organic pollution of sources is related to trophic level of its ecosystem and shows (Fig. 6) that communities of each source are represented by different groups of indicators of trophic state. In the trend of increasing trophic level from oligotrophic indicators (ot) to eutrophic (e and o-e) can be seen that most part of indicators was related to oligo- and mesotrophic groups in each source. Eutrophic groups were represented by about 20% of indicators in Jelandy, Avadg, and Barshor sources. We can see eutrophic groups as half of indicators in the Sist only, but can be keeping in mind that all species in Sist are represented by nine taxa. Therefore, ecosystems of studied sources can be characterized as the oligo-mesotrophic level that usually is in the unpolluted protected areas.

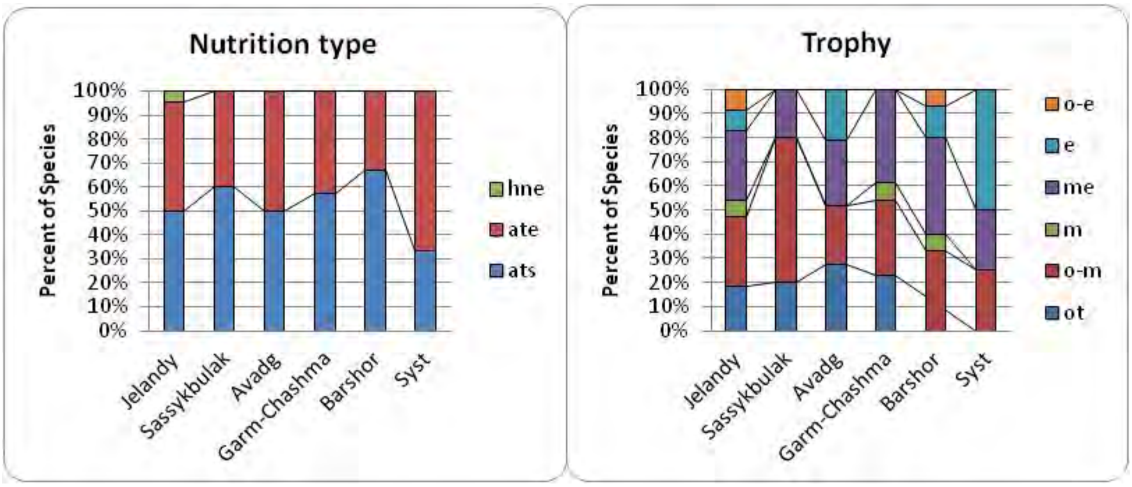

Figure 6: Distribution of indicator species of algal nutrition type and trophic level of aquatic ecosystem in the studied thermal and mineral sources of Pamir.

CONCLUSIONS

Algae diversity study in the sources of the Pamir Mountains is far from complete, but it is very important because thermal and mineral springs in Pamir are represented by diversity in the natural protected areas. Bioindication of diverse variables in six studied sources help us to characterize the environmental variables that have not yet been measured on these hard-to-reach sources. We implemented bioindication approach for the first time for Pamir sources ecosystem assessment. The results can confirm or disprove the applicability of bioindication methods for such different source waters. This first experience can help to characterize the effectiveness of natural conservation and protection mechanisms for Pamir protected areas.

Bioindication on the base of 166 revealed taxa of diatom algae characterize six studied sources environment as low-alkaline, well oxygenated waters with low salinity, and low to middle organically polluted in which diatom community preferred to survive as periphytonic and benthic occupants that preferred temperate temperature waters and photosynthetic way of protein synthesis. The trophic level of each studied source was assessed for the first time, and the data revealed that all of them have a state from oligotrophic to mesotrophic. These results can confirm the effectiveness of a nature conservation system in Tajikistan as well as the relevance of bioindication methods used to assess and monitor water sources on the protected territories.

ACKNOWLEDGEMENTS
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REPRODUCTIVE ECOLOGY OF *BRUGUIERA CYLINDRICA* (L.) BL. (RHIZOPHORACEAE), A TRUE VIVIPAROUS MANGROVE TREE SPECIES IN CORINGA MANGROVE FOREST, ANDHRA PRADESH (INDIA)

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KEYWORDS: Hermaphrodite, facultative xenogamy, melittophily, true vivipary.

ABSTRACT

Bruguiera cylindrica (L.) Bl. bloom during September-March. It is hermaphroditic, protandrous, self-compatible and facultative xenogamous. The flowers possess an explosive pollination mechanism and are pollinated by bees and wasps. The pollination mechanism is characterized by special petal-stamen configuration in which each petal encloses two stamens and becomes tensed after anthesis. Each petal behaves independently and the explosion of all petals of a flower requires one or two visits. Individual flowers produce only one seed which produces seedlings on the maternal plant. The seedlings use self-planting strategy at low tide and stranding strategy at high tide. Both strategies are useful for regeneration in maternal environment and in areas away from material environment.

ZUSAMMENFASSUNG: Fortpflanzungsökologie von *Bruguiera cylindrica* (L.) Bl. (Rhizophoraceae), eine echte vivipare Mangrovenbaumart im Coringa Mangrovenwald von Andhra Pradesh (Indien).

Bruguiera cylindrica (L.) Bl. blüht von September bis März. Sie ist eine hermaphrodite, protandrische, selbst-kompatible und fakultativ xenogame Art. Die Blüten besitzen einen explosiven Bestäubungsmechanismus und werden von Bienen und Wespen bestäubt. Der Bestäubungsmechanismus ist durch eine spezielle Blütenblatt-Staubgefäße-Konfiguration gekennzeichnet, bei der jedes Blütenblatt zwei Staubblätter umschließt, die sich nach dem Verblühen straffen. Jedes Blütenblatt verhält sich unabhängig eines vom anderen und die Explosion aller Blütenblätter einer Blüte benötigt einen oder zwei Bestäuberbesuche. Einzelne Blüten erzeugen nur einen Samen, der einen Keimling an der Mutterpflanze entwickelt. Die Keimlimge verwenden eine Selbstpflanzungsstrategie während der Ebbe und eine Grundberührungs- bzw. Strandungsstrategie während der Flut. Beide Strategien sind für die Regenerierung im Umfeld der Mutterpflanze von Nutzen sowie auch in entfernter gelegenen Gebieten.

REZUMAT: Ecologia reproducerii speciei *Bruguiera cylindrica* (L.) Bl. (Rhizophoraceae), o adevărată specie vivipară lemnoasă în pădurea de mangrove de la Coringa, Andhra Pradesh (India).

Bruguiera cylindrica (L.) Bl. înflorește din septembrie până în martie. Este hermafrodită, protoandrică, auto-compatibilă și facultativ xenogamă. Florile posedă un mecanism explosiv de polenizare, fiind polenizate de albine și viespi. Mecanismul de polenizare are o configurație de petală-stamine, cu două stamine la fiecare petală, care se netezesc după anteză. Fiecare petală se comportă independent, iar explozia tuturor petalelor unei flori necesită una sau două vizite ale speciilor polenizatoare. Florile individuale produc o sământă, care dezvoltă un germen pe planta maternă. Germenii florilor folosesc o strategie de autoplantare în timpul refluxului și o strategie de aruncare la țărm în timpul fluxului. Ambele strategii sunt utile pentru regenerarea în apropierea plantei mamă dar și pentru cea îndepărtată de aceasta.

INTRODUCTION

Mangrove frests are among one of the world's most productive tropical ecosystems (Roy and Krishnan, 2005). They are important in protecting coasts from erosion by fierce tides, in promoting the diversity of marine organisms and fisheries by contributing a quantity of food and providing favourable habitats for animals (Bandaranayake, 1998; Zheng et al., 1999; Kathiresan, 2003a, b). They are sources of timber, fuel wood, poles, thatching material, grass, honey, wax and industrial raw material (Zhengyun et al., 2003) but they are under immense threat worldwide due to their multiple economic uses and alterations of freshwater inflows by various upstream activities in catchment areas (Blasco et al., 2001). Therefore, there is an immediate need for their effective conservation and management in order to use them sustainably (Alang et al., 2010; Aziz and Hashim, 2011; Sabai and Sisitka, 2013).

Little is known about pollination and seedling ecology despite the fact that this information is important to understand regeneration and distribution of mangrove flora. Few scientists reported on mangrove plants with reference to their interaction with pollinators for pollination and the level of reproductive effort needed by them to produce a single propagule and whether there is any resource or pollinator limitation in propagule production (Coupland et al., 2006). Such a state of information warrants for detailed studies on all aspects of reproductive ecology of mangrove plant species in all areas of their distribution in the world. In India, *Bruguiera* genus is represented by four species, *B. gymnorrhiza, B. sexangula, B. parviflora* and *B. cylindrica*; the first two species produce large and solitary flowers while the last two species produce small and many-flowered clustered inflorescenes (Tomlinson, 1986). In these species, the stamens remain enclosed in pairs within the petals under tension after flower-opening, and the pollen release occurs explosively when the flower is triggered. Birds trigger the process in the large-flowered species, while butterflies trigger the process in small-flowered species (Juncosa and Tomlinson, 1987; Chiou-Rong et al., 2005). *B. gymnorrhiza* has mixed mating system with out-crossing as a main mating system (Ge et al., 2003). Reproductive ecology information is totally lacking for all other *Bruguiera* species. Therefore, the present study provides information on the reproductive ecology of *Bruguiera cylindrica* (L.) Bl., occurring in Coringa mangrove forest in the State of Andhra Pradesh, India.

MATERIALS AND METHODS

Bruguiera cylindrica distributed in the Coringa Mangrove (16^{o}30'-17^{o}00'N and 82^{o}10'-80^{o}23'E) (Fig. 2) in the State of Andhra Pradesh, India, was used for the study during February 2015 – April 2017. This species is represented by a few individuals with scattered occurrence in this forest. The present state of this species is attributed to its use as fuel wood and as source material for the construction of traditional homes and furniture. The flowering season, floral biology, pollen production, nectar analysis, breeding system, natural fruit set, stigma receptivity, pollination mechanism, pollinators and seedling ecology were investigated following the protocols described in Dafni et al. (2005). Foragers captured from flowers were washed in ethanol for pollen separation and they were then stained with aniline-blue on a glass slide for observation under microscope in order to count pollen grains present. This procedure was repeated for each capture forager specimen. Then, the mean number of pollen grains present on the body of each species was calculated separately to record the pollen carrying rate.

RESULTS

It is a medium evergreen tree with diffused spreading branches, growing to a height of more than 12 m (Fig. 1a). The flowering occurs during September-March. The inflorescence is a simple pedunculate dichasium cyme with pedicellate erect flowers; each cyme is three-flowered and borne in leaf axils (Figs. 1b, c).

The mature buds open during 07.00-09.00 h. The sepals diverge gradually presenting the closed, erect petals in the cocked position (Figs. 1d-f). The petals enclose the stamens in tensed state due to the pressing of the latter against the interlocked margins of the petals (Fig. 1g). The petals are retained in an erect position by the adherent ventral margins. The anther dehiscence occurs in mature buds by longitudinal slits. A delicate touch to the petal margins would result in release of the anthers which simultaneously eject pollen to the centre of the flower. In case of touch by forager to the petal margins, the pollen would be ejected and deposited on the head and body. In a flower, petals unzip independently and non-violently. The unzipped petals stay back against the calyx lobes during which the stamens are empty, twisted and also disorganized. Petals and stamens last three days in unzipped flowers. Unzipped petals stay in tensed state for six days after which they fall off. Stigmatic lobes are receptive on 2nd and 3rd day (Fig. 1h). Individual flowers produce a mean number of 20,635 pollen grains and pollen-ovule ratio is 5,518: 1. The pollen grains are light yellow, powdery, tricolporate and 16.6 µm long. Nectar is secreted in the calyx cup which is surrounded by hairs; it is 1.43 ± 0.31 µl per flower. The nectar sugar concentration is 15.2 ± 1.57% with glucose, fructose, sucrose and maltose but the first sugar is dominant. The flowers are self-compatible and self-pollinating. Fruit set occurs in unmanipulated and manipulated autogamy, geitonogamy and xenogamy but it is highest in the last mode. Further, fruit set stands at 64% in open-pollinations which are affected by foragers (Tab. 1).

The flowers were foraged during day time from 07.00-17.00 h by one bee and two wasp species; the former for pollen and nectar while the latter for only nectar (Fig. 2). The bee made 38% and wasps 62% of total foraging visits (Fig. 3). While probing the flowers for forage, they invariably tripped the tensed petals due to which the petals exploded and ejected pollen. The petal tip and its apical appendages are insensitive but vigorous probing into the calyx cup by foragers caused petal tripping. One or two visits to individual flowers caused all petals to unzip and release pollen. The foraging visits resulted ended in pollination. The foragers visited the flowers of different conspecific plants frequently seeking more forage due to the occurrence of a few rewarding flowers daily on individual trees; this foraging activity made them disperse pollen across individual trees which are spatially isolated; such pollen dispersal pattern contributed to both self and cross pollination. Bees and wasps carried pollen on their bodies and the mean number of pollen grains ranged from 262 to 448.2 (Tab. 2).

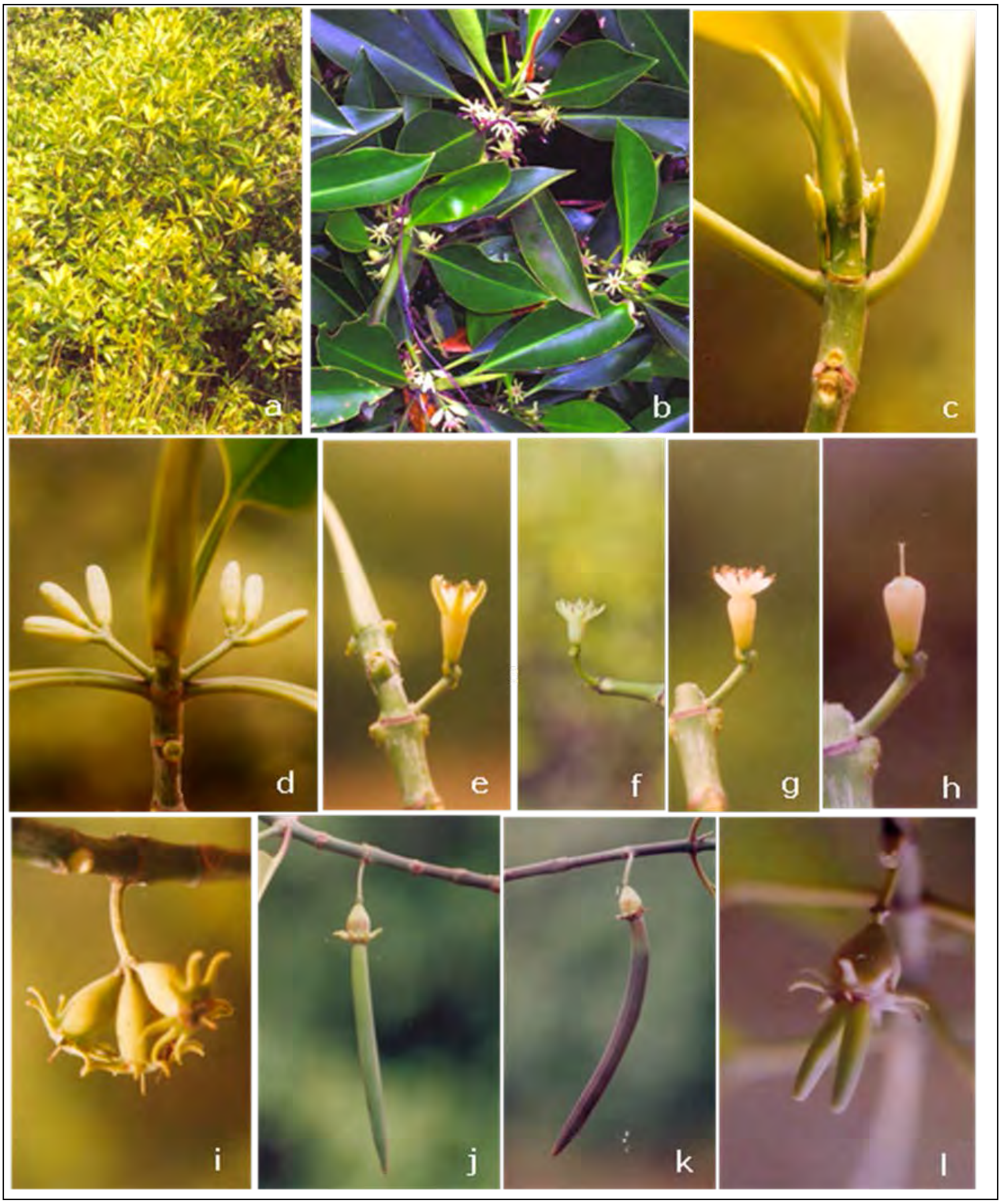

Figure 1: *Bruguiera cylindrica*: a. Habit; b. Tree with flowering; c. Cymes emerging from the axils of leaves; d. Mature buds; e. Anthesing bud; f. Fully open flower; g. Stamens enclosed in petals; h. Style with bifid stigma; i. Mature fruits; j. Green hypocotyl; k. Purple hypocotyl; l. Fruit with two hypocotyls.

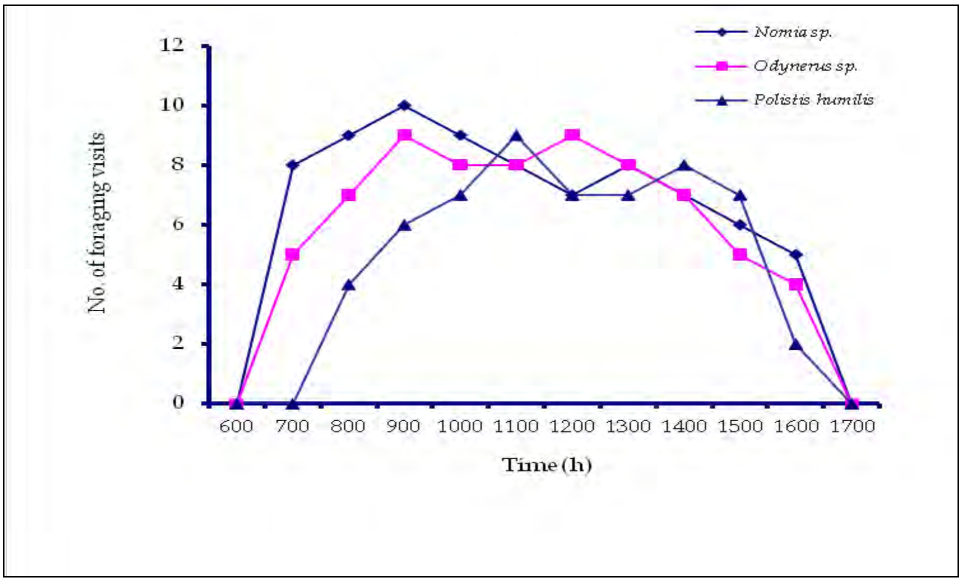

Figure 2: Hourly foraging activity of insects on *Bruguiera cylindrica*.

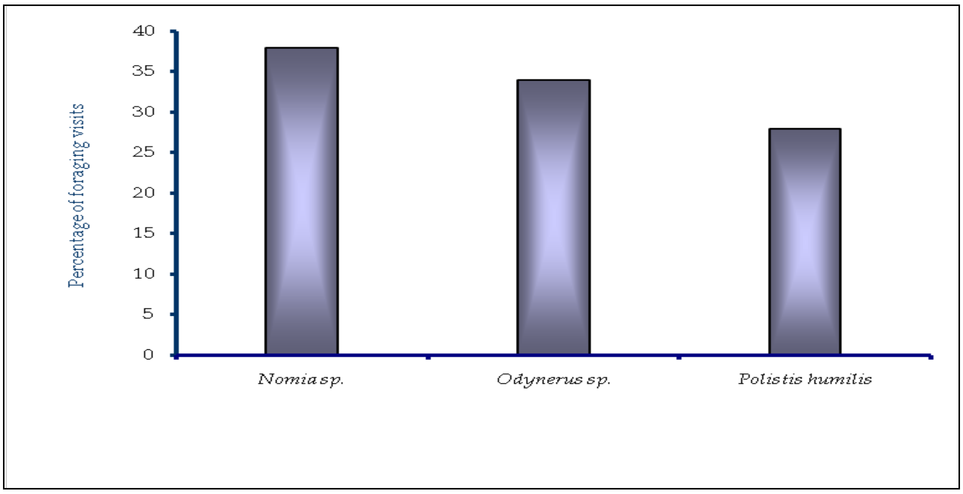

Figure 3: Percentage of foraging visits of insects on *Bruguiera cylindrica*.

Fruits mature in about three weeks (Fig. 1i). Each fruit produces only one seed although each flower produces four ovules. The production of two seeds by a fruit is a rare event (Fig. 1l). Individual seeds produce cylindrical elongate but slightly curved, green to purple, pendulous seedlings with blunt apex in four weeks (Figs. 1j, k). The seedlings anchor in the mud at low tide when the forest floor is exposed or float in and disperse by tidal currents at high tide. The chronological events of reproduction are listed in table 3.

Table 1: Results of breeding experiments on *Bruguiera cylindrica*.

Breeding system	No. of flowers pollinated	No. of flowers set fruit	Fruit set (%)
Autogamy (bagged)	30	12	40
Autogamy (hand-pollinated and bagged)	25	14	56
Geitonogamy	30	19	63.3
Xenogamy	30	24	80
Open pollinations	73	47	64.4

Table 2: Pollen pick up efficiency of foraging bees on *Bruguiera cylindrica*.

Bee species	Sample size	Range	Mean ± S. D.
Nomia sp.	10	210-642	448.2 ± 93.8
Odynerus sp.	10	126-520	342 ± 78.09
Polistis humilis	10	116-426	262 ± 60.7

Table 3: Chronology of floral and fruiting aspects in *Bruguiera cylindrica*.

Floral event	*B. cylindrica*
Anthesis	07.00-09.00 h
Anther dehiscence	Mature bud
Sepals	Not reflexed throughout flower life and persistent even after propagule detachment
Petals	Up to three days
Stamens	Up to three days
Stigma receptivity	2nd-3rd day
Pollen output/flower	20,635
Pollen-ovule ratio	5,158:1
Nectar volume/flower (µl)	1.43 ± 0.31
Nectar sugar concentration (%)	15.2 ± 1.57
Nectar sugars	Glucose, fructose, sucrose and maltose
Pollination mechanism	Explosive mechanism
Pollinators	Bee and wasps
Breeding system	Self and cross
Fruit set in open pollinations (%)	64.4
Fruit maturation time (days)	18-20
Hypocotyl length (mm)	136 ± 16
Hypocotyl orientation	Hanging
Hypocotyl growth duration (days)	30-35
Planting strategy	Self-planting and stranding

DISCUSSION

Bruguiera cylindrica blooms uniformly during September-March. Pollinator activity is not intense and also inconsistent on the flowers. The long period of flowering enables the plant to maximize fruit set rate. The flowers project outwards from the crown of leaves. They display different orientations, horizontal, downward and slightly erect – these orientations enable the foragers to collect forage with ease. The morning anthesis with flowers providing forage day long coincides well with day-active foragers. The described floral characteristics suggest that the plant has specialized explosive pollination mechanism adapted for insects, bees and wasps in the study area. This pollination mechanism is the characteristic of *Bruguiera* genus (Tomlinson et al., 1979). *B. cylindrica* with small flowers is reported to be pollinated by butterflies by Tomlinson et al. (1979) and by small insects including butterflies by Tomlinson (1986). In the study site, *B. cylindrica* is pollinated by insects consisting of bee and wasp species only. They use the nectar with low sugar concentration with hexose-dominant sugars produced by *B. cylindrica* but this nectar is produced in small quantity at flower level forcing these insects to make multiple visits across spatially isolated plants and the process cross-pollination is promoted. The nectar quantity and quality characters displayed by this plant agree partially with the generalization made by Baker and Baker (1983) who stated that bee-flowers characteristically produce a small quantity of nectar with high sugar concentration and the flowers adapted for pollination by short-tongued bees produce hexose-rich nectar while wasp-pollinated flowers produce sucrose-rich nectar. Tomlinson (1986) reported that bees and wasps nest in mangroves, and some of their populations are completely dependent on mangrove plants for their survival. Similarly, Ghosh et al. (2008) also mentioned that some wasps and flies use mangrove plants for nesting. Therefore, bees and wasps are reliable as pollinators since they nest in mangroves and use the same plants as food sources.

B. cylindrica is facultatively xenogamous as it produces fruit set in both self- and cross-pollination modes but all modes of pollination are vector-dependent. The ability to fruit through selfing enables this plant to set fruit even isolated trees if pollinators are present in the habitat. The flowers are four-ovuled but each fruit produces only one seed and very rarely two seeds. This state of seed set appears to be related either to maternal resource constraint or maternal regulation of seed set.

In *B. cylindrica*, the seed produces seedling on the mother plant. The seedling pierces through fruit pericarp and remains naked until it is separated from the fruit. This mode of seed germination is a characteristic of “true viviparous” species (Tomlinson, 1986) and allows seedlings to develop tolerance to salinity prior to detaching from the fruit or plant (Smith and Snedaker, 1995). It allows the seedlings to produce photosynthate and store nutrients before their detachment, acquire floating ability for dispersal and quick rooting in the mudd (Kathiresan, 2003). Therefore, a suite of characteristics associated with vivipary ensures the plant to overcome the tidal environment for seedling establishment and subsequent growth.

Van Speybroeck (1992) reported that the *Bruguiera* seedlings establish either by self-planting or by stranding strategy depending on the height of the tide, low or high. In this study, it is found that *B. cylindrica* seedlings disperse both self-planting and stranding strategies according to the tide level. The self-planting strategy facilitates establishment in undisturbed mangrove forest while the stranding strategy facilitates establishment in exploited and open mangrove forest. These two plant strategies are important for this plant for regeneration in the vicinity of parental environment and in areas far away from parental environment.

CONCLUSIONS

Bruguiera cylindrica is an evergreen true viviparous tree species. It is hermaphroditic, self-compatible, self-pollinating and facultative xenogamous. The flowers have explosive pollination mechanism and functional only when it is unzipped by bees and wasps or else they fall off without fruit set. Seedlings are produced while fruit is still attached to the parent tree and detach when time is ripe for them. The fallen seedlings settle at the parental environment using self-planting strategy or outside the parental environment using stranding strategy.

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AQUATIC MACROPHYTE COMMUNITIES OF THE GORGOVA-ISAC-UZLINA AREA (DANUBE DELTA, ROMANIA)

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KEYWORDS: types of channels and lakes, macrophyte communities, quality indicators, ecological gradients, human-induced changes.

ABSTRACT

With its diversity of water body types, the Danube Delta offers large possibilities for studies of aquatic macrophytes, their ecological requirements, ecological amplitude and communities. Sensitive to changes in water quality and physical parameters due to human intervention in the natural ecological network, aquatic macrophytes are used as quality indicators. Using the example of the system of channels and lakes of the Gorgova-Isac-Uzlina complex and some examples from the neighboring area, the aquatic macrophytes and their communities are presented and discussed in relation to the characteristics of the habitats and the changes of the environment in the course of decades, since human intervention in the delta.

ZUSAMMENFASSUNG: Die Wasserpflanzengesellschaften des Seenkomplexes von Gorgova-Isac-Uzlina (Donau-Delta, Rumänien).

Mit ihrer Vielfalt an Gewässertypen, gibt es im Donau-Delta umfassende Möglichkeiten für Untersuchungen der Gewässer-Makrophyten, ihrer ökologischen Ansprüche und ihrer Pflanzengesellschaften. Da die Gewässermakrophyten auf Änderungen der Gewässergüte und der physikalischen Parameter durch menschliche Eingriffe in das natürliche ökologische Gefüge empfindlich reagieren, werden sie als Qualitätsindikatoren eingesetzt. Am Beispiel des Systems von Fließgewässern und Seen des Gorgova-Isac-Uzlina Komplexes und einigen Beispielen aus benachbarten Gebieten werden die Gewässermakrophyten und ihre Gesellschaften vorgestellt und in Zusammenhang mit ihren Habitaten und deren Veränderungen im Laufe mehrerer Jahrzehnte diskutiert.

REZUMAT: Comunitățile de macrofite acvatice din complexul de lacuri Isac-Uzlina-Gorgova (Delta Dunării, România).

Datorită diversității tipurilor de corpuri de apă, în Delta Dunării există multiple posibilități pentru cercetarea macrofitelor acvatice, a cerințelor lor ecologice și a comunităților pe care le edifică. Deoarece macrofitele acvatice reacționează sensibil la schimbările calității apei și a parametrilor fizici cauzate de impactul uman asupra ecosistemelor naturale, acestea sunt folosite ca indicatori de calitate. Folosind drept exemplu sistemul brațelor Dunării cu rețeaua de canale, gârle și lacuri din zona Gorgova-Isac-Uzlina și a unor arii înconjurătoare, sunt prezentate și discutate macrofitele și fitocenozele în relație cu caracteristicile habitatelor, precum și schimbările mediului în decurs de mai multe decenii.

INTRODUCTION

With its diversity and complexity of water body types, the Danube Delta offers large possibilities for studies concerning aquatic macrophytes, their ecological requirements and their communities, as well as the changes in their composition by human induced changes (Hanganu and Constantinescu, 2008; Strat, 2015). Sensitive to environmental factors, aquatic macrophytes can be used as good indicators for the ecological state of water bodies and physical characteristics (Neagu-Godeanu, 1875; Ossterberg and Staraș, 2000; Ellenberg et al., 2002; Schneider, 2009, 2014)

The hydrological regime is the main and deciding ecological factor for ecosystem function to be considered in order to characterize and evaluate the ecological state of different types of water bodies and their macrophyte communities. For a first evaluation the general inundability of the different sites is usually considered. It is represented for the whole Danube Delta in the "Danube Delta's inundability map" with five categories of inundation levels named hydro-grades (Munteanu and Curelariu, 1996), the hydro-grade being the tenth part of the difference between the lowest and the highest registered water level at a measured point (Botzan, 1984). These data offer general information about mean values of water levels over a longer period, without demonstrating a concrete situation for a certain year or season in a year. But for a detailed consideration it is needed to know the yearly water level dynamics, the period of flooding, the duration, height and frequency, consecutiveness of flooding over a number of years, and as well the exchange and circulation of waters from the main branches to the smaller ones in the inner of the delta and the residence time (Gâştescu and Driga, 1989; Covaliov et al., 2003; Gâştescu and Ştiucă, 2008; Schneider, 2009). All these mentioned factors are crucial for the macro- and microhabitat ecological development and diversity and are varying greatly between the years. This fact is clearly visible, if we compare the row of water level changes from different years measured on the gauge Tulcea (data researched at the Danube Delta Institute Tulcea) and below exemplified on the water level changes from two different years, one with extremely high and one with extremely low water levels measured at gauge Tulcea (Fig. 1).

As a consequence of hydro-technical works in the second half of the 20th century, transformation of wetlands in reed-harvesting polders as well for agricultural and forestry purposes, the structure of the water network has suffered many changes. The measures have affected the relation between main branches and the water network, i.e. channels and lakes in the inner part of the delta (Neagu-Godeanu, 1975; Gâştescu and Driga, 1989; Gâştescu and Ştiucă, 2008). A large number of natural channels disappeared and other artificial new canals arose. With the increased connectivity between the main branches and the inner part of the delta, more unfiltered water entered directly into the system. Due to these conditions an increased eutrophication became visible by changes in the macrophyte communities' composition as well the abundance-dominance relation of characteristic water macrophytes.

The eutrophication has been subject to a number of studies (Oosterberg and Staraş 2000) and is regularly monitored by the researchers of the Danube Delta National Institute Tulcea. To exemplify the changes to the water macrophytes communities, the area of Gorgova-Isac-Uzlina situated in the morphogenetic type of the depressions area of the Fluvial Delta (Gâştescu and Ştiucă, 2008) between the Sulina and Sfântul Gheorghe branches was selected but also data from area north of the Sulina Branch, taking part of the depressions area of the fluvial Delta (Lopadna, Eracle), have been included. Also for comparison older data from the 1960s and 1970s (Neagu-Godeanu, 1973, 1975) – natural and transformed area of the Danube Delta – have been taken into consideration.

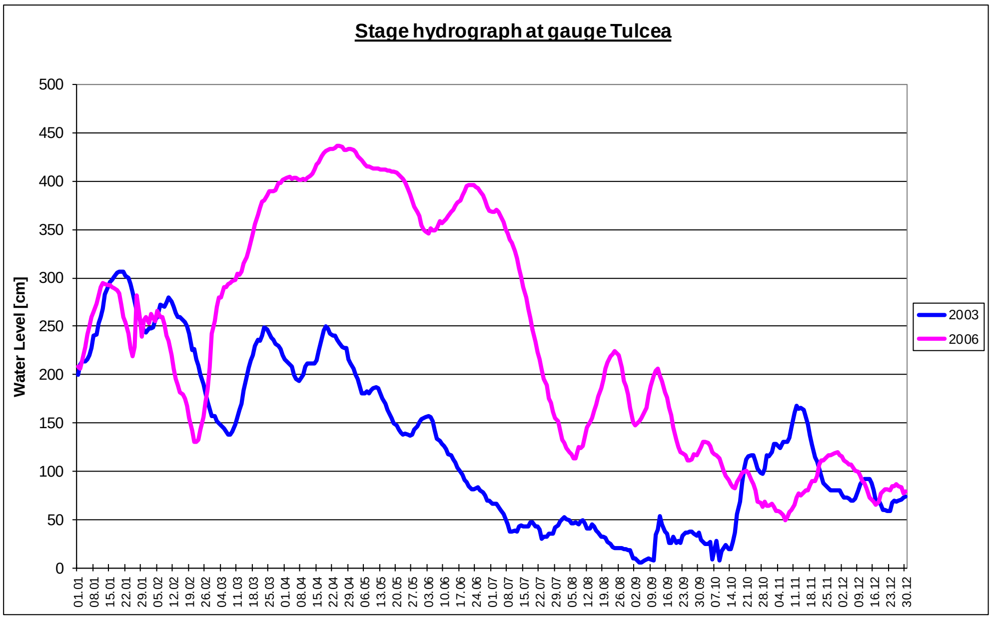

Figure 1: Stage hydrograph of the Danube at gauge Tulcea for the years 2003 with generally low water levels, and 2006 with high water levels during the vegetation period (hydrological data from the Danube Delta National Institute in Tulcea/Romania).

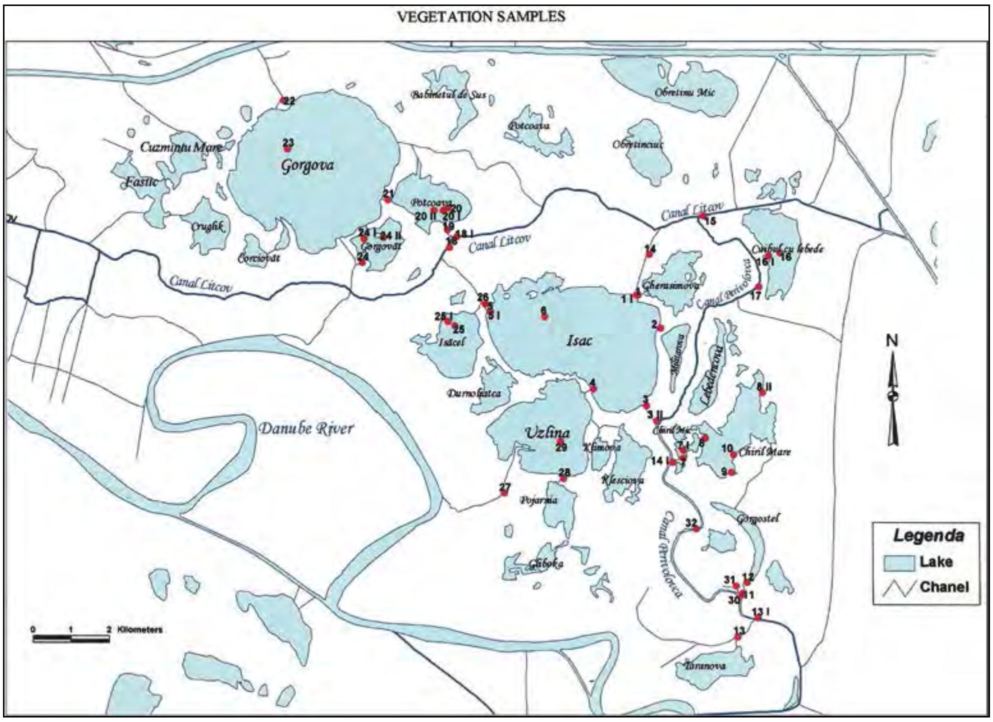

Figure 2: Map of the study area Gorgova-Isac-Uzlina with sampling points (source of map Danube Delta National Institute, Tulcea).

MATERIAL AND METHODS

The paper presents a synthesis of water macrophyte researches over more than two decades in the Danube Delta and are the result of sampling and monitoring in the area of restoration projects of former agricultural polders and other area studied in relation to the implementation of the Water Framework Directive and the Natura 2000 network. To have an overview of the aquatic macrophytes known from the Danube Delta (Ciocârlan, 1994, 2009; Doroftei and Covaliov, 2003), data from smaller publication and our own field researches of all known species are listed (Tab. 1) showing for each species the life form, indicator values for light (L), temperature (T), wetness/humidity (U), indicator value for the preference of plants to chemical reaction of water and soil I, nitrogen (N) according to Ellenberg et al. (2002) as this scale is widely used in Europe. In some cases the value is re-adapted to the conditions of South-Eastern Romania (Sârbu et al., 2013) and verified according to Sanda et al. (1983). In the species list are given categories of threat according to the Red List of species of the Danube Delta (Fundația Aves, 2000; Dihoru and Negrean, 2009) and the occurrence in slow running (slr) and standing waters (st).

In the list of species, beside the aquatic life forms are included from the hydro-helophytes only those species that have aquatic forms, such as *Polygonum amphibium*, *Sagittaria sagittifolia* and *Sparganium emersum*, species with the indicator value for wetness 10 (hydro-helophytes). The indicator value 10 includes also aquatic species which support longer time without water or with changing water levels. The indicator values 11 (hydrophytes) includes species with roots in the water, with leaves above the water surface, floating and emerging over or floating on the water surface. The value 12 includes aquatic plants under the water surface, permanently or mostly covered by water.

From the large number of samples (125) taken by the method of Braun-Blanquet (1964) with the seven degree abundance-dominance scale only synthetic data are given including the frequency values (I-V) of each species of the community. A network of sampling points is represented with points in different type of water bodies like channels, canals and different type of lakes connected to the main branches, to secondary branches, canals and more isolated lakes. At each indicated point (Fig. 2) transparency, depth, temperature, ph and conductivity have been measured. The scientific names of the associations follow Sanda et al. (2008).

RESULTS AND DISCUSSION

The list of the macrophytic flora of the Danube Delta comprises 88 species (Tab. 1), including 11 stonewort (Characeae) species. Considering their indicator value for light, most species are in the categories 5-7, i.e. species in half-shadow to half-light conditions. The temperature requirements are expressed with values mostly between five moderate temperatures to indicators for temperature characteristic for the planar level and with some Mediterranean influences (Oberdorfer, 2001; Ellenberg et al., 2002). Concerning the pH values I, the species are mostly indicators for moderate to low acidity (indicator values five, six) and species as indicators for low alkaline to alkaline conditions (value seven).

Table 1: List of aquatic macrophytes of the Danube Delta; indicator values for: L = light, T = temperature, U = umidity (Ellenberg et al., 2002) F = umidity/Feuchtigkeit, R = pH/soil reaction, N = nitrogen/nutrients, ThrC = threatening categories; fizical state: r = running water, slr = slowly running water, st = standing water.

	Indicator value	L	T	U	R	N	ThrC	r	st
Lifef.	Species								
Hd	*Aldrovanda vesiculosa* L.	5	8	12	7	4	CR	–	st
HH	*Alisma gramineum* Lej.	7	7	11	7	4	–	slr	st
HH	*Alisma lanceolatum* With.	7	7	10	7	5	R	–	st
HH	*Alisma plantago-aquatica* L.	7	5	10	x	8	–	slr	st
Hd, T	*Azolla filiculoides* Lam.	6	8	11	x	8	–	slr	st
HH	*Berula erecta* (Huds.) Coville.	8	6	10	8	6	–	r slr	st
G-HH	*Butomus umbellatus* L.	6	6	10~	x	7	–	slr	st
HH	*Caldesia parnassifolia* (Bassi) Parl.	7	7	10	8	7	EX	–	st
Hd	*Callitriche palustris* L.	6	x	11	5	4	–	–	st
Hd	*Ceratophyllum demersum* L.	6	7	12~	8	8	–	slr	st
Hd	*Ceratophyllum submersum* L.	5	8	12	8	7	R	–	st
Hd	*Elodea □btuse□sis* Rich. In Michx	7	6	12	7	7	–	slr	st
Hd	*Elodea nuttallii* (Planchon) H. St. John	7	6	12	?	7	–	–	st
HH	*Glyceria maxima* (Hartm.) Holmbg.	9	5	10~	8	9	–	slr	st
Hd	*Groenlandia densa* (L.) Fourr.	8	6	12	8	5	VU, R	slr	st
Hd	*Hippuris vulgaris* L.	7	5	10	8	5	VU	slr	st
Hd	*Hottonia palustris* L.	7	6	12	5	4	VU, R	slr	st
Hd	*Hydrocharis morsus-ranae* L.	7	6	11	7	6	–	slr	st
Hd	*Lemna gibba* L.	8	6	11	8	8	–	–	st
Hd	*Lemna minor* L.	7	5	11	x	6	–	–	st
Hd	*Lemna trisulca* L.	7	6	12	5	5	–	–	st
Hd	*Marsilea quadrifolia* L.	7	9	10	7	6	CR	–	st
Hd	*Myriophyllum spicatum* L.	5	6	12	9	7	–	slr	st
Hd	*Myriophyllum verticillatum* L.	5	6	12	7	8	–	slr	st
Hd	*Najas marina* L.	5	6	12	9	6	–	–	st
Hd	*Najas minor* All.	6	7	12	8	4?	–	–	st
Hd	*Nasturtium officinale* R. Br.	7	x	10	7	7	–	r slr	-
Hd	*Nuphar lutea* (L.) Sibth. Et Sm.	8	6	11	7	6	–	slr	st
Hd	*Nymphaea alba* L.	8	6	11	7	5	–	–	st
Hd	*Nymphaea candida* C. Presl.	8	6	11	4	4	R	–	st
Hd	*Nymphoides peltata* (Gmel. S. G.)	8	7	11	8	7	–	slr	st
HH	*Oenanthe aquatica* (L.) Poir.	7	6	10	7	6	–	slr	st
Hd, G	*Polygonum amphibium* L.	7	6	11	6	4	–	–	st
Hd	*Potamogeton acutifolius* Link	7	6	12	5	6	–	slr	st
Hd	*Potamogeton berchtoldii* Fieber	6	6	12	7	5	R	–	st
Hd	*Potamogeton compressus* L.	6	5	12	8	4	R	slr	st
Hd	*Potamogeton crispus* L.	6	5	12	7	5	–	slr	st
Hd	*Potamogeton gramineus* L.	8	4	12	5	3	–	–	st

Table 1 (continued): List of aquatic macrophytes of the Danube Delta; indicator values for: L = light, T = temperature, U = umidity (Ellenberg et al., 2002) F = umidity/Feuchtigkeit, R = pH/soil reaction, N = nitrogen/nutrients, ThrC = threatening categories; fizical state: r = running water, slr = slowly running water, st = standing water.

Hd	*Potamogeton lucens* L.	6	6	12	6	7	–	–	st
Hd	*Potamogeton natans* L.	6	5	11	7	5	–	–	st
Hd	*Potamogeton nodosus* Poiret	6	6	12	8	5	–	slr	st
Hd	*Potamogeton pectinatus* L.	6	x	12	8	8	–	slr	st
Hd	*Potamogeton perfoliatus* L.	6	x	12	7	6	–	slr	st
Hd	*Potamogeton pusillus* L.	6	5	12	6	x	R	slr	st
Hd	*Potamogeton trichoides* Cham. And Schlec.	8	6	11	5	4	R	slr	st
Hd	*Ranunculus aquatilis* L.	7	5	11	6	6	–	slr	st
Hd	*Ranunculus baudotii* Godr.	8	6	10	9	7	–	–	st
Hd	*Ranunculus circinatus* Sibth.	6	6	12	7	8	R	–	st
Hd	*Ranunculus fluitans* Lam.	8	6	12	x	8	–	r	-
Hd	*Ranunculus peltatus* Schrank	8	5	12	x	5	–	–	st
Hd	*Ranunculus penicillatus* (Dumort) Bab.	8	6	11	7	x	–	–	st
Hd	*Ranunculus rionii* Lagger	8	6	12	x	5	–	–	st
Hd	*Ranunculus trichophyllus* Chaix.	7	x	12	5	7	–	r	-
HH	*Rorippa amphibia* (L.) Bess.	7	6	10	7	8	–	slr	st
Hd	*Ruppia maritima* L.	X	6	10	7	?	VU, R	–	st
Hd	*Ruppia cirrhosa* (Petagna) Grande	x	6	10	7	–	VU	–	st
HH	*Sagittaria latifolia* Willd	7	6	10	–	–	–	–	st
HH	*Sagittaria sagittifolia* L.	7	6	10	7	6	–	slr	st
HH	*Sagittaria trifolia* L.	7	6	10	7	–	VU	slr	st
Hd	*Salvinia natans* (L.) All.	7	8	11	7	7	Br I	–	st
Hd	*Sparganium emersum* Rehm.	7	6	10	6	7	–	slr	st
Hd	*Spirodela polyrhiza* (L.) Schleiden	7	6	11	6	6	–	–	st
HH	*Stratiotes aloides* L.	7	6	12	8	6	–	slr	st
Hd	*Trapa natans* L.	8	7	11	6	8	nt/Br. I	–	st
Hd	*Utricularia australis* R. Br.	9	6	12	5	3?	R	–	st
Hd	*Utricularia bremii* Heer	8	7	12	3	2?	–	–	st
Hd	*Utricularia minor* L.	8	6	12	6	2?	EX	–	st
Hd	*Utricularia vulgaris* L.	7	6	12	5	4	–	–	st
Hd	*Vallisneria spiralis* L.	7	8	12	7	7	–	slr	st
Hd-HH	*Veronica anagallis-aquatica* L.	7	6	9=	x	6	–	slr	–
Hd-HH	*Veronica beccabunga* L.	7	x	10	7	6	–	slr	–
Hd-HH	*Veronica scutellata* L.	8	5	9=	3	3	–	–	st
Hd	*Wolffia □btuse* (L.) Horkel ex Wimm.	7	6	11	7	6?	–	–	st
Hd	*Zannichellia palustris* L.	6	7	12	7	6	R	–	st
Hd	*Z. pal. pedicellata* (Wlbg and Rosén) Arcang	6	7	12	7	6	R	–	st
Hd	*Zostera noltii* Hornem.	7	6	12	7	6	VU, R		st
Hd	*Zostera marina* L.	X	6	12	7	6	VU		st
Hd	*Chara aspera* Deth. Ex Willd.	–	–	–	–	–	–	–	st
Hd	*Chara contraria* Braun A.	–	–	–	–	–	–	–	st
Hd	*Chara crassicaulis* Schleicher	–	–	–	–	–	–	–	st
Hd	*Chara globularis* Thuill.	–	–	–	–	–	–	–	st
Hd	*Chara gymnophylla* Braun A.	–	–	–	–	–	–	–	st

Table 1 (continued): List of aquatic macrophytes of the Danube Delta; indicator values for: L = light, T = temperature, U = umidity (Ellenberg et al., 2002) F = umidity/Feuchtigkeit, R = pH/soil reaction, N = nitrogen/nutrients, ThrC = threatening categories; fizical state: r = running water, slr = slowly running water, st = standing water.

Hd	*Chara hispida* Linné	–	–	–	–	–	–	–	st
Hd	*Chara tomentosa* Linné	–	–	–	–	–	EX?	–	st
Hd	*Chara vulgaris* Linné	–	–	–	–	–	–	–	st
Hd	*Nitella gracilis* (Smith) Agardh	–	–	–	–	–	EX?	–	st
Hd	*Nitella syncarpa* (Thuill.) Chev.	–	–	–	–	–	EX?	–	st
Hd	*Nitelopsis obtusa* (Desv. In Lois. – Desl.) J. Grov.	–	–	–	–	–	–	–	st

The analysis of indicator values for Nitrogen of the macrophytes according to Ellenberg et al. (2002) shows a predominance of species with values of four to eight, the majority of species are represented in the value classes of six and seven (Fig. 2). This high presence of nitrophilous species indicates the general eutrophic character of the system. This can be followed by studies of the vegetation along ecological gradients from the main branches to the larger secondary channels, the smaller ones and to the lakes.

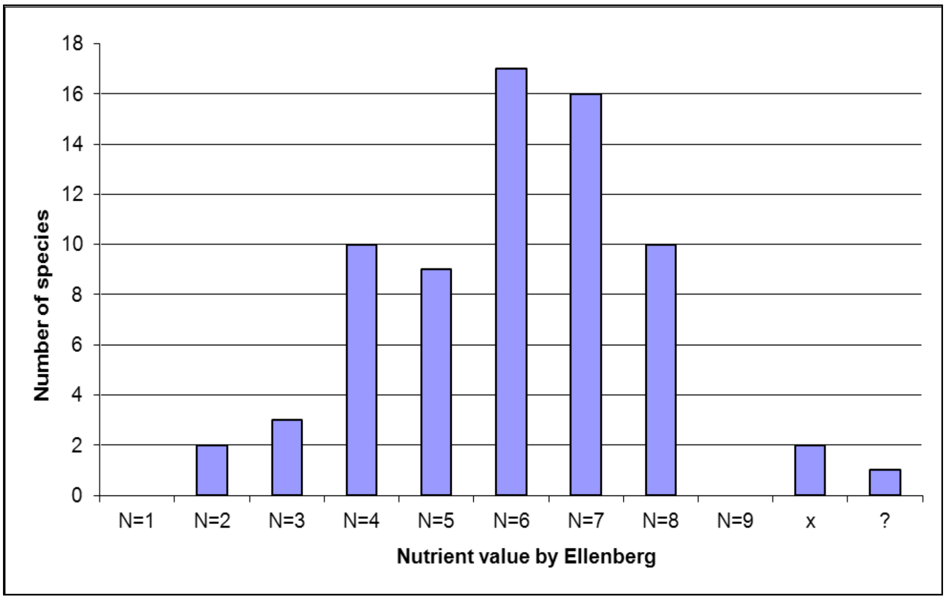

Figure 3: The macrophytes of the Danube Delta grouped according to categories of nutrient values (Nitrogen).

Concerning the category of threat, the list of aquatic macrophytes includes some Rare, Vulnerable and Critically Endangered species and also species considered as Extinct. In the list is included also water chestnut (*Trapa natans*) and floating water-moss (*Salvinia natans*), species which in the Danube Delta occur frequently and at high abundance. These species are endangered and rare in Middle and Western Europe, being thermophilous species on the border of their distribution boundary.

A remarkable regressive tendency can be observed for stonewort species, some of which are endangered by extinction or are considered as extinct. The following species have been mentioned from the Danube Delta area and are included in the above-mentioned list.

Chara aspera Detharding ex Willdenow 1809 occurs in lakes with clear and calcium carbonate-rich water in Central and Western Europe, but also in Southern Europe to a depth of 1.5 m. The species builds communities which in deeper waters are followed frequently by those of *Chara contraria*, which in its turn is replaced at increasing depth by communities of *Nitelopsis □btuse* (Krause, 1997). In the Danube Delta these species have been found in the Polder Popina area in the north-eastern part of the Danube Delta, building together with *Chara vulgaris* communities with a high degree of cover. (observation and monitoring Schneider – 2000 and 2001).

Chara contraria Braun A. ex Kütting 1845 is characteristic of meso-saprobic clear lakes and occurs in small temporary lakes and pools as was reported on the Babina restored area (western part) and in the area of Popina in water of slight salinity (Schneider et al., 2008).

Chara gymnophylla Braun A. 1835, a circum-Mediterranean and South-Eastern species builds monospecific communities in small lakes of dry regions. In the Danube Delta area stands with this species have been registered during studies in the restoration area of island-polder Cernovca (Schneider, 1998 – personal data). It is rare all over its distribution area (Krause, 1997).

Chara globularis Thuill. 1799 is a more widespread species in calcium carbonate-rich waters reaching high dominance as was reported in the Cernovca restoration area lakes and the lakes Chiril Mare and Clesciova. Its fast growth allows the species to spread in a short time over a large area (Krause, 1997).

Chara hispida L. 1753 until the present was not mentioned for the Danube Delta. We found the species in 2003 in the Nebunu Lake in the northern end of the Letea Dune area, nearby the village of Periprava. It is characteristic for calcium carbonate-rich oligo-saprobic waters on mineral soils with high organic matter content. As well its growth is stimulated through the influx of groundwater supply. The species is known for its high requirements for clean waters (Krause, 1997), as they are given in function of the water level of the Danube in strong relation with the ground water table and the filtering capacity of the dune area.

As one of the most frequent species recorded was *Chara vulgaris* L. 1753, a widely distributed species. It occurs in lakes with meso-saprobic water quality. This species with a high capacity for fast growth can occupy a large area in a short time. As well *Chara vulgaris* is more resistant to eutrophication as other Characeae species (Krause, 1997). In the Danube Delta restoration area we reported the species in the area of Popina polder and the Cernovca area. As well, another Characeae species *Chara crassicaulis* Schleicher 1821 has been found in small lakes and also temporary pools in the re-flooded Cernovca polder area. The species with a distribution in Central and South-Eastern Europe is characteristic for waters with direct supply from groundwater.

The stonewort species *Chara tomentosa* L. 1753 has been mentioned as Charetum tomentosae (Sauer 1937) Corillion 1957 from the Danube Delta in the area of Şontea-Sireasa and the lake area of Roşu-Roşuleţ (Godeanu, 1976). Although this species is given from the Danube Delta, it is not mentioned by Krause (1997) from Romania. Due to increasing eutrophication, the species was not identified in recent decades.

As a characteristic species of lakes with clear and deeper waters for many lakes of the fluvial part of the Danube Delta should be mentioned *Nitellopsis □btuse* (Desvaux in Loisleur-Deslangchamps) Groves J. 1919. It occurs in deeper lakes (5-10 m) in exclusive stands.

Aquatic plant communities

Due to the above-mentioned high diversity of water body types in the Danube Delta, the macrophyte vegetation presents in its distribution a distinct mosaic of interlocking communities. This mosaic is exemplified in the lakes area of Gorgova-Isac-Uzlina between the main branches Sulina and Sfântul Gheorghe with secondary water courses such as Perivolovca (more natural) and Litcov (more artificial), third and fourth category of waters consisting of smaller and narrow channels between the larger channels and lakes. These last are represented by large lakes such as Gorgova, Isac and Uzlina, as well as numerous smaller lakes connected to the larger ones by small channels (gârla), but also some small lakes more isolated in the reeds.

Analysing the differences between running and standing waters, there is a clear delineation of occurrence for the pondweed species *Potamogeton nodosus*, which occurs at high abundance and constancy only in running waters (Schneider, 2009) such as for the studied area the Litcov Canal, Uzlina Canal and some smaller channels such are the Isac I and II. Near *Potamogeton nodosus* are some accompanying species such as *Potamogeton perfoliatus*, *Trapa natans*, *Nuphar lutea*, *Ceratophyllum demersum* and *Potamogeton pectinatus*, which beside their occurrence in standing water are present also in slowly running waters. The identifies, together with *Potamogeton nodosus*, transition stages from running to standing waters (Tab. 2). *Potamogton nodosus* (Fig. 4) occurs also in the main branches, as it has been observed on the Danube's mile 2 near to Sulina in 2011.

Figure 4: *Potamogeton nodosus*, characteristic species for running waters.

Another species occurring in standing shallow water but also in running waters without slope is *Nymphoides peltata*. The species has been remarked in the Litcov Channel constituting large patches on the edge of the water together with *Butomus umbellatus*, a good indicator for shallow waters in the course of silting up. *Nymphoides peltata* has been observed also in the border area of the main Chilia Branch, downstream from Periprava.

A species that has spread more recently is *Elodea nutallii*, replacing more and more *Elodea* □*btuse*□*sis*. From its first mention in the Danube Delta (Ciocârlan et al., 1998) the species had a high dispersal, occupying at present a larger area and stable communities.

Apart from *Potamogeton nodosus* all the other species can occur and identify phytocoenoses also in the standing waters and are present in the lakes following ecological gradients. The repartition is different in function of the water current and nutrient content. The communities identified by *Trapa natans* occur in places near to the connectivity channels from where a quantity of nutrients transported by running waters enters into the lake as is visible in the Uzlina Lake. In sediment-rich lakes *Trapa natans* can act with its root system as a trap for fine sediments, as has been observed in the case of Rotund (formerly Cruglic) lake north of the Sulina Branch. It plays a similar role in the Uzlina area.

In the large lakes such as Isac and Gorgova large parts are settled by *Potamogeton pectinatus* with *Potamogeton trichoides*, also in some places the small pondweed *Potamogeton bertholdii* which requires clear and more mesotrophic habitats.

In general can be stated gradients between lakes and channels, gradients in the lakes, gradients between the different lakes, gradients in the channels from the river bank to the mid of the water course, in dependence of the river bank structure, the depth of the water and the flow velocity.

In smaller channels crossing the reeds such as the Lopadna and Eracle Channels, the macrophyte communities are situated along the reeds, forming smaller or larger belts. In transects the following structures can be observed:

Lopadna:

Phragmites australis reed – *Trapa natans* stands – open water in mid-channel – *Trapa natans* – *Phragmites* reed;

Eracle:

Phragmites reed – *Trapa natans* stands – open water – *Trapa stands* – *Nymphaea alba* – *Phragmites* reed;

Phragmites reed – *Trapa natans* stands – open water – *Trapa natans* stands – *Nuphar luteum* stands – *Nymphaea alba* stands – *Phragmites* reed;

Phragmites reed – *Nuphar luteum* stands – *Trapa natans* stands – open water – *Trapa natans* stands – *Phragmites* reed;

Crossing point of Lopadna and Eracle:

Phragmites reed – *Stratiotes aloides* stands – *Trapa natans* stands – *Salvinia natans* cover – open water surface in the mid – *Salvinia natans* cover – *Trapa natans* stands, *Nymphaea alba* stands – *Stratiotes aloides* stands *Phragmites* reeds;

This succession is characteristic for the channels in the fluvial part of the delta and indicates – in the places with presence of *Stratiotes aloides* – active evolution of "*plav*" or floating reed formations, *Stratiotes aloides* building the support for the reeds, which fall down and on the nodes of the lying stems grow new small stems and leaves of *Phragmites*, covering in time the Stratiotes belt.

Table 2: Synthetic table of macrophyte communities based on frequency classes; A = association, the other are accompanying species. Colum 1: Potamogetonetum nodosi with samples from Litcov Canal, Uzlina Canal, mouth of Isac Canal II into Isac Lake, (habitat type 3260); Column 2: Potamogetonetum perfoliati subass. With Potamogeton nodosus, high constancy, but lower abundance-dominance as the name giving species (Litcov, Uzlina and Caraorman Canal); Column 3: Trapetum natantis with samples (from the Uzlina, Iacub, Gorgova, Gorgoştel lakes); Column 4: Trapetum natantis facies with *Stratiotes aloides* (gârla between Gorgoştel Lake and Perivolovca Canal); Column 5: Stratiotetum aloidis, gârla Gorgoştel, fac. With *Hydrocharis morsus ranae* from Taranova Lake; Column 6: Nymphaeetum albae (with high frequency of *Trapa natans* but low abundance-dominance) from the Cuibul cu Lebăda Lake, Chiril Mic, Clesciova; Column 7: Nupharetum luteae (Perivolovca, Chiril Mare, Gorgoştel with samples from the whole lake area); Column 8: Ceratophylletum demersi with *Elodea nutallii* and *Myriophyllum spicatum* (Cuibul cu Lebăda Lake); Column 9: Potamogetonetum pectinati from Isac Lake, Gorgova; Column 10: Nitellopsidetum obtusae (Potcoava Lake, Chiril Mare) the species occurs with high frequency also in the association Ceratophylletum demersi, but with low abundance; Column 11: Nymphoidetum peltatae (Litcov Canal).

	Serial number of column	1	2	3	4	5	6	7	8	9	10	11
	No. of samples	25	10	11	5	10	5	25	6	21	5	5
A	*Potamogeton nodosus*	V	V	–	–	–	–	–	–	I	–	–
A	*Potamogeton perfoliatus*	III	V	–	–	–	–	–	–	–	–	–
A	*Trapa natans*	III	III	V	V	I	I	-	I	II	-	–
A	*Stratiotes aloides*	–	–	I	II	V	IV	–	–	I	–	–
A	*Hydrocharis morsus-ranae*	–	–	I	–	V	I	–	–	I	–	–
A	*Nymphaea alba*	–	–	–	–	I	V	II	–	–	–	–
A	*Nuphar luteum*	I	–	II	II	–	II	V	–	I	–	–
A	*Ceratophyllum demersum*	II	III	IV	V	III	III	–	V	III	II	–
A	*Potamogeton pectinatus*	III	III	I	II	–	–	I	II	V	III	–
A	*Nymphoides peltata*	I	–	–	–	–	–	–	–	–	–	V
	Potamogeton crispus	I	I	I	III	–	–	I	–	III	I	–
	Myriophyllum spicatum	–	–	–	–	I	–	–	III	I	–	–

Table 2 (continued): Synthetic table of macrophyte communities on the base of frequency classes.

	Serial number of column	1	2	3	4	5	6	7	8	9	10	11
	No. of samples	25	10	11	5	10	5	25	6	21	5	5
	Elodea nutalii	I	–	II	–	–	II	II	III	I	III	–
	Potamogeton trichoides	–	–	I	–	–	–	I	–	II	II	–
	Potamogeton berchtoldii	–	–	–	–	–	–	I	–	II	II	–
	Potamogeton lucens	–	I	–	–	–	–	I	–	–	–	–
A	*Nitelopsis obtusa*	–	–	–	–	–	–	I	IV	I	V	–
	Chara globularis	–	–	–	–	–	–	–	–	I	–	–
	Lemna minor	I	–	I	III	II	I	–	II	I	–	–
	Lemna trisulca	–	–	I	I	I	I	–	II	–	–	–
	Spirodela polyrhiza	II	–	II	IV	III	II	I	–	II	–	–
	Salvinia natans	I	–	II	II	IV	II	–	II	–	–	I
	Berula erecta	–	–	–	–	I	–	–	–	–	–	–
	Phragmites australis	I	–	I	I	I	–	I	–	–	–	–
	Sagittaria sagittifolia	–	–	I	I	–	–	–	–	I	–	I
	Alisma lanceolatum	–	I	–	–	–	–	–	–	–	–	–
	Vallisneria spiralis	–	–	–	–	–	–	I	–	–	–	–
	Alisma plantago aquatica	–	–	–	–	–	–	I	–	–	–	–
	Thelypteris palustris	–	–	–	–	–	–	–	I	–	–	–
	Polygonum amphibium	–	–	–	–	–	–	–	–	I	–	–
	Ceratophyllum submersum	–	–	–	–	–	–	–	–	I	–	–
	Butomus umbellatus	–	–	–	–	–	–	–	–	–	–	II

Figure 5: *Nuphar lutea* carpets in the lake “Cuibul cu Lebăda” in eutrophic conditions.

Figure 6: White water lily (*Nymphaea alba*) community with *Nuphar* in moderate eutrophic conditions.

In smaller lakes with structured borders and connectivity to channels can be observed a repartition of communities or fragments of them in function of water current and border structure of the lake. For example in the “Cuibul cu lebăda” southern part there are concentrated communities of *Nitellopsis* *btuse* and *Elodea nutallii* together with *Potamogeton crispus* and *P. pectinatus.* In the western part near to the bordering reed beds we found stands of white water lily (*Nymphaea alba*) and *Stratiotes aloides*, whereas more to the open part of the lake stands of *Nuphar lutea* prevail (Fig. 5). In channels have also been observed a belt of *Nymphaea* on the border of the reeds where the water enters cleaner and filtered through the reeds, in some cases interlocking with *Stratiotes* and followed by *Nuphar luteum* stands. In old channels of the “gârla” type the most dominant species is *Stratioates aloides*, in some cases accompanied by *Hydrocharis morsus-ranae*.

In most specific cases can be observed regressive tendencies for the species living in mesotrophic conditions and an increase of species with larger ecological amplitude such as *Potamogeton pectinatus* and *Ceratophyllum demersum*.

The majority of Characeae species are good indicators for water quality. They have been studied in the 1970s (Godeanu and Ţeculescu, 1971) in the context of macrophyte communities of the Danube Delta. The association Charetum tomentosae (Sauer 1937) Corillion 1957 has been mentioned in the area of Şontea-Sireasa and the lake area of Roşu-Roşuleţ (Godeanu and Ionescu-Ţeculescu, 1971; Godeanu, 1976). Although the species and its communities are described from the Danube Delta they are not mentioned by Krause (1997) from Romania. Due to increasing eutrophication, this species and its communities were not identified in the last decades.

The association Nitellopsidetum obtusae, almost characteristic for beta-meso-saprobic lakes (Krause, 1997), can support in the frame of larger limits eutrophication. During field research communities with *Nitellopsis* *btuse* were reported in the Isac-Uzlina area in the lakes Taranova, Chiril Mare, Cuibul cu Lebăda, and Clesciova, but on a reduced scale and with visible regress. This is in strong relation to eutrophication; especially the content of phosphorus with values higher than 20 mg/l is a factor for decrease of Characeae populations, because the phosphorus content is favoring the development of plankton, which in turn promotes increasing plankton quantity, causing turbidity. As well the increasing phosphorus content promotes the development of macrophytes and an increased organic production. Also high nitrogen content promotes the macrophytes, but displaces the stoneworts (Krause, 1997).

According to the list of European Union habitats (EUR28, 2013) including the habitat type 3150 Natural eutrophic lakes with Magnoüotamion or Hydrocharition-type vegetation, only the *Potamogeton nodosus* community is typical for running waters and has to be included in the habitat type 3260 Water courses of the plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation, being a transition type to the macrophyte communities included in the habitat type of eutrophic lakes.

Table 3: Plant communities of the study area according to Neagu-Godeanu (1973, 1975) and data from the last two decades (Schneider-Binder).

	Associations according to Neagu-Godeanu 1973 and 1975	Associations according to recent data
1.	Charetum tomentosae (Sauer 1937), Corillion 1957	Not mentioned in the last time
2.	Nitellopsidetum obtusae (Sauer 1937) Dombska 1961	Nitellopsidetum obtusae (Sauer 1937) Dombska 1961
3.	Ceratophylletum demersi Hild 1956	Ceratophylletum demersi Hild 1956
4.	Stratiotetum aloidis Nowinski 1930	Stratiotetum, aloidis Nowinski 1930 (= Hydrochari-Stratiotetum (Langendonck 1935) Westhoff 1945)
5.	Hydrocharitetum morsus-ranae van Lang 1935	Lemno-Hydrocharitetum (Oberdorfer 1957) Passarge 1978
6.	Groups of Utricularia	Lemno-Utricularietum vulgaris Soó 1928
7.	Nymphoidetum peltatae Allorge 1922	Nymphoidetum peltatae (Allorge 1922) Bellot 1951
8.	Nymphaeetum albo-luteae Nowinski 1928	Nymphaeetum albae Oberdorfer 1957; Nymphaeetum albo-luteae 1928
9.	Trapetum natantis Müller et Görs 1960	Trapetum natantis Müller and Görs 1960
10.	Myriophylleto-Potametum lucentis Soó 1934	–
11.	Potametum perfoliate Koch W. 1926/ em. Passarge 1964	Potamogetonetum perfoliati Koch 1926 em. Passarge 1964
12.	Potametum crispi	Potamogetonetum crispi Soó 1927
13.	Potametum pectinati Carstensen 1955	Potamogetonetum pectinati Carstensen 1955
14.	Potametum lucentis Hueck 1931	Potamogetonetum lucentis, only very small patches
15.	–	Elodeetum nutallii Ciocârlan et al. 1997
16.	–	Potamogetonetum trichoidis Freit et al. 1956

Figure 7: Belt of abundant *Nymphaea alba* along the reeds in the Eracle Channel.

CONCLUSIONS

The occurrence and repartition of water macrophyte communities is in strong relation to the hydrological regime, water body types and their quality. The larger canals such as the Litcov and Uzlina canals shelter typical communities for running waters with the dominance of *Potamogeton nodosus*, accompanied by some other species such as *Potamogeton perfoliatus*, *P. pectinatus* and *Trapa natans*, occurring also in the lakes of the Danube Delta. The Perivolovca Canal and smaller channels of various lengths are characterised more by species which occur predominantly in standing waters. The macrophyte communities have in general a eutrophic character, whereas some smaller lakes more isolated in the reed-beds present a mesotrophic character, but a shifting of communities to waters with a eutrophic character is clearly visible. The most frequent communities in the lakes are those of *Nuphar lutea* and *Nymphaea alba*, the last occurring frequently as a belt in contact with the reeds (Fig. 7). *Trapa natans* occurs as well over a large area in the lakes and is often situated near the mouth of channels with water currents. In larger lakes with different niches on the shore a larger diversity of communities can be observed. Pondweed species such as *Potamogeton pectinatus* and *P. trichoides* occur in the open large lakes of eutrophic character.

The lakes with former high abundance of Characeae change their character as they disappear due to eutrophication and growing turbidity by plankton and fast-growing macrophytes producing high organic matter. The changes in water quality are also responsible for the reduction of the occurrence of *Potamogeton lucens*, which has been observed only in some small patches in the lakes. Even if there are many changes in dominance and abundance of macrophytes conditioned by short term variations of the hydrological regime long term changes became visible also taking into account the changes induced by human impact.

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MORPHOLOGY OF *LERNANTHROPINUS TRACHURI* (BRIAN, 1903) (COPEPODA, SIPHONOSTOMATOIDA, LERNANTHROPIDAE) FROM BANDIRMA BAY (TURKEY)

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ABSTRACT

The parasitic copepod, *Lernanthropinus trachuri* (Brian, 1903) (Copepoda, Siphonostomatoida, Lernanthropidae) was found on the Mediterranean horse mackerel, *Trachurus mediterraneus* in Bandırma Bay, Turkey. The aim of this study is to present female *Lernanthropinus trachuri* with morphological characters with photos from Turkey. The details unseen in photos were supported with drawings. All parasites were firmly attached to the gill filaments of the host. This parasite is also specific for the genus *Trachurus* (Costa et al 2017). Therefore, this parasite may use as biomonitor or tag species for fish stock studies in Turkey.

ZUSAMMENFASSUNG: Die Morphologie von *Lernanthropinus trachuri* (Brian, 1903) (Copepda, Siphonostomatoida, Lernanthropidae) aus der Bandirma Bucht (Türkei).

Der als Parasit lebende Ruderfußkrebs *Lernanthropinus trachuri* (Brian, 1903) (Copepoda, Siphonostomatoida, Lernanthropidae) wurde an der mediterranen Pferdemackrele *Trachurus mediterraneus* in der Bandirma Bucht/Türkei gefunden. Daraus ergibt sich das Ziel vorliegender Arbeit für die Türkei das Weibchen von *Lernanthropinus trachuri* mit seinen morphologischen Kennzeichen anhand von Photos zu dokumentieren. Detauils, die in den Phtos nicht sichtbar ware, wurden mithilfe von Zeichnungen dargestellt. Sämtliche Parasiten hafteten fest an den Kiemenfäden der Wirtsart. Dieser Parasit ist auch kennzeichnend für die Gattung Trachurus (Costa et al. 2017). Daher kann er Zeigerart bei Biomonitoring eingesetzt oder als Leitart für die Untersuchungen an Fischbeständen in der Türkei verwendet werden.

REZUMAT: Morfologia speciei *Lernanthropinus trachuri* (Brian, 1903) (Copepda, Siphonostomatoida, Lernanthropidae) din golful Bandirma (Turcia).

Copepodul parazitar *Lernanthropinus trachuri* (Brian, 1903) (Copepoda, Siphonostomatoida, Lernanthropidae) a fost identificat pe specia stavridul mediteraneean *Trachurus mediterraneus* în Golful Bandirma din Turcia. Această descoperire a determinat obiectivul acestei lucrări de a studia în Turcia cu ajutorul unor fotografii, femela de *Lernanthropinus trachuri* cu toate caracterele ei morfologice. Detaliile care nu au fost vizibile în fotografii au fost documentate cu ajutorul unor desene: Toți paraziții au fost strâns alipiți de filamentele branchiale ale speciei gazdă. Parazitul de asemenea este caracteristic pentru genul *Trachurus* (Costa et al. 2017). Din acest considerent poate fi folosit ca inidcator la monitorizări sau ca specie indicatoare pentru cercetarea stocurilor de pești din Turcia.

INTRODUCTION

Mediterranean horse mackerel, *Trachurus mediterraneus* (Steindachner, 1868), is a commercially-important marine fish species with a wide geographical distribution, they inhabit the pelagic-oceanic zone (Froese and Pauly, 2017).

Lernanthropidae is the most common family of parasitic copepods on fishes. The family Lernanthropidae Kabata, 1979, currently comprises about 150 species belonging to eight genera (Boxshall and Halsey, 2004). The genus *Lernanthropus* de Blainville, 1822, is the largest of the family, containing approximately 120 valid species, all of which parasitize marine fish hosts, belonging to least 31 different teleost families (Boxshall and Halsey, 2004).

Bahri et al. (2002) examined *Lernanthropus kroyeri* as a bio-indicator species of populations that belong to two fish species, *Dicentrarchus labrax* and *Dicentrarchus punctatus* in Tunisia. Their preliminary analysis seems to indicate that samples of *L. kroyeri* from the north differ from those in the south. Manera and Dezfuli (2003) examined *Lernanthropus kroyeri* infections and pathology in cultured sea bass in Greece. They determined that *Lernanthropus kroyeri* cause the erosion, desquamation and necrosis on the secondary lamellae and laceration on the tissue and vessels of infested gill.

The genus, *Lernanthropinus*, includes ten species (Walter, 2015). Venmathi Maran et al. (2014) referred that the diagnostic features of the genus *Lernanthropinus* are: the presence of posterolateral plate-like structures on the trunk; the absence of dorsal and ventral plates on the trunk; both leg four and the urosome are visible in dorsal and ventral views (Ho and Do, 1985 cited by Venmathi Maran et al., 2014).

Nine species of the family, Lernanthropidae, have previously been recorded as parasitizing fishes in Turkish marine habitats. They are: *Lernanthropus kroyeri* Van Beneden, 1851 (Tokşen, 1999; Özel et al., 2004; Öktener et al., 2010); *Lernanthropus brevis* Richiardi, 1879 (Akmirza, 2003); *Lernanthropus indefinitus* Koyuncu, Castro Romero and Karaytuğ, 2012 (Koyuncu et al., 2012); *Lernanthropus gisleri* Van Beneden, 1852 (Özak et al., 2016); *Lernanthropus callionymicola* El-Rashidy and Boxshall, 2012 (Özak et al., 2016); *Lernanthropsis mugilis* (Brian, 1898) (Altunel, 1983); *Lernanthropinus trachuri* (Brian, 1903) (Öktener and Trilles, 2004); *Mitrapus oblongus* (Pillai, 1964) (Romero and Öktener, 2010); *Sagum posteli* Delamare-Deboutteville and Nunes-Ruivo, 1954 (Tokşen et al., 2012). This study aims to present the morphological characters of *Lernanthropinus trachuri* from Turkey and is given with drawings and photos.

MATERIAL AND METHODS

Three hundred twenty of Mediterranean horse mackerel were collected by local gears from the Bandırma Bay, Sea of Marmara in Turkey. Parasites recovered from the hosts were fixed in 70% ethanol. Some specimens were cleared in lactic acid and their appendages were dissected out by using Wild M5 stereo microscope. Dissected parts were mounted on slides in glycerin-gelatine mounting medium. The photos were taken with the aid of Canon camera (EOS 1100D) connected to a microscope. The appendages were drawn with the aid of a camera lucida (Olympus BH-DA). All measurements are in millimeters. Terminology of appendage structure follows Kabata (1979; 2003). The scientific names, synonyms of parasite and host were checked with Walter and Boxshall (2018a, b, c).

RESULTS AND DISCUSSION

Subclass Copepoda Milne Edwards, 1840; Order Siphonostomatoida Thorell, 1859; Family Lernanthropidae; *Lernanthropinus trachuri* (Brian, 1903) (Figs. 1-3); Syn. *Lernanthropus trachuri* Brian, 1903; *Lernanthropus lichiae* Goggio, 1906 (Walter and Boxshall 2018 a, b, c)

Host: *Trachurus mediterraneus* (Steindachner, 1868) (Pisces: Carangidae); Mediterranean horse mackerel.

Total number of parasites: 28 females. Dissected material: 10 females.

All parasites attached to the gill filaments. The prevalence of parasites was 8.75%.

Figure 1: *Lernanthropinus trachuri* female.

Description – Female morphology (Fig. 1): Body length varies from 2.75 to 3.25 mm. Antennule (Figs. 2a and 3a) seven segments; first segment without segmentation, second segment two setae, third segment with three setae, fourth segment with one seta, fifth segment with two setae; sixth segment with one seta, seventh segment with nine setae. Antenna (Figs. 2b and 3b) two segmented; robust and bearing small papilliform process and small spine; subchela forming as strongly curved claw; claw two short spiniform processes, distal part with longitudinal ringes. Maxillule (Figs. 2c and 3c) bilobed; smaller outer lobe (exopod) with inflated base and tipped with a papilliform process; longer inner lobe (endopod) bearing three unequal terminal process. Maxilliped (Figs. 2d and 3d) two segments; corpus robust and myxal area with unarmed; subchela bears two small spines on medial surface of shaft; claw with fine longitudinal ridges. Mandible (Figs. 2e and 3e) two segmented, basal segment short, distal segment elongated, with seven teeth on terminal blade. Maxilla (Figs. 2f, 2g and 3f) two segmented, brachiform; proximal part robust with no arms and longer than brachium; distal part (brachium) distally long with a spine on inner margin and terminal claw with one spiniform process and two rows of sharp denticles on inner margin. First leg (Figs. 2i and 3h) protopod with an outer seta and an inner seta; exopod larger than endopod; exopod 1-segmented and tipped with five robust spines; endopod inflated lobe tipped with slender seta. Second leg (Figs. 2j and 3i) smaller than first leg; with inconspicuous protopod carrying a blunt inner process; exopod tipped with five spines and endopod with short apical seta; a lateral large outer protuberance on protopod. Leg three not fused, unarmed. Leg four and leg five represented by pair of bilobate process, long, fleshy, having identical blunt tips. Uropod (Figs. 2h and 3g) with two short setae distally; two long setae posteriorly.

Lernanthropinus trachuri has been found in the North Atlantic, Mediterranean, and Adriatic seas (Walter and Boxshall 2018 a, b, c). This lernanthropid is mainly a parasite of carangid fishes. It was reported from four fish families. *Lernanthropinus trachuri* (Brian, 1903) were mostly reported as *Lernanthropus trachuri* (Brian, 1903) on *Trachurus lathami* (Timi and Etchegoin, 1996; Braicovich et al., 2012; Luz et al., 2012), on *Trachurus trachurus* (Brian, 1903, 1906; Nunes-Ruivo, 1954; Papoutsoglou, 1976; Diebakate, 1994; Benmansour and Ben Hassine, 1998; MacKenzie et al., 2008), on *Trachurus capensis* (syn. *T. trachurus c.*) (Piasecki, 1982; Roux, 2013; Bowker et al., 2016), on *Trachurus picturatus* (Gaevskaya and Kovaleva, 1985), on *Trachurus murphyi* (syn. *Trachurus symmetricus murphyi*; *Trachurus picturatus murphyi*) (Romero and Kuroki, 1985; George-Nascimento and Arancibia, 1992; Oliva, 1994; Oliva, 1999; George-Nascimento, 2000; Quiroz Gil, 2014), on *Ariomma bondi* (syn. *Paracubiceps ledanoisi*) (Delamare-Deboutteville and Nunes-Ruivo, 1954; Capart, 1959), on *Chloroscombrus chrysurus* (Diebakate, 1994), on *Erythrocles monodi* (Diebakate, 1994), on *Seriolella violacea* (Romero and Kuroki, 1985; Jara and Díaz-Limay, 1995; Iannacone, 2003), on *Trachurus mediterraneus* (Öktener and Trilles, 2004), on *Campogramma glaycos* (syn. *Lichia vadigo*) (Brian, 1903), *Caranx rhonchus* (syn. *Caranx ronchus*) (Delamare-Deboutteville and Nunes-Ruivo, 1954). *Lernanthropinus trachuri* (Brian, 1903) was also reported as *Lernanthropus lichiae* Goggio, 1906 on *Erythrocles monodi* (Capart, 1959) and *Campogramma glaycos* (syn. *Lichia vadigo*) (Goggio, 1906).

The hosts' parasitism with *Lernanthropinus trachuri* was examined according to family characteristics nine of 12 host species belongs to Carangidae, one species to Centrolophidae, one species to Emmelichthyidae; and one species to Ariommatidae. The hosts' parasitism with *Lernanthropinus trachuri* was examined according to habitat selections; four of 12 host fish species are pelagic-neritic; three species of benthopelagic; three species of pelagic-oceanic; one species of demersal; one species of reef-associated. The hosts parasitism with *Lernanthropinus trachuri* according to feeding habits; all hosts are carnivorous.

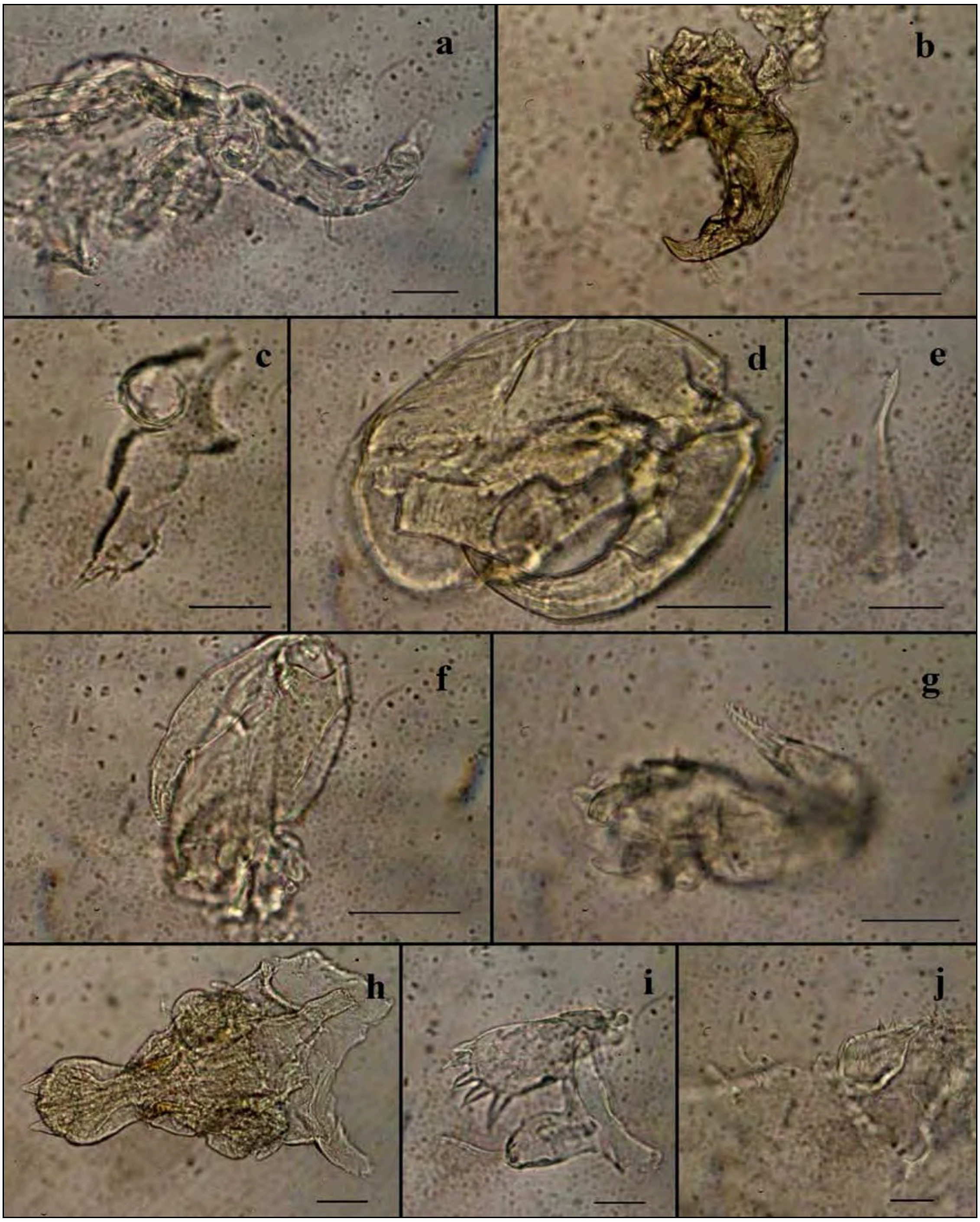

Figure 2: *Lernanthropinus trachuri*; (a) Antennule (0.02 mm), (b) Antenna (0.13 mm), (c) Maxillule (0.03 mm), (d) Maxilliped (0.05 mm), (e) Mandible (0.03 mm), (f) Maxilla (0.045 mm), (g) Maxilla (0.045 mm), (h) Caudal ramus (0.07 mm), (i) First leg (0.015 mm), (j) Second leg (0.04 mm).

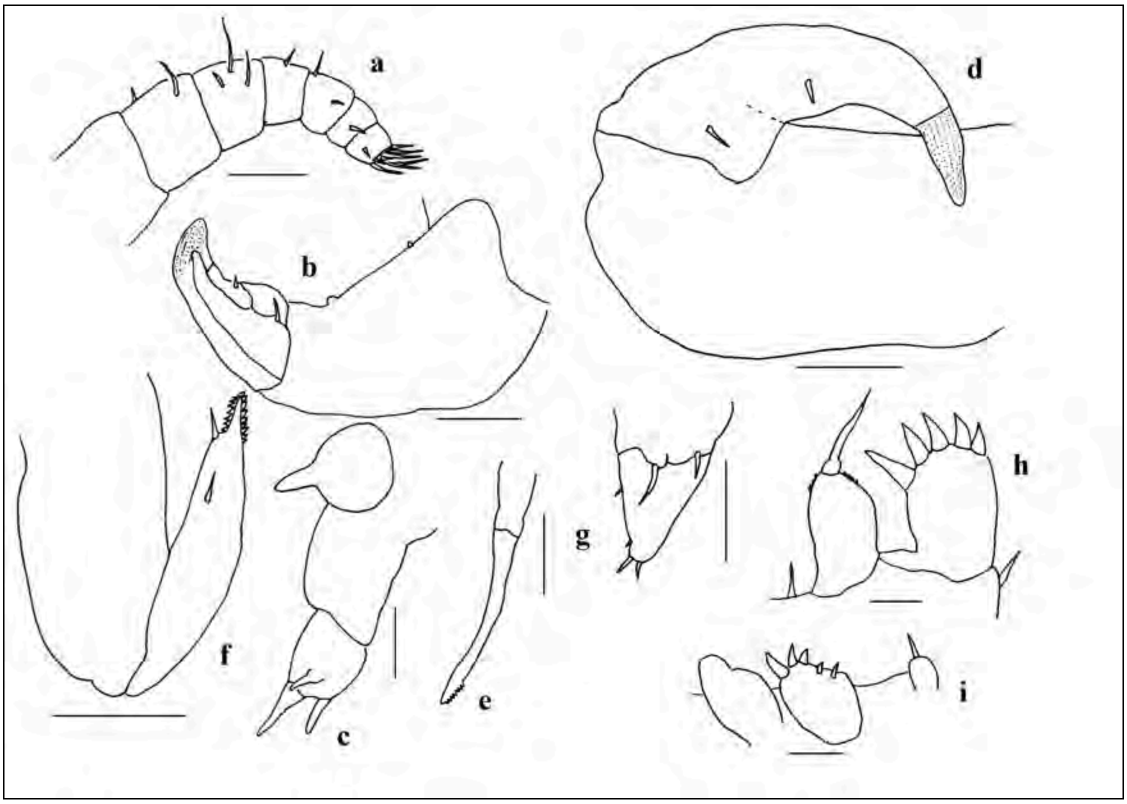

Figure 3: *Lernanthropinus trachuri,* (a) Antennule (0.03 mm), (b) Antenna (0.065 mm), (c) Maxillule (0.03 mm), (d) Maxilliped (0.05 mm), (e) Mandible (0.05 mm), (f) Maxilla (0.05 mm), (g) Uropod (0.05 mm), (h) First leg (0.015 mm), (i) Second leg (0.04 mm).

General body status, first and second legs, mouth parts such as antennules, antenna, maxilliped, maxillule, maxilla of *Lernanthropinus trachuri* described from specimens collected in this study were in agreement with previous descriptions of this species by (Brian 1906; Goggio, 1906; Nunes-Ruivo, 1954; Piasecki, 1982; Romero and Kuroki, 1985; Diebakate, 1994), except of seta number on segments of antennules.

CONCLUSIONS

Lernanthropinus trachuri (Brian, 1903) (Copepoda, Siphonostomatoida, Lernanthropidae) was reported from the Bosphorus, Sea of Marmara by Öktener and Trilles (2004). But the morphological characters of it could not be presented by the first author's limited laboratory possibilities and literature. Now, the same author found this parasite from the same host species. This study aims to present the morphological characters from Turkey and to compare other morphological characters from various countries in the future.

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LAND SNAIL COMMUNITIES IN LIMESTONE GORGES FROM THE SOUTHERN PART OF THE METALIFERI MOUNTAINS (APUSENI MOUNTAINS, ROMANIA)

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KEYWORDS: land snail communities, biodiversity, limestone, Metaliferi Mountains, Glodului, Cibului, Mada.

ABSTRACT

This study focuses on terrestrial gastropod communities in a karst area, where the presence of water and the limestone generates favourable environment for land snails. Three limestone gorges were analysed located in the southeast of the Metaliferi Mountains. Four different habitats in three limestone gorges were analysed – Glodului, Cibului and Mada. A total of 42 species of land snails were identified. The terrestrial gastropod communities in the area are dominated by calciphile species, such as *Granaria frumentum, Truncatellina cylindrica* and *Alopia bielzii madensis.* The differences between the analysed habitats are not pronounced enough to be reflected in the structure of the snail communities. Significant positive correlation was found between the abundance of land snails and the habitat exposure.

RÉSUMÉ: Communautés de gastéropodes terrestres des gorges calcaires dans la partie Sud des Montagnes Metaliferi (Montagnes Apuseni, Roumanie).

L'étude est axée sur les communautés de gastropodes terrestres dans une zone karstique ou la présence d'eaux et le substrat calcaire favorise les mollusques terrestres. Trois gorges calcaires ont été analysées, Glodului, Cibului et Mada et diferentes d'habitats. Un total de 42 espèces de gastéropodes terrestres a été identifié. Les communautés de gastéropodes terrestres de la zone considérée sont dominées par des espèces calciphile telles que *Granaria frumentum*, *Truncatellina cylindrica* et *Alopia bielzii madensis*. Les différences entre les habitats analysés ne sont pas suffisamment importantes pour se refléter dans la structure des communautés de mollusques. Une corrélation positive significative a été trouvée entre l'abondance des gastéropodes terrestres et l'exposition de l'habitat.

REZUMAT: Comunități de gastropode terestre din chei calcaroase din sudul Munților Metaliferi (Munții Apuseni, România).

Studiul se concentrează pe comunitățile de gastropode terestre dintr-o zonă carstică în care prezența apei și substratul calcaros generează un mediu favorabil pentru moluștele terestre. Trei chei calcaroase au fost analizate, Cheile Glodului, Cibului și Măzii în diferite habitate. Un număr de 42 de specii de gastropode terestre au fost identificate. Comunitățile de gastropode terestre din zona analizată sunt dominate de specii calcifile precum *Granaria frumentum, Truncatellina cylindrica* și *Alopia bielzii madensis*. Diferenţele dintre habitatele analizate nu sunt suficient de accentuate pentru a fi reflectate în structura comunităților de moluște. Corelație pozitivă semnificativă a fost găsită între abundența gastropodelor terestre și expoziția habitatului.

INTRODUCTION

Water by its morphogenetic action generates the karst landscape valuable not only through its spectacularity but also through the diversity of organisms that find a favourable environment here. The diversity and complexity of habitats in karst areas is associated with a large diversity of organism (Pipan and Culver, 2007). Among the invertebrate species inhabiting these areas, land snails are one of the most representatives. The water source, calcium availability, diversity of habitats, presence of shelter, relief and vegetation (which offer shade as well as resources), are all responsible for the presence of important land snail communities, often with species developing very large populations (Kerney and Cameron, 1979; Nekola, 1999; Horsák, 2006).

The Geoagiu River, with its tributaries Cib, Glodului, and Mada (Balșa), drains the south-eastern part of the Metaliferi Mountains, a region consisting of a petrographic mosaic of conglomerates, sandstone, and marl which are associated with Jurassic limestone rocks (Cocean, 1988). There are two limestone massifs in the basin of the Geoagiu River – Pleașa Glodului (855 m) in the north and Pleașa Mare (712 m) in the south. The tributaries of the Geoagiu have cut five key sectors. Among them, the Glodului, Cibului, and Mada gorges are the most important (Cocean, 1988). Each of these three limestone gorges are nature reserves, and are also included in ROSCI0029 Natura 2000 site (Glodului, Cibului and Mada gorges), with a total area of 735 ha.

The malacofauna of the Apuseni Mountains has been the subject of several recent publications (Bába and Sárkány-Kiss, 1998; Bába and Sárkány-Kiss, 2001; Domokos and Váncsa, 2005; Domokos and Lennert, 2007; Lengyel and Páll-Gergely, 2010) dealing mostly with their western part. These publications successfully complete the classical malacological works including information regarding the Apuseni Mountains (Bielz, 1867; Grossu, 1981, 1983, 1987; Kimakowicz, 1890).

This paper is focussed on the land snail fauna of the limestone gorges included in the Natura 2000 site Cheile Glodului, Cibului and Măzii (Glodului, Cibului and Mada gorges), area lacking recent information on terrestrial gastropod fauna and where studies of gastropod communities are absent.

MATERIAL AND METHODS

Semi-quantitative samples were taken during 2015 from three sampling areas – Mada Gorge, Glodului Gorge and Cibului Gorge. The location of the study area is represented in figure 1. In each sampling area, samples were taken from the forest, at the base of the limestone cliffs, and near the water. Four types of habitats were considered, and 12 sampling points were selected, varying in size of limestone outcrops, forestation and humidity. The location of the sampling points, habitat type and exposure is described in table 1. Snails were collected by hand, by visual searching by two collectors for about one hour, and an additional leaf litter sample was taken. About 20 l. of leaf litter was sieved and the material was sorted and identified in the laboratory (Pokryszko and Cameron, 1995). The works of Grossu (1981, 1983, 1987) and Welter-Schultes (2012) were used for species identification. The taxonomic list follows Fauna Europaea (Bank, 2017).

The list of species was registered. The number of living individuals and fresh empty shells were used to estimate snail abundance. The community structure was assessed using the relative abundance of each species. The presence/absence of snail species was used to build a Jaccard similarity diagram of the sampling stations (single linkage method, Euclidean distance). Diversity was calculated based on the Shannon-Wiener biodiversity index.

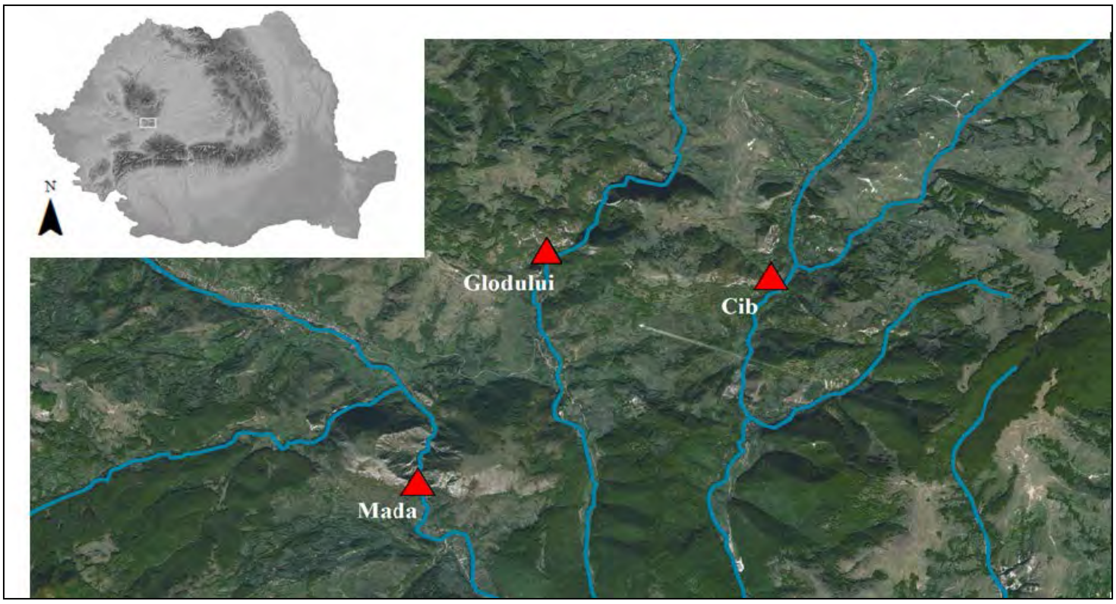

Figure 1: The location of sampling areas.

Table 1: Location and characteristics of the sampling points (G1-G4, Glodului; M1-M4, Mada; C1-C4, Cibului). The following codification was used for habitat type: 1 – limestone wall; 2 – limestone cliffs in the forest; 3 – limestone outcrops in the forest; 4 – limestone outcrops near the water.

Sampling point	**G1**	**G2**	**G3**	**G4**	**M1**	**M2**
Exposure	NE	NE	NE	N	S	SV
Habitat type	3	4	2	1	2	4
Coordinates	46.0175N 23.1451E	46.0173N 23.1459E	46.0172N 23.1459E	46.0328N 23.1411E	46.0073N 23.1250E	46.0073N 23.1258E
Altitude	437	416	419	481	348	348
Sampling point	**M3**	**M4**	**C1**	**C2**	**C3**	**C4**
Exposure	SV	SV	SE	NE	E	N
Habitat type	3	1	3	1	4	2
Coordinates	46.0074N 23.1253E	46.0075N 23.1258E	46.0363N 23.1777E	46.0363N 23.1771E	46.0319N 23.1782E	46.02178N 23.1719E
Altitude	348	351	526	526	472	382

RESULTS AND DISCUSSION

A total of 16,303 specimens from 42 species were found in the samples. The species diversity is comparable to that found in other karst areas of Romania (Gheoca, 2016). The systematic list of encountered species is presented in table 2. Consistent with the nature of the karst habitats, most of the land snail's species present in the area are specific for dry open calcareous habitats. Twenty-eight species were found in all three gorges. The rest of the species are less common, occasionally present in some of the samples and only in small number; the exception was *Pupilla triplicata*, which was only found in Glodului and Mada gorges, and was very abundant in the latter.

Table 2: Systematic list of land snail species identified in the area. The presence in the sampling areas is represented as well the zoogeographic elements, the relative abundance (A) and frequency (F) expressed as percentages (all the samples are considered). The highest values are presented in bold; Mada-M, Glodului-G, Cib-C.

Species	Area	A%	F%	Zoogeogarphic elements
Platyla banatica (Rossmässler 1842)	C	0.006	8.33	E-European
Platyla perpusilla (Reinhardt 1880)	M, G, C	0.035	66.66	E-European
Succinella oblonga (Draparnaud 1801)	M, G, C	0.006	8.33	Eurasian
Cochlicopa lubricella (Rossmässler 1834)	M, G, C	0.808	83.33	European
Sphyradium doliolum (Bruguière 1792)	M, G, C	0.717	**91.66**	European
Spelaeodiscus triarius (Rossmässler 1839)	M, G, C	0.791	**91.66**	CE-Eurropean
Vallonia costata (Müller O. F. 1774)	M, G, C	**4.733**	83.33	Palearctic
Vallonia excentrica Sterki 1893	M, G, C	0.864	75	Holarctic
Acanthinula aculeata (Müller O. F. 1774)	M, G, C	0.622	**91.66**	W Palearctic
Pupilla muscorum (Linnaeus, 1758)	M, G, C	0.328	50	European
Pupilla triplicata (Studer S., 1820)	M, C	3.580	58.33	SE-Eurropean
Pyramidula pusilla Gitt. and Bank 1996	M, G, C	**4.952**	**91.66**	European
Granaria frumentum (Draparnaud 1801)	M, G, C	**27.041**	**100**	CE-European
Chondrina clienta (Westerlund 1883)	M, G, C	5.206	91.66	CE-European
Truncatellina cylindrica (Férussac 1807)	M, G, C	**11.480**	100	W Palearctic
Vertigo pusilla Müller O. F. 1774	M, G, C	0.048	50	European
Vertigo pygmaea (Draparnaud 1801)	M, C	0.011	16.66	Holarctic
Merdigera obscura (Müller O. F. 1774)	M, C	0.012	25	W Palearctic
Chondrula tridens (Müller O. F. 1774)	M, G, C	2.116	66.66	European
Alopia bielzii madensis (Fuss C. 1855)	M, G, C	**8.162**	83.33	Endemic
Cochlodina laminata (Montagu 1803)	M, G, C	0.588	75	European
Cochlodina orthostoma (Menke 1828)	M, G, C	0.201	50	CE-European
Ruthenica filograna (Rossmässler 1836)	M, G, C	**7.132**	**100**	E-European
Clausilia dubia Schmidt A. 1856	M, G, C	**7.211**	**100**	European
Laciniaria plicata (Draparnaud 1801)	M, C	2.110	**91.66**	CE-European
Balea biplicata (Montagu 1803)	C	0.006	8.33	C-European
Bulgarica vetusta (Rossmässler 1836)	C	1.84	58.33	E-European
Cecilioides acicula (Müller O. F. 1774)	C	0.006	8.33	W-Palearctic
Punctum pygmaeum (Draparnaud 1801)	M, C	0.435	58.33	Holarctic
Discus perspectivus (von Mühlfeld 1816)	G, C	0.131	25	CE-European
Vitrea diaphana (Studer S. 1820)	M, C	0.320	33.33	CE-European
Euconulus fulvus (Müller O. F. 1774)	C	0.150	16.66	Holarctic
Oxychilus glaber (Rossmässler 1835)	C	0.006	8.33	European
Aegopinella minor (Stabile 1864)	M, G, C	1.851	83.33	European
Vitrina pellucida (Müller O. F. 1774)	M, G, C	1.318	66.66	Holarctic
Fruticicola fruticum (Müller O. F. 1774)	M, G, C	0.113	25	European
Euomphalia strigella (Draparnaud 1801)	M, G, C	1.223	83.33	CE-European
Lozekia transsilvanica (Westerlund 1876)	M, G, C	2.361	83.33	E-Carpathian
Drobacia banatica (Rossmässler 1838)	M	0.031	8.66	Carpathian endemic
Faustina faustina (Rossmässler 1835)	M, G, C	1.282	75	Carpathian
Cepaea vindobonensis (Pfeiffer C. 1828)	M, G, C	0.061	33.33	CE-European
Helix pomatia Linnaeus 1758	M, G, C	0.062	41.66	European

The most abundant species for all the samples was *Granaria frumentum* (27.041%) followed by *Truncatellina cylindrica* (11.48%), *Alopia bielzii madensis* (8.126%), *Clausilia dubia* (7.211%) and *Ruthenica filograna* (7.132%). Regarding the frequency values, *Granaria frumentum, Ruthenica filograna* and *Clausilia dubia* were present in all the sampling points, while *Sphyradium doliolum, Spelaeodiscus triarius, Acanthinula aculeata, Pyramidula pusilla* and *Laciniaria plicata* in 11 of 12 sampling points.

Significant differences were recorded in snail abundance for the three karst areas, with values as different as 8,811 specimens (33 species) in Mada Gorge to only 5,294 (38 species) in Cibului Gorge and 2,198 (35 species) in Glodului Gorge (Fig. 2). Although the land snail abundance was very different in the three gorges, the Shannon-Wiener biodiversity index values were high, ranging between 2.035 and 2.948. Higher species richness could imply higher Shannon-Wiener diversity, not always applied due to the presence of extremely large populations for some of the snail species in several sampling stations. The Shannon-Wiener index values are higher than those found by Stamol (1991) in forest phytocoenoses in Croatia.

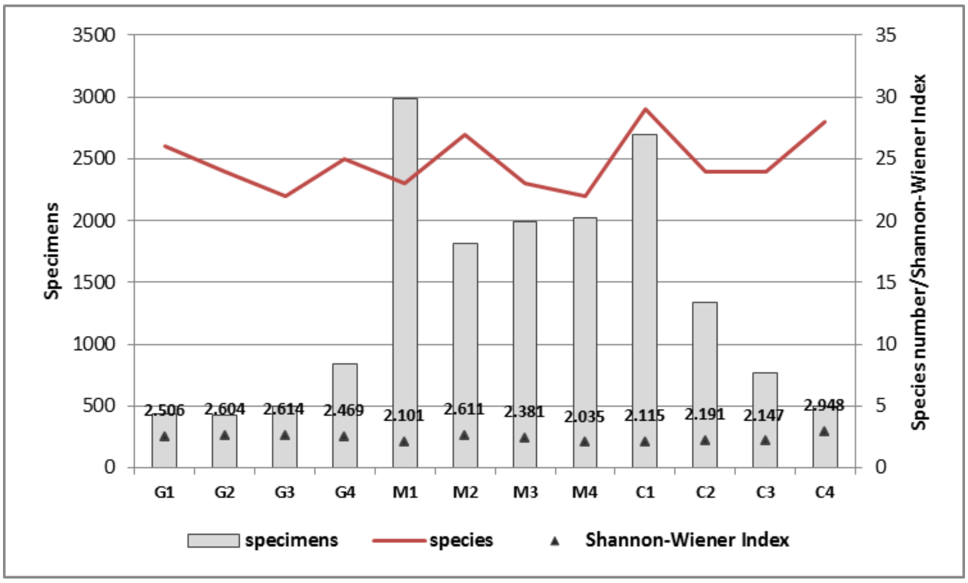

Figure 2: The number of species and specimens at each sampling point.

The differences in abundance between the three karst areas are only partly sustained by differences in community structure. The most abundant snail species in each of the three sampling areas are represented in figure 3. In Mada Gorge the land snail community is numerically dominated by microsnails such as *Truncatelina cylindrica,* and *Vallonia costata. Granaria frumentum* is also abundant, along with *Clausilia dubia* and *Alopia bielzii madensis.*

Glodului Gorge has a smaller community dominated by *Granaria frumentum, Alopia bielzii madensis* and *Lozekia transsilvanica*. *G. frumentum* is also the most abundant in Cibului Gorge, followed by *Ruthenica filograna*; the rest of the species are less abundant here.

Regarding the effect of habitat type and exposure on snail assemblages, significant positive correlation was found only between land snail abundance and exposure (Pearson $r = 0.8743$; $p < 0.001$).

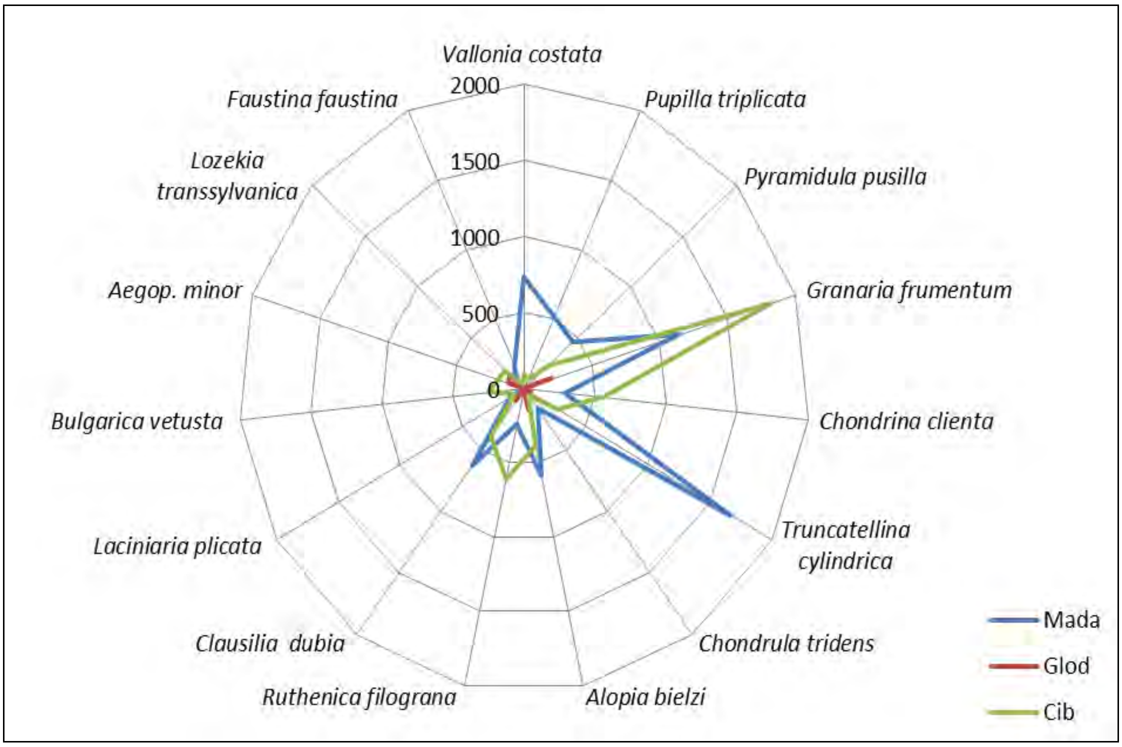

Figure 3: Abundance of the most common species in each of the three gorges.

As mentioned, the type of habitat does not significantly alter the structure of the terrestrial gastropod community. Differences between the considered habitats proved to be not so pronounced as to significantly affect the structure of the species. The habitats located near water are slightly different, where the humidity factor allows the presence of species that are not characteristic of karst habitats. Thus, species such as *Drobacia banatica, Fruticicola fruticum, Euomphalia strigella*, and *Vitrea diaphana* are only present in the areas near the water. However, their presence in small number does not significantly affect the land snail assemblage.

Exposure is the only element that seems to affect the terrestrial gastropods community, by the composition of the species, but especially by the number of individuals. This dependence, as demonstrated previously by the value of the Pearson correlation coefficient, is also reflected in the tree diagram built on the species relative abundance (Fig. 4). The tree diagram rather demonstrates a grouping after the exposure than an affinity depending on the area or type of habitat. This is due to the fact that the dominant species here, which constitute the largest part of the community in all three investigated areas, are calciphile species that are good at tolerating the high temperatures caused by direct sunlight exposure and the capacity of limestone to accumulate heat, being more abundant on the southern slopes. An example is *Granaria frumentum*, which represents almost a third of the land snails inhabiting the area, but also *Truncatellina cylindrica* and *Vallonia costata*.

Other species, such as *Lozekia transsilvanica, Clausilia dubia*, and *Ruthenica filograna*, become codominant only in the forested areas with a northern or western exposure.

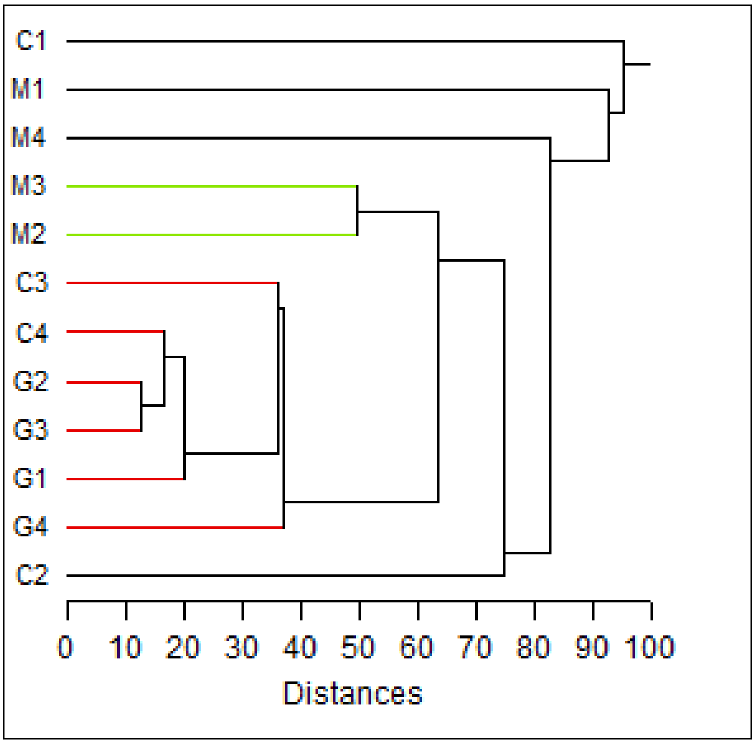

Figure 4: Cluster analysis of sampling sites based on species relative abundance (single linkage, Euclidean distance).

CONCLUSIONS

The karst area in the southwest of the Metaliferi Mountains has characteristic malacofauna, as is usually found in limestone areas, dominated by species associated with limestone habitats that sometimes develop very large populations. The three gorges are significantly different in terms of land snail abundance; the largest number of individuals was collected in Mada Gorge, followed by Cib Gorge and the lowest abundance characterized the habitats of Glodului Gorge, with about a quarter of the abundance found in Mada Gorge.

The most abundant species are *Granaria frumentum*, *Truncatellina cylindrica, Clausilia dubia*, *Ruthenica filograna* and the endemic calciphile species *Alopia bielzii madensis.* In humid habitats other species like *Drobacia banatica, Fruticicola fruticum*, *Vitrina pellucida* and *Euomphalia strigella* can be present but without significantly affecting the community structure.

A significant positive correlation was found between land snail abundance and exposure, the southern slopes having significantly larger populations of the calciphile species.

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TECHNICAL SOLUTIONS TO MITIGATE SHIFTING FISH FAUNA ZONES IMPACTED BY LONG TERM HABITAT DEGRADATION IN THE BISTRA MĂRUI RIVER – STUDY CASE

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KEYWORDS: Carpathian river, fragmentation mitigation technical elements.

ABSTRACT

The Bistra Mărului River fish fauna has been severely impacted by man-made activities, especially through longitudinal fragmentation, over the past 40 years. Fish fauna monitoring revealed structural changes and technical methods have been proposed, in order to restore the natural connectivity and the conservation of fish species. Benefits should accrue for key species: *Salmo trutta fario, Cottus gobio, Thymallus thymallus, Eudontomyzon danfordi, Eudontomyzon vladykovi, Gobio uranoscopus, Barbus meridionalis,* and *Condrostoma nasus*.

RÉSUMÉ: Solutions techniques pour atténuer les modifications des zones piscicoles touchées par la dégradation à long terme de l'habitat dans le Bistra Mărului – étude de cas.

La faune piscicole de la rivière Bistra Mărului a été soumise, durant les derniers 40 ans, à un fort impact anthropique, particulièrement due à la fragmentation longitudinale. La surveillance de l'ichtyofaune a mis en évidence le changement de sa structure. Des méthodes techniques ont été proposées, strictement adaptées aux catégories majeures de constructions hydrotechniques présentes sur la rivière étudiée, afin de remettre en état la connectivité naturelle et la conservation particulièrement des espèces clé de poissons: *Salmo trutta fario, Cottus gobio, Thymallus thymallus, Eudontomyzon danfordi, Eudontomyzon vladykovi, Gobio uranoscopus, Barbus meridionalis et Condrostoma nasus.*

REZUMAT: Soluții tehnice pentru reducerea deplasării zonelor ihtiologice afectate de degradarea habitatului pe termen lung în râul Bistra Mărului – studiu de caz.

Ihtiofauna râului Bistra Mărului a suferit în ultimii 40 de ani un impact antropic major, în special datorită fragmentării longitudinale. Monitoringul ihtiofaunei a relevat modificarea structurii acesteia. Au fost propuse metode tehnice adaptate strict la categoriile majore de construcţii hidrotehnice prezente pe râul studiat, în vederea refacerii conectivităţii naturale şi a conservării unor specii cheie de peşti: *Salmo trutta fario, Cottus gobio, Thymallus thymallus, Eudontomyzon danfordi, Eudontomyzon vladykovi, Gobio uranoscopus, Barbus meridionalis* şi *Condrostoma nasus*.

INTRODUCTION

Freshwater ecosystems are shared by multiple users and highly vulnerable to human interventions (Cambray and Bianco, 1998). Unfortunately, most systems are not inventoried sufficiently (Stiassny, 2002) due to the lack of resources. Freshwater systems, in this regard, have declined more rapidly than marine habitats (Sala et al., 2000). Streams and rivers are among the most degraded ecological systems in the world (Vörösmarty et al., 2010). Urgent steps are needed to come up with viable solutions that deal with development impacts.

The Danube Basin is the second largest, and most developed, in Europe. Extensive development over the past decades severely impacted aquatic habitats and fauna (Tockner et al., 2008; Bănăduc et al., 2016). A significant stressor which affects aquatic communities (Birk et al., 2012) is longitudinal fragmentation. The construction of regulators, dams and weirs can negatively influence the environmental river flow requirements (Acreman and Dunbar, 2004) and, subsequently, fish communities (Soolutayo, 2012; Olopade, 2013; Rumana et al., 2015). Fish are one of the most sensitive taxa group to reduced connectivity in Carpathian rivers and streams (Bănăduc 1999, 2000; Bănăduc et al., 2013; Voicu and Merten, 2014; Telcean and Cupşa, 2015; Voicu et al., 2017) because migration barriers can block access to important feeding, spawning and nursery habitat (Rathert et al., 1999; Oberdorff et al., 2011).

Globally, over 50,000 large dams and an unidentified number of smaller barriers for fish (Richter et al., 2010) threaten fish communities.

Barriers to upstream fish migration can be partially overcome by using fish passes; a channel through or around a migration barrier. If adapted to local specific conditions, even though the favorable outcome of such measures depends on multiple factors such as size of structure, volume and hydraulics of water moving through, fish communities can be rehabilitated (Mallen-Cooper and Brand, 2007). At structures like small culverts or weirs, solutions may be inexpensive (Katopodis, 1990; Aadland, 2010; Kemp and O'Hanley, 2010; Voicu et al., 2017, 2018). But it is important to note that fish passes need to be effective in a bi-directional sense. That is, consideration must be given to downstream movement to protect the downstream drift of fish eggs and larvae which is a characteristic of the life cycle of numerous fish species (Baumgartner et al., 2014).

In accordance with Water Framework Directive, river administrators must restore and maintain the longitudinal and lateral connectivity of rivers (Voicu and Merten, 2014). This is both a priority and a challenge for the specialists in the field (Voicu and Dominguez, 2016; Voicu and Baki, 2017). Restoring longitudinal connectivity is an essential component of the lotic ecosystems functions (Voicu and Breţcan, 2014) and must represent the basis of the protection of watercourses (Voicu et al., 2015). But rarely are potential impacts on fish considered in the design stages of river development programs.

We hypothesise that habitat fragmentation including habitat modifications, deficit and loss, is a long term driver of fish fauna change. A case study in the Timiş River basin (Fig. 1), Bistra Mărului River (Fig. 2) was implemented to determine the extent of human impacts and determine possible technical solutions.

Bistra Mărului River (Timiş and Danube basins) was selected for this study. The river has fish monitoring data from over 40 years and has many migration barriers, from the smallest 0.20 cm to the largest two m high. River flow is regulated by the Măru Dam of 125 m high (completed in 1992).

The Timiş River basin is the main hydrographic basin of the south-western side of Romania, the largest basin from the historical region Banat, with a surface of 5,795 km^2, its largest part laying on Romania's national territory. The upper side of the Timiş Basin includes the western slopes of the Banat Mountains, western slopes of the Ţarcu Mountains, Muntele Mic Mountain and Poiana Ruscă Mountains and the Timiş-Cerna corridor. The middle-lower side of the Timiş Basin includes the following relief units: Lugoj Hills, Pogăniş Hills, Lugoj Plain and Timiş Plain. The extreme lower side of this basin is managed by Serbia.

Timiș Basin was significantly developed from the economic point of view since the 17th century. The current ecological state of some lotic sectors habitats has changed from "natural" to "severely modified"; and has significantly impacted fish populations. (Bănăduc et al., 2013; Burghelea et al., 2013; Stavrescu-Bedivan et al., 2017)

Comprehensive studies on the Timiș River ichthyofauna were made in the 60's of the last century (Bănărescu, 1964), and recently (Bănăduc et al., 2013).

Furthermore, it is known that species with high conservation value from the Bistra River to the Timiş River increases the conservative value and the resilience of the Timiş River sector from Maciova and Peștere towards downstream (Bănăduc et al., 2013).

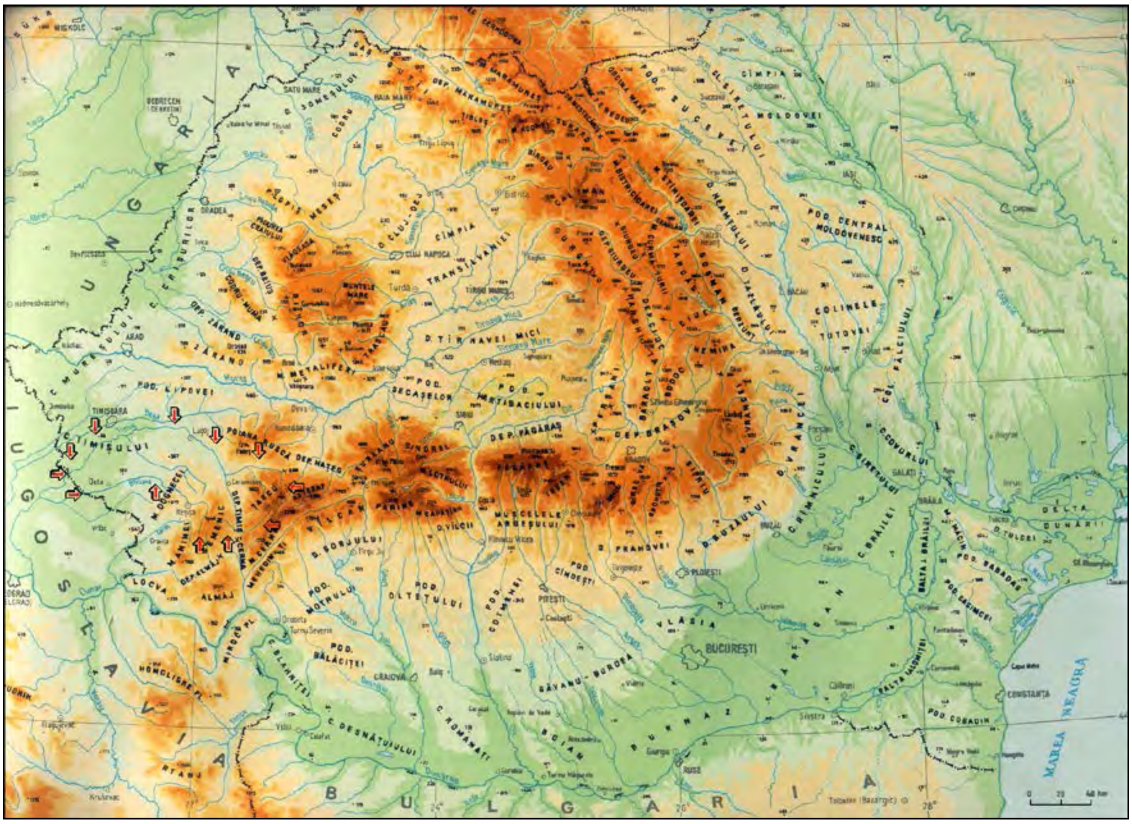


Figure 1: The Timiş River basin localization
(Badea et al., 1983 – modified).

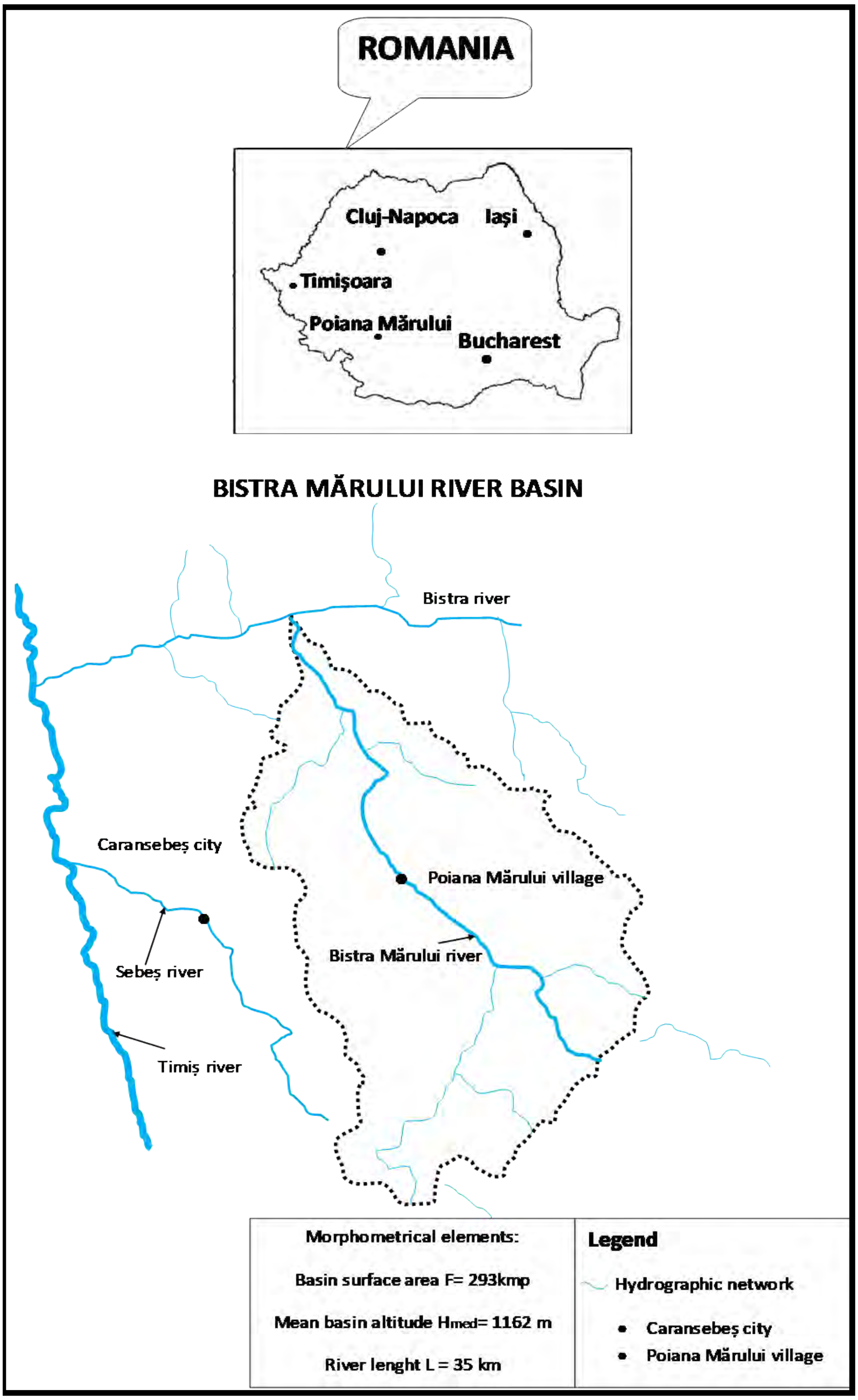


Figure 2: Bistra Mărului River basin.

Environmental conditions and fish fauna vary both qualitatively and quantitatively in Carpathian streams, the habitat conditions variation led to the establishment of fish zonation based on the characteristic/indicator fish species (Bănărescu, 1964). For instance, large and medium size Carpathian rivers, which spring in mountain areas have five such specific fish zones: I brown trout zone, II grayling and Mediterannean barbell zone, III nase zone, IV barbell zone, and V carp zone. Zone (I) is characterised by a fairly constant and cold temperature (variations do not exceed 7-8°C maximum) fast flow, with waterfalls, oxygen-saturated water, and short periods of frost. The indicator fish species of this zone is *Salmo trutta fario*, characteristic also being *Cottus gobio*, *Phoxinus phoxinus*, and *Orthrias barbatulus.*

This first section transitions into zone (II), which is dominated by fish species like: *Barbus meridionalis, Thymallus thymallus, Alburnoides bipunctatus, Sabanejewia romanica,* and *Sabanejewia aurata*. Zone (II) is characterised by a generally higher flow, less accentuated water current, generally devoid of waterfalls, permanently rocky bottom, being made up in general by of smaller boulders, water saturated in oxygen, oscillations of temperature 12-14°C.

The final zone (III) includes the hilly lotic sectors, characterised in general by a hard rocky (sometimes mixed with pebbles, sand, clay and/or mud) riverbed substrata. The rivers' water temperature oscillations are relatively high (18-19°C), in summer the water temperature can be over 20°C. Water levels also fluctuate and are high in the periods with precipitations and snow melt. The water is often high turbidity and can freeze on long sectors in winter. Indicator species in this zone are *Chondrostoma nasus*, also numerous being *Squalius cephalus, Barbus barbus,* and *Vimba vimba*. Other fish species in this zone can be: *Barbus meridionalis, Cottus gobio, Phoxinus phoxinus, Orthrias barbatulus, Gobio uranoscopus, Alburnoides bipunctatus, Gobio gobio, Gobio kessleri, Cobitis aurata, Cobitis romanica,* and *Alburnus alburnus*.

MATERIALS AND METHODS

This ichthyological monitoring study was done on the whole 35 km length of Bistra Mărului River (at an average altitude of 1,162 m a.s.l.), a river with a basin of 293 km^2, from its mountainous springs area to its end in the Oţelu Roşu locality, in the period 1980-2018. Among the total of 51 sampling stations (Fig. 3), 50 were lotic habitats stations with quantitative samples and one lenitic habitat (Poiana Mărului Lake) station with qualitative samples. For the stations localisation a "Garmin GPSmap 62s" global positioning system was used.

The fishing method which was used in this study, was the electrofishing in time/effort unit (30 minutes). The device which was used was an Aquatech IG 600, 30 A, 0.65/1.2 kw, with two net stopers. All the sampled fish, were identified, counted and immediately released in situ. The local fisherman captures were also checked, both in lenitic and lotic habitats.

The Carpathian Fish Index of Biotic Integrity (CF-IBI) (Bănăduc and Curtean-Bănăduc, 2002) was used in highlighting anthropogenic determined negative effects on fish fauna integrity, based on life history and feeding relationships selected metrics.

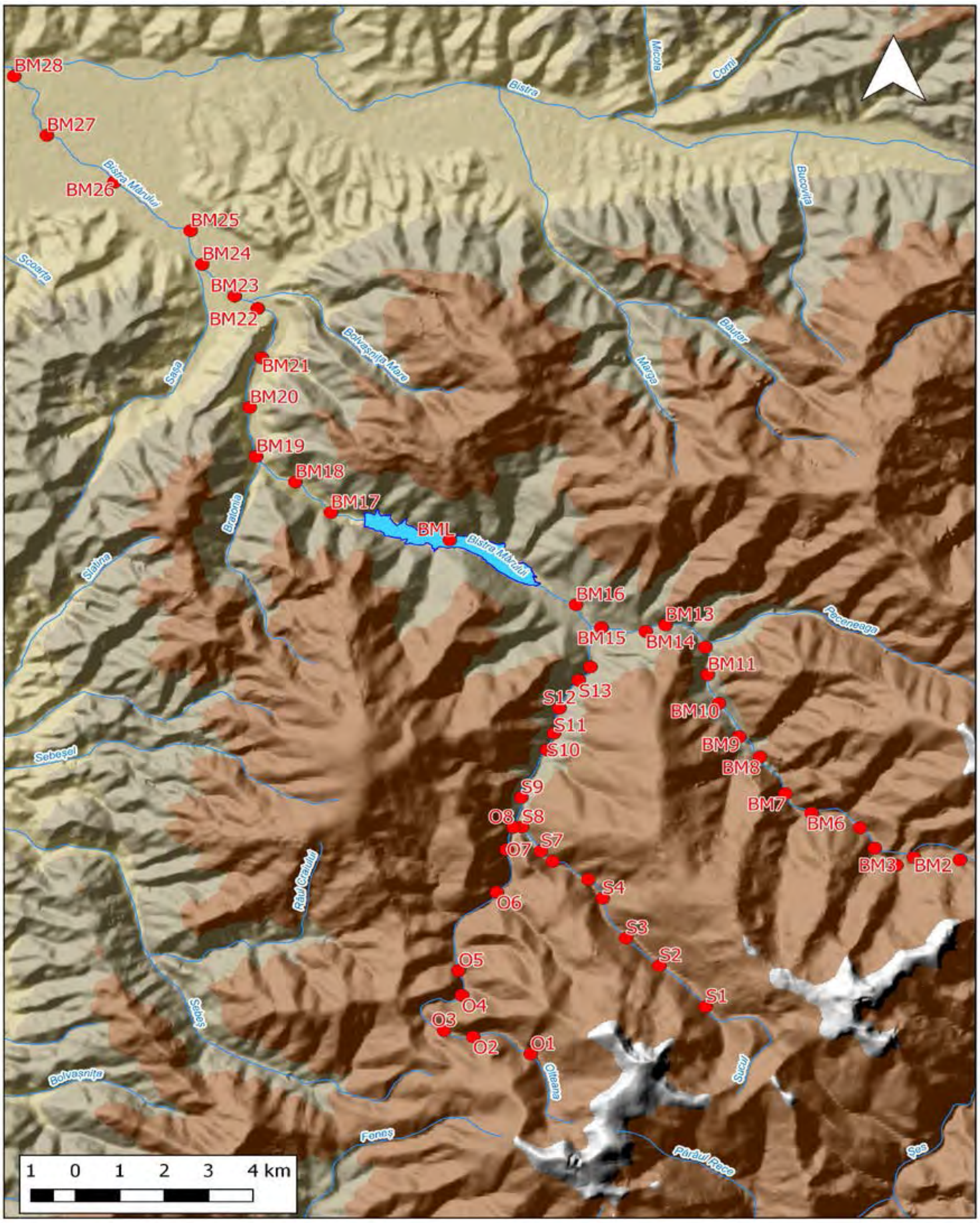


Figure 3: Sampling stations:
Bistra Mărului River (BM_n), Şucu Stream ($Ş_n$), Olteana Stream (O_n),
(GIS support – Pătrulescu A.).

RESULTS AND DISSCUSION

This study is based on the long term monitoring results in Bistra Mărului River of the local fish fauna species and especialy on the folowings key and/or indicator fish species: *Salmo trutta fario* Linnaeus, 1758, *Cottus gobio* (Linnaeus, 1758), *Thymallus thymallus* (Linnaeus, 1758), *Eudontomyzon danfordi* Regan, 1911; *Eudontomyzon vladykovi* Oliva and Zanandrea, 1959, *Gobio uranoscopus* (Agassiz, 1828), *Barbus meridionalis* Riso, 1827, and *Condrostoma nasus* (Linnaeus, 1758).

The synthetic results of the Bistra Mărului River and two of its main tributaries (Şucu and Olteana streams) sampling stations (Fig. 3) fish fauna long term monitoring indicate a total catch of 19 fish species. The proportion of each species in the total catch changed substantially between 1980 and 2018 (Tabs. 1 and 2).

Table 1: The Şucu and Olteana streams, Bistra Mărului tributaries, sampling stations fish communities species; P/A – presence/absence, * parasite on Osteichthyes; ** in the substrate of the confluence areas of some small brooks tributaries of the Bistra Mărului Lake; CF-IBI values.

Stations	Species	1980-1990	CF-IBI	1990-2000	CF-IBI	2000-2010	CF-IBI	2010-2018	CF-IBI
Şucu and Olteana streams – Bistra Mărului tributaries									
Ş$_{1-4}$	–	–	–	–	–	–	–	–	–
O$_{1-4}$	–	–	–	–	–	–	–	–	–
Ş$_{5}$	*Salmo trutta fario*	P	45	P	45	P	45	P	45
O$_{5}$	–	–	–	–	–	–	–	–	–
Ş$_{6}$	*Salmo trutta fario*	P	45	P	45	P	45	P	45
O$_{6}$	*Salmo trutta fario*	P	45	P	45	P	45	P	45
Ş$_{7}$	*Salmo trutta fario*	P	45	P	45	P	45	P	45
O$_{7}$	*Salmo trutta fario*	P	45	P	45	P	45	P	45
Ş$_{8}$	*Salmo trutta fario*	P	45	P	45	P	45	P	45
O$_{8}$	*Salmo trutta fario*	P	45	P	45	P	45	P	45
Ş$_{9}$	*Salmo trutta fario*	P	45	P	45	P	45	P	45
Ş$_{10}$	*Salmo trutta fario*	P	45	P	45	P	45	P	43
Ş$_{11}$	*Salmo trutta fario*	P	45	P	45	P	45	P	43
Ş$_{12}$	*Salmo trutta fario*	P	45	P	45	P	45	P	43
	Cottus gobio	P		P		P		P	
Ş$_{13}$	*Salmo trutta fario*	P	45	P	45	P	45	P	43
	Cottus gobio	P		P		P		P	
Ş$_{14}$	*Salmo trutta fario*	P	45	P	45	P	45	P	43
	Cottus gobio	P		P		P		P	
	Eudontomyzon danfordi	P		P		P		P	

Table 2: The Bistra Mărului River sampling stations fish communities species; P/A – presence/absence, * parasite on Osteichthyes; ** in the substrate of the confluence areas of some small brooks tributaries of the Bistra Mărului Lake; CF-IBI values.

Bistra Mărului River									
BM_{1-3}	–	–	–	–	–	–	–	–	–
BM_{4-9}	*Salmo trutta fario*	P	45	P	45	P	44	P	43
BM_{10}	*Salmo trutta fario*	P	45	P	43	P	43	P	43
	Cottus gobio	P		P		P		P	
BM_{11}	*Salmo trutta fario*	P	45	P	43	P	43	P	43
	Cottus gobio	P		P		P		P	
BM_{12}	*Salmo trutta fario*	P	45	P	44	P	44	P	42
	Cottus gobio	P		P		P		P	
	Eudontomyzon danfordi	P		P		P		P	
BM_{13}	*Salmo trutta fario*	P	45	P	44	P	44	P	42
	Cottus gobio	P		P		P		P	
	Eudontomyzon danfordi	P		P		P		P	
BM_{13}	*Salmo trutta fario*	P	45	P	44	P	44	P	42
	Cottus gobio	P		P		P		P	
	Eudontomyzon danfordi	P		P		P		P	
BM_{14}	*Salmo trutta fario*	P	45	P	44	P	44	P	42
	Cottus gobio	P		P		P		P	
	Eudontomyzon danfordi	P		P		P		P	
BM_{15}	*Salmo trutta fario*	P	45	P	42	P A P P P A A P	35	P A P P P P P P	30
	Cottus gobio	P		A					
	Eudontomyzon danfordi	P		A					
	Phoxinus phoxinus	A		A					
	Sabanejewia aurata b.	A		A					
	Alburnoides bipunctatus	A		A					
	Squalius cephalus	P		A					
BML	*Salmo trutta fario*	P	45	P	35	P	25	P	15
	Cottus gobio	P		P		P		P	
	*Eudontomyzon danfordi**	P		P		P		P	
	*Eudontomyzon vladykovi***	P		P		P		P	
	Phoxinus phoxinus	A		P		P		P	
	Sabanejewia aurata b.	A		P		P		P	
	Alburnoides bipunctatus	A		P		P		P	
	Alburnus alburnus	A		A		P		P	
	Squalius cephalus	A		A		P		P	
	Scardinius erythrophthalmus	A		A		A		P	
	Carassius gibelio	A		A		A		P	
	Esox lucius	A		A		A		P	

Table 2 (continued): The Bistra Mărului River sampling stations fish communities species; P/A – presence/absence, * parasite on Osteichthyes; ** in the substrate of the confluence areas of some small brooks tributaries of the Bistra Mărului Lake; CF-IBI values.

Stations	Species	1980-1990	CF-IBI	1990-2000	CF-IBI	2000-2010	CF-IBI	2010-2018	CF-IBI
Bistra Mărului River									
BM$_{16}$	*Salmo trutta fario*	P	45	A	1	P	36	P	36
	Cottus gobio	P		A		A		A	
	Eudontomyzon danfordi	P		A		A		A	
	Thymallus thymallus	P		A		A		A	
BM$_{17}$	*Salmo trutta fario*	P	45	P	36	P	31	P	30
	Cottus gobio	P		P		P		A	
	Eudontomyzon danfordi	P		P		A		A	
	Thymallus thymallus	P		A		A		A	
BM$_{18}$	*Salmo trutta fario*	P	45	P	36	P	42	P	30
	Cottus gobio	P		P		P		A	
	Eudontomyzon danfordi	P		P		P		P	
	Thymallus thymallus	P		A		A		A	
BM$_{19}$	*Salmo trutta fario*	P	45	P	36	P	42	P	30
	Cottus gobio	P		P		P		A	
	Eudontomyzon danfordi	P		P		P		P	
	Thymallus thymallus	P		A		A		A	
BM$_{20}$	*Salmo trutta fario*	P	45	P	36	P	42	P	30
	Cottus gobio	P		P		P		A	
	Eudontomyzon danfordi	P		P		P		P	
	Thymallus thymallus	P		A		A		A	
BM$_{21}$	*Salmo trutta fario*	P	45	P	36	P	42	P	30
	Cottus gobio	P		P		P		A	
	Eudontomyzon danfordi	P		P		P		P	
	Thymallus thymallus	P		A		A		A	
BM$_{22}$	*Salmo trutta fario*	P	45	P	36	P	42	P	30
	Cottus gobio	P		P		P		A	
	Eudontomyzon danfordi	P		P		P		P	
	Thymallus thymallus	P		A		A		A	

Table 2 (continued): The Bistra Mărului River sampling stations fish communities species; P/A – presence/absence, * parasite on Osteichthyes; ** in the substrate of the confluence areas of some small brooks tributaries of the Bistra Mărului Lake; CF-IBI values.

Stations	Species	1980-1990	CF-IBI	1990-2000	CF-IBI	2000-2010	CF-IBI	2010-2018	CF-IBI
Bistra Mărului River									
BM_{23}	*Salmo trutta fario*	P	45	P	36	P	34	A	24
	Cottus gobio	P		P		A		A	
	Eudontomyzon danfordi	P		P		P		A	
	Thymallus thymallus	P		P		A		A	
	Phoxinus phoxinus	A		P		P		P	
	Sabanejewia a. balcanica	A		P		P		P	
	Barbus meridionalis	A		A		A		P	
	Squalius cephalus	A		A		A		P	
	Orthrias barbatulus	A		P		P		P	
	Alburnoides bipunctatus	A		A		P		P	
BM_{24}	*Salmo trutta fario*	P	45	P	36	P	34	A	24
	Cottus gobio	P		P		A		A	
	Eudontomyzon danfordi	P		P		P		A	
	Thymallus thymallus	P		P		A		A	
	Phoxinus phoxinus	A		P		P		P	
	Sabanejewia a. balcanica	A		P		P		P	
	Barbus meridionalis	A		A		A		P	
	Squalius cephalus	A		A		A		P	
	Orthrias barbatulus	A		P		P		P	
	Alburnoides bipunctatus	A		A		P		P	
BM_{25}	*Salmo trutta fario*	A	42	A	36	A	29	A	22
	Cottus gobio	A		A		A		A	
	Eudontomyzon danfordi	A		A		A		A	
	Thymallus thymallus	P		P		A		A	
	Phoxinus phoxinus	P		P		P		P	
	Sabanejewia a. balcanica	A		P		P		P	
	Barbus meridionalis	A		A		P		P	
	Squalius cephalus	A		A		A		P	
	Gobio gobio	A		A		P		P	
	Orthrias barbatulus	P		P		P		P	
	Alburnoides bipunctatus	P		P		P		P	
	Gobio uranoscopus	P		P		A		A	
	Chondrostoma nasus	P		P		P		A	

Table 2 (continued): The Bistra Mărului River sampling stations fish communities species; P/A – presence/absence, * parasite on Osteichthyes; ** in the substrate of the confluence areas of some small brooks tributaries of the Bistra Mărului Lake; CF-IBI values.

Stations	Species	1980-1990	CF-IBI	1990-2000	CF-IBI	2000-2010	CF-IBI	2010-2018	CF-IBI
Bistra Mărului River									
BM_{26}	*Salmo trutta fario*	A	42	A	36	A	29	A	22
	Cottus gobio	A		A		A		A	
	Eudontomyzon danfordi	A		A		A		A	
	Thymallus thymallus	P		P		A		A	
	Phoxinus phoxinus	P		P		P		P	
	Sabanejewia a. balcanica	A		P		P		P	
	Barbus meridionalis	A		A		P		P	
	Squalius cephalus	A		A		A		P	
	Gobio gobio	A		A		P		P	
	Orthrias barbatulus	P		P		P		P	
	Alburnoides bipunctatus	P		P		P		P	
	Gobio uranoscopus	P		P		A		A	
	Chondrostoma nasus	P		P		A		A	
BM_{28}	*Salmo trutta fario*	A	42	A	36	A	29	A	22
	Cottus gobio	A		A		A		A	
	Eudontomyzon danfordi	A		A		A		A	
	Thymallus thymallus	P		P		A		A	
	Phoxinus phoxinus	P		P		P		P	
	Sabanejewia a. balcanica	A		P		P		P	
	Barbus meridionalis	A		A		P		P	
	Squalius cephalus	A		A		A		P	
	Gobio gobio	A		A		P		P	
	Orthrias barbatulus	P		P		P		P	
	Alburnoides bipunctatus	P		P		P		P	
	Gobio uranoscopus	P		P		A		A	
	Chondrostoma nasus	P		P		A		A	

Key species, common not sensible species, ichthyological zones evolution and trend

Salmo trutta fario Linnaeus, 1758; Brown trout; Order Salmoniformes, Family Salmonidae. The decreasing abundance and spread with arround 50%, especialy in the middle and lower sectors, in the studied decades in Bistra Mărului basin, reflect the human activities (mainly damming, but also poaching, pollution and riverbed exploitation) negative impact on river continuum, water flowing regime and temperature and oxygenation. In the present the trend of this species was consider as a decreasing one, till the moment when a proper management measures will be designed and constantly implemented in the field.

Cottus gobio (Linnaeus, 1758); Miller's thumb, Sculpin, Bullhead; Order Scorpaeniformes, Family Cottidae; Natura 2000 Code – 1163. This protected species is in a worse situation than the brown trout, decreasing abundance and spread with over 75%, due to the same anthropogenicaly reasons at which have to be add the fact that no stocking and restoking are made like for *Salmo trutta fario* and their direct competition (these two species adults eat the juveniles of the other one) and indirect trophic competition (relatively simmilar trophic macroinvertebrate base at least for some age classes individuals).

Thymallus thymallus (Linnaeus, 1758); European grayling; Order Salmoniformes, Family Salmonidae, Natura 2000 Code – 1109. The 100% disappearance of this fish species in the studied river is largely due to fragmentation. These speices are still present in the near Bistra, Mara and Bistra Bouţarului rivers, where a well balanced population of grayling still thrive.

Eudontomyzon danfordi Regan, 1911 (Bănărescu, 1969, 2005); Carpathian lamprey; Order Petromyzontiformes, Family Petromyzontidae; Natura 2000 Code – 4123. Decreased by 50% but is not protected, especially in the middle and lower reaches. Fragmentation and habitat isoltation is likely a large impact. It is interesting to highlight that in its lower confluence area and its near Mara, Bistra Bouţarului and Bistra rivers are characterised by stable populations of *Eudontomyzon danfordi*.

Eudontomyzon vladykovi Oliva and Zanandrea, 1959; Danubian brook lamprey; Natura 2000 Code – 4123; Order Petromyzontiformes, Family Petromyzontidae. This elusive extremely rare protected species in the Romanian Carpathians it is unfortunately on the brink of local extinction, due to the fact that its small sector of existence was inundated by the Bistra Mărului big lake. In the last decade it was found a single individual in the stomach of a *Squalius cephalus* captured in the lake, that individual caming from one of the local small tributaries of this anthropogenic lake.

Gobio uranoscopus (Agassiz, 1828); Danube Gudgeon; Order Cypriniformes; Family Cyprinidae; Natura 2000 Code – 1122. Is now locally extinct and significantly impacted by migratory obstruction. Good populations of this species appear again in the lower Bistra River.

Barbus meridionalis Riso, 1827; Mediterranean barbell; Order Cypriniformes; Family Cyprinidae; Natura 2000 Code – 1138. It is a protected species which after the lotic habitat conditions in the middle and lower sectors changed due to the human impact, collonised from downstream and replaced some of the more upper described protected fish species.

Chondrostoma nasus (Linnaeus, 1758); Common nase; Order Cypriniformes; Family Cyprinidae. This key species has been absent for over a decade, in spite of the fact that it is still present downstream in Bistra River.

As a whole, the fish comunities ecological status analysed based on the CF-IBI (Tabs. 1 and 2) register drastic deacrising especialy in the middle and lower streches and in the periods 1990-2000 – 2000-2010 – 2010-2018 (Fig. 4).

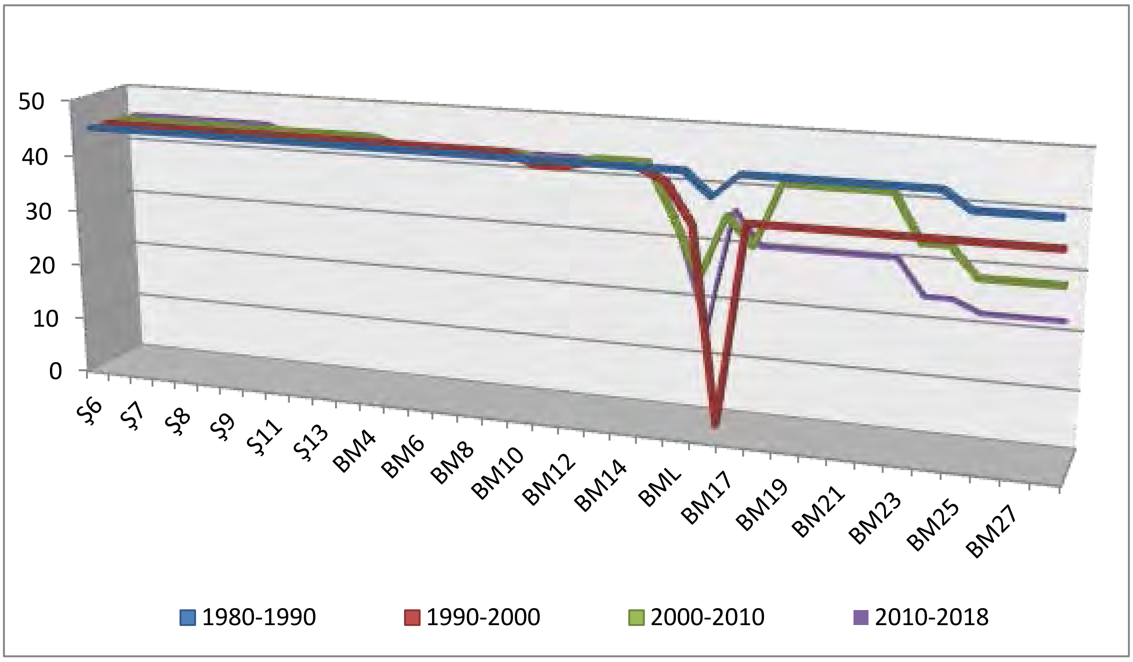


Figure 4: The decreasing trend of CF-IBI values/ecological status along the Bistra Mărului River and its tributaries Şucu and Olteana streams.

Technical proposals for diminishing the human impact of lotic fragmentation

1. The upper Bistra Mărului River and its tributaries Şucu and Olteana (50 sampling stations) has over 20 variable in size (small to medium: 0.20 cm – 2 m) human obstacles, which can be split in two main categories, which need two main categories of technical proposals with the needed role of reconect the longitudinal lotic sectors for the improoving the local fish fauna.

1.1 Spillways first category of proposed fish migration system solution – discharge sill located on a Bistra Mărului tributary

On a tributary of the Bistra River (even at the confluence with it) (Fig. 4a) there is a spill threshold (1) of about 15 m long, the width of the canopy of about one m and the height of 2.3 m (Fig. 4b). The water passes through this spillway frontally through several rectangular internal breaches (Fig. 5). These characteristics block the upstream fish migration on this tributary. The engineering solution is the construction of a rectangular channel with a slope smaller than that of the river that is approximately 14‰. Thus, a rectangular channel of 1.5 cm thick concrete pallets (sheet piles) is fixed by the overflow threshold in front of the existing three breaches (Fig. 5). This concrete channel is also fixed to the concrete wall (Fig. 6) existing on the left bank of the river (tributary).

Figure 4a: Positioning the discharge sill
at the confluence with the Bistra Mărului River.

Figure 4b: The discharge sill on the tributary of the Bistra River.

Figure 5: The three breaches located in the spill threshold 1.

Figure 6: Positioning of the concrete wall
at the left bank of the river.

The concrete channel has a width of 40 cm and a hight of 30 cm and is fixed in metal dowels above the three existing breaches (1, 2 and 3). We mention that each bust is 25 cm high and 30 cm wide. In the sheet pile which is fixed directly to the spill threshold there are rectangular spaces of the same size as the existing breaches in the spill threshold (Fig. 7). The water level captured from the bridges 2 and 3 must overcome by a few centimetres the first breach (1) or at least the water level in the rectangular channel for fish migration occupy two-thirds of the breach 1 (Fig. 7). Under these conditions, fish can easily migrate through the first breach. In the upper part of the first breech a rectangular parallelepiped must be constructed to light the brace 1. This rectangular parallelepiped is closed at the top (the crown of the spill threshold) and on the lower part (direct connection with the bust 1) with two rectangular glass surfaces transparent and very resistant (Fig. 8).

Before the fish migration canal goes over the concrete wall, an ihtyofauna rest pool is being built. This basin is actually a pocket of the fish migration channel and supports a concrete pillar (Fig. 7). The water inside the fish migration channel produces a remittal phenomenon within the breach 1, reducing the existing speed in this breach, thus favouring the climbing of the fish through the breach and reaching them upstream of the spillway 1. By this system, the breaches do not clog or obstruct they operate at normal capacity. Between the bust 1 and the bust 2 a metal fence is fixed to redirect the fish to the breach 1 (Fig. 7).

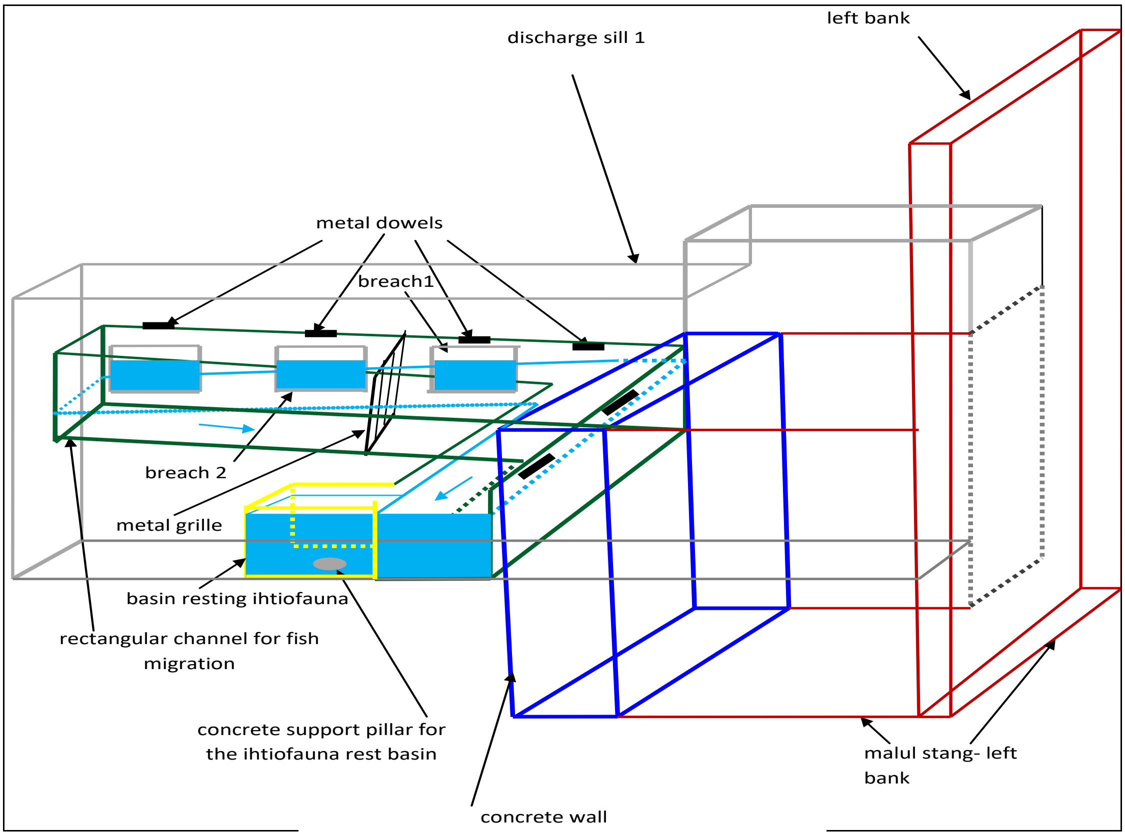


Figure 7: Positioning of the concrete channel on the spillway and the concrete wall – indicative scheme.

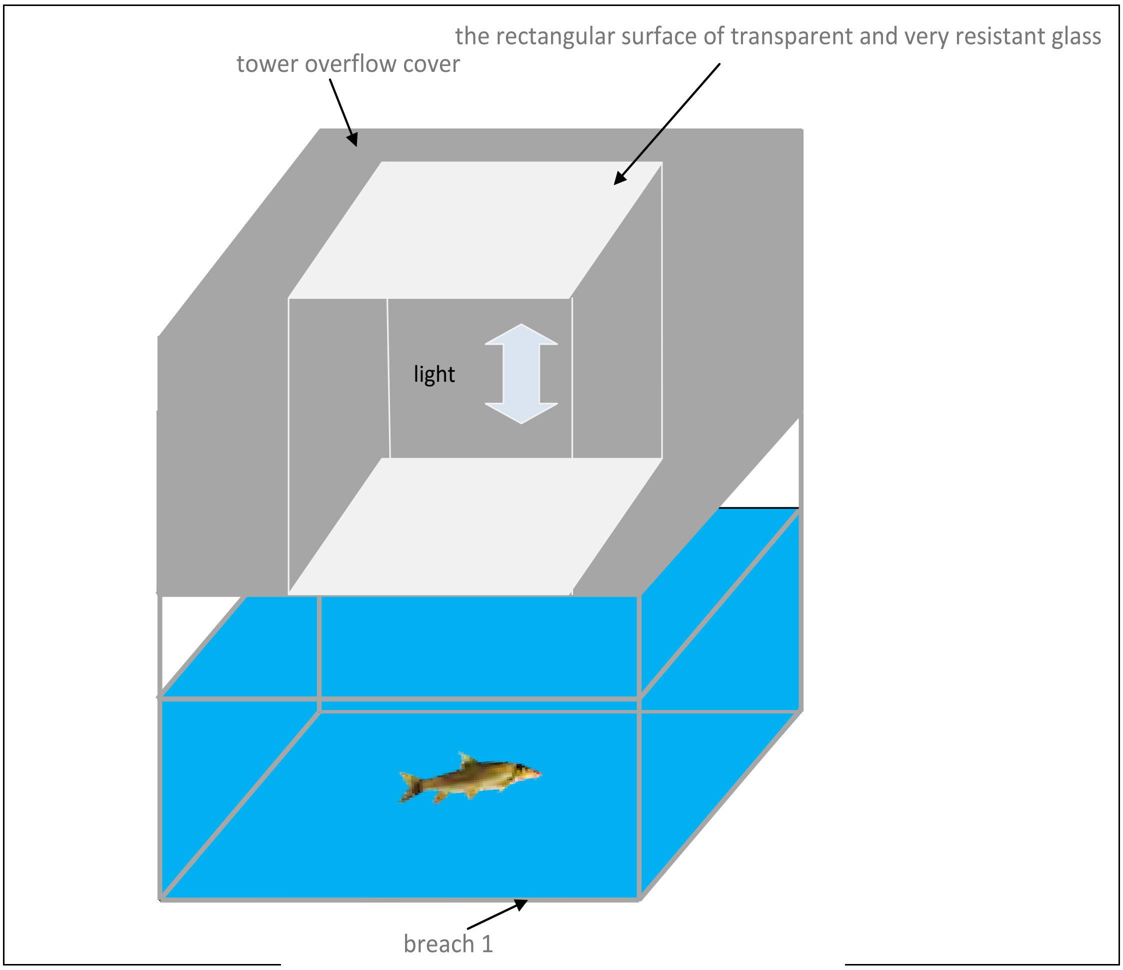


Figure 8: Positioning of the rectangular window
with a transparent and very resistant glass – indicative scheme.

After the entire concrete wall passes, the channel rises to the right until it reaches the water course (Fig. 9). The entire fish migration channel will have upper grids protecting the fish against poaching. The downstream end of the canal is in a reception pool where the water has a depth of about 30 cm. In direct connection with the fish migration channel, fences are fed into the riverbed for redirecting the ichthyofauna to the receiving basin, thus allowing the fish to climb over the spillway 1.

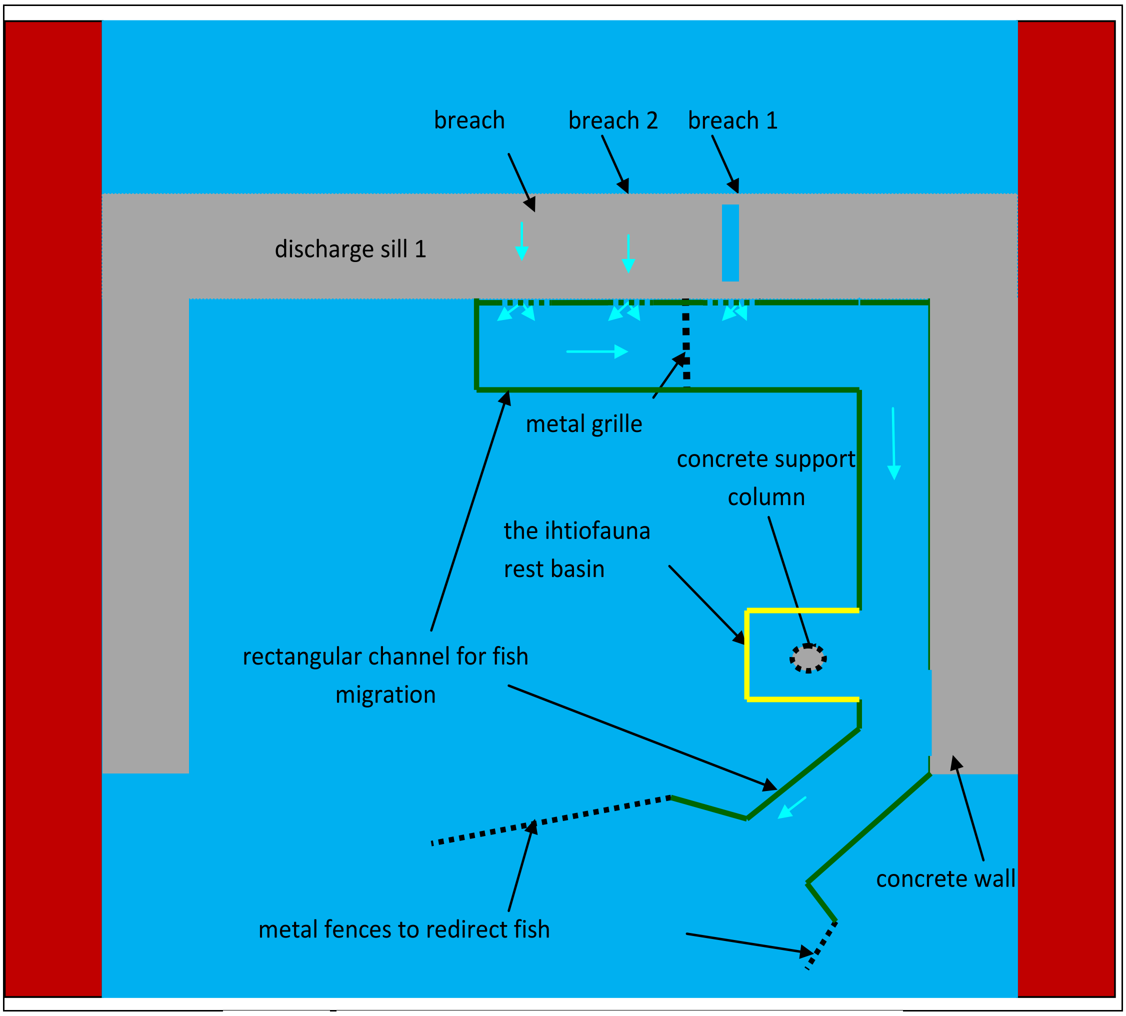


Figure 9: The overall scheme of the fish migration system over the spillway 1 – indicative scheme.

The fish migration channel could be assembled as modules and can be easily disassembled and assembled at another spill threshold if required. In case of exceptional floods, any damaged module can easily be replaced. The construction cost is not high and the realization of this fish migration system does not require very advanced technology that is actually useful for many countries.

1.2 Spillways first category of proposed fish migration system solution – spillway number five study case downstream to tributary Peceneaga.

The length of the spill threshold (Fig. 10) on the Bistra River is about 10 m and the water speed is close to 0.8 m/s. The height of the spill threshold is 1.4 m and the width of the canopy of one m and the slope of the river in the area is about 12‰. At the threshold of the spillway 5 near the left bank of the river Bistra, a meter from the concrete wall is a breach (Fig. 11). The breach has a height of one m and a width of 40 cm.

Figure 10: Discharge sill 5.

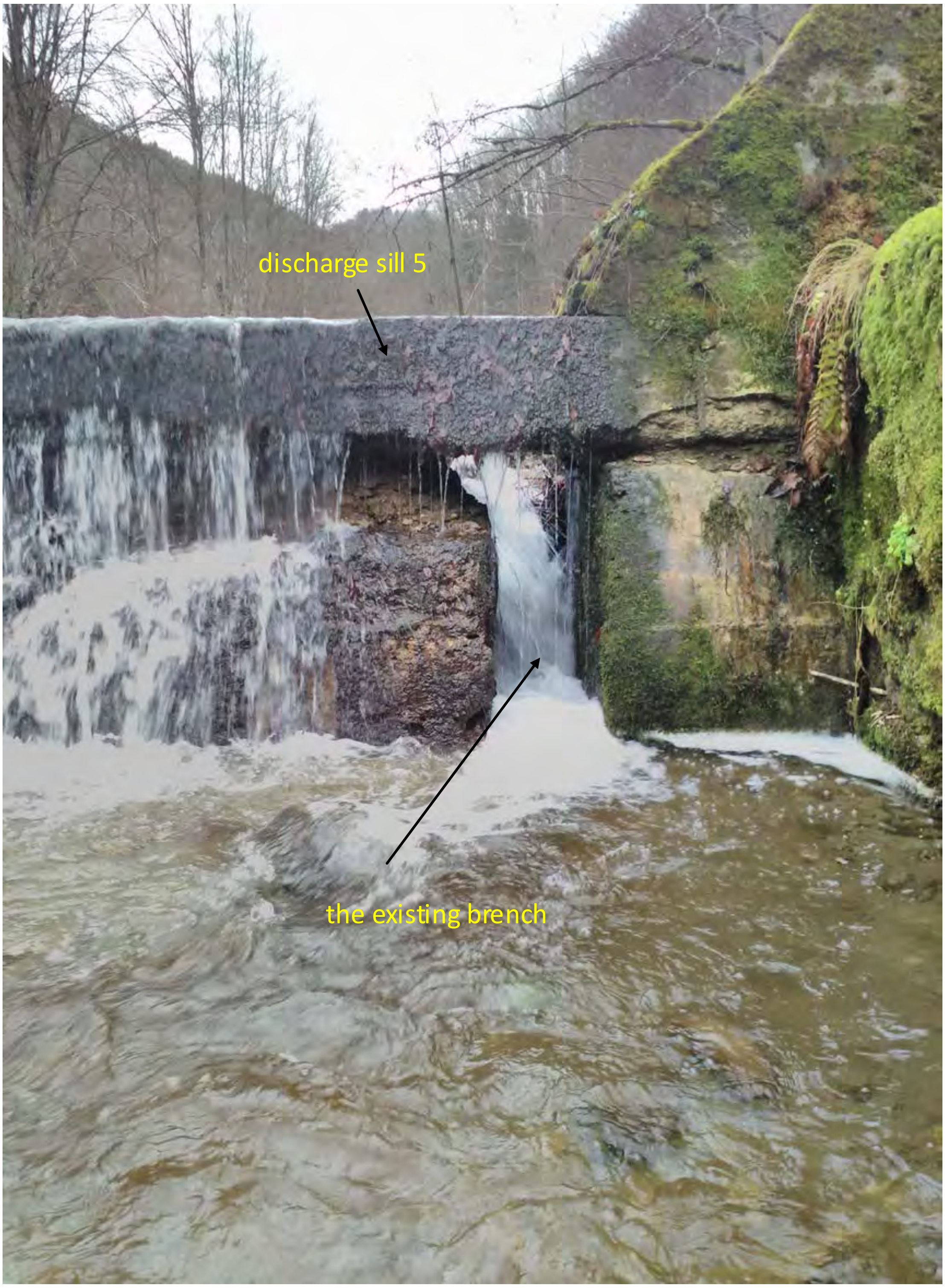


Figure 11: Positioning of the brench in the discharge sill 5.

The water is captured in this breach by a natural semicircular slope with a large slope of about 60% (Fig. 12).

Figure 12: Capturing water in the existing breach with the help of the semicircular slope.

A fish migration system must be developed within the existing breach. To reduce the slope, half of the slab must be filled with concrete. Fill it with a rectangular prism with a tilted surface (Figs. 13a and b).

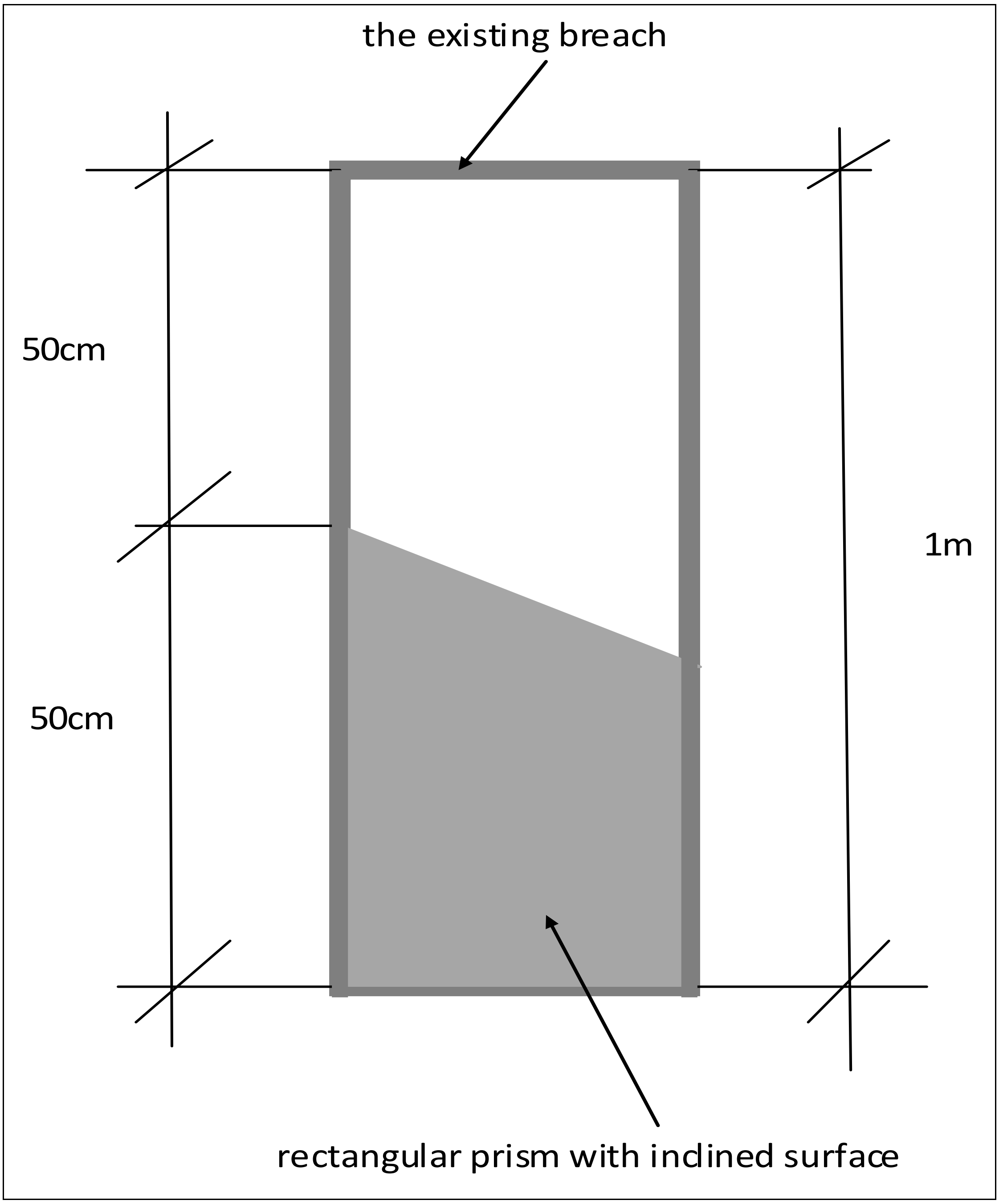


Figure 13a: Rectangular prism positioning with inclined surface
– cross section – indicative scheme.

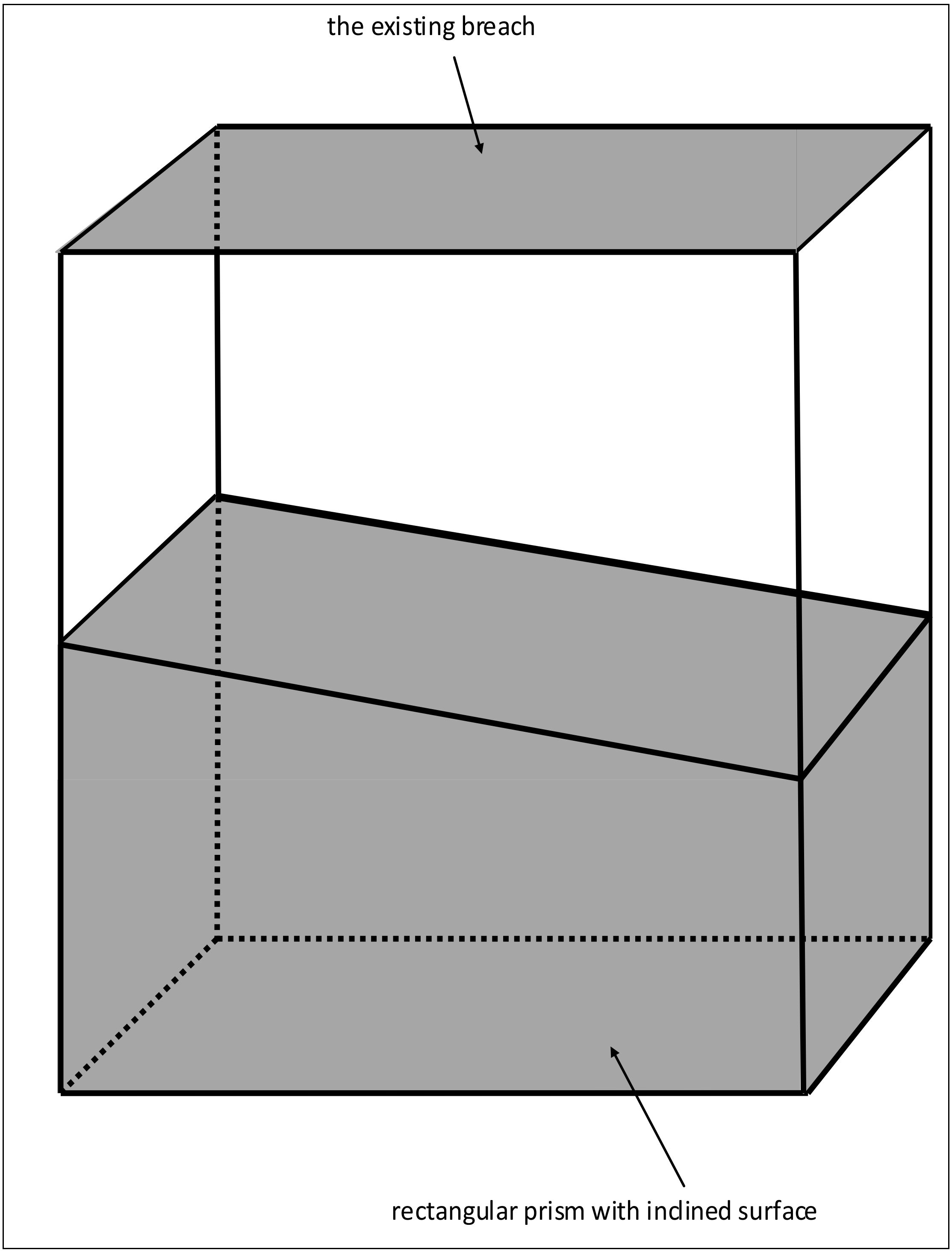


Figure 13b: Positioning the rectangular prism
with a tilted surface – indicative scheme.

The inclined surface will extend upstream of the discharge sill 5 to the upper level of the Bistra riverbed (Fig. 14). The river's riverbed must be arranged in a tilted plane on which will be fixed stones (Fig. 14). On the inclined surface, a concrete platform downstream of the discharge sill 5 will be fixed to the level of the Bistra riverbed (Fig. 14) and the downstream end will be fixed by a concrete pillar. The concrete platform will be fastened by a concrete pillar and at the upstream end (Fig. 14).

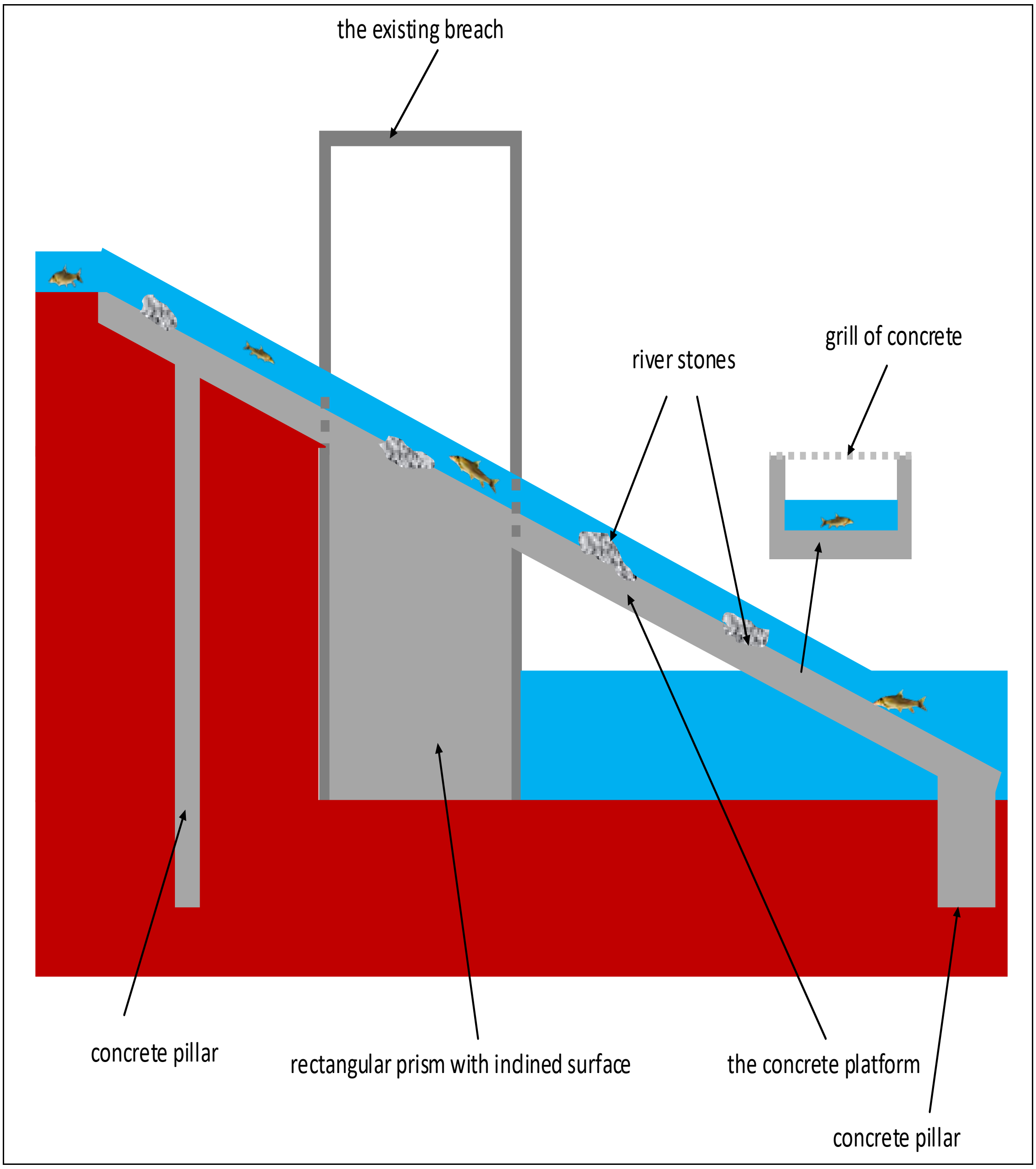


Figure 14: Positioning of the concrete platform upstream and downstream of the discharge sill 5 – indicative scheme.

Downstream of the discharge sill the concrete platform will be framed by concrete parapets and above it will have a concrete grid as a defence against the poachers (Fig. 14). Upstream, the slopes limiting the concrete platform that the fish pass upstream – downstream of the spillway are stabilized with a concrete layer on which river stones are attached (Fig. 15). The slopes cannot be crossed by the fish.

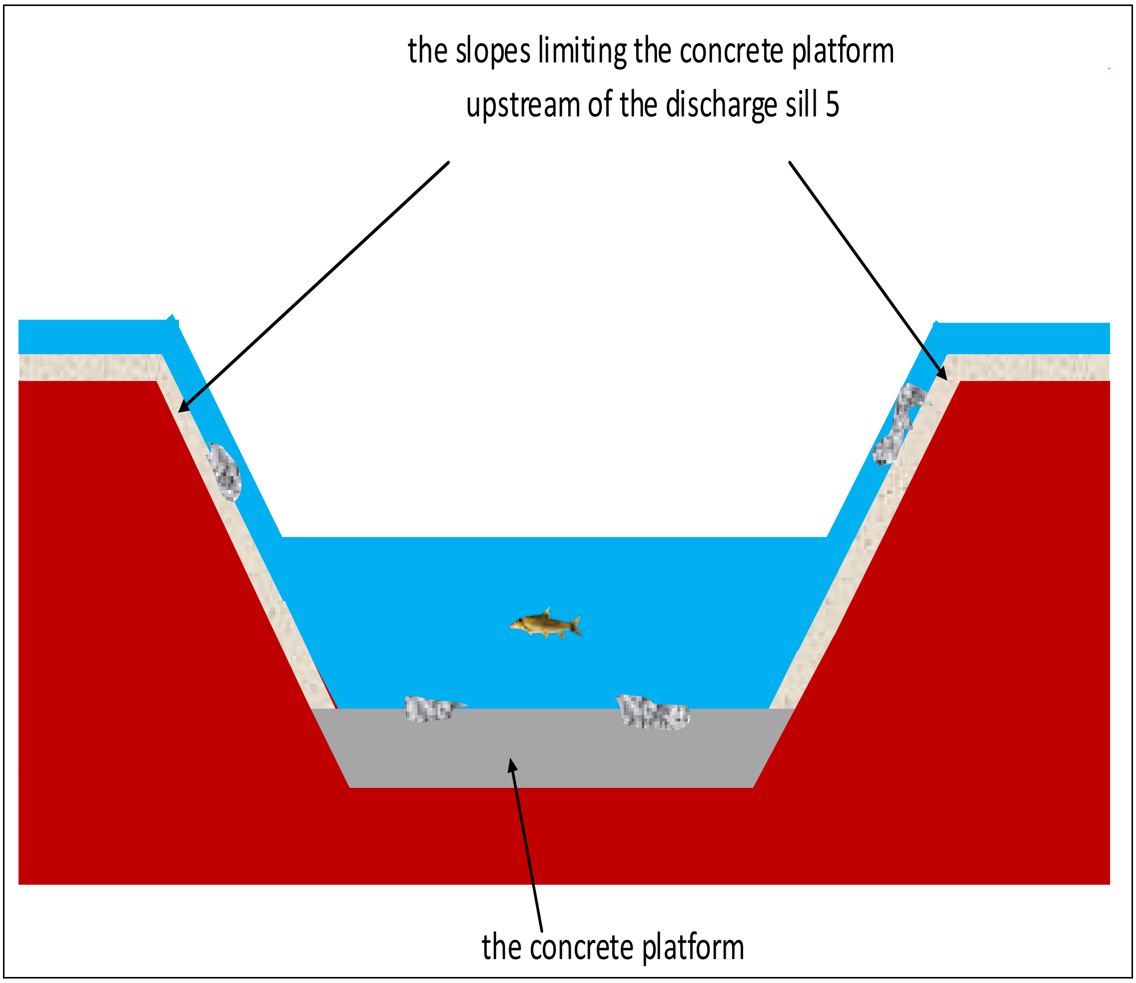
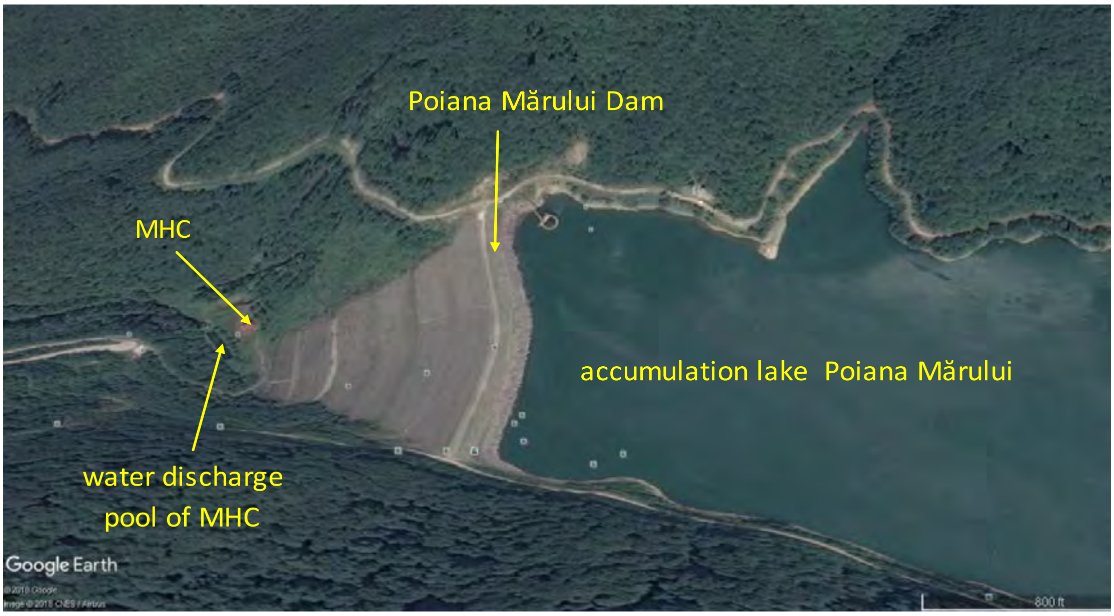


Figure 15: Reconstruction of the concrete platform slopes upstream of the discharge sill 5 – indicative scheme

This solution category provides a safe migration solution to the upstream fish, does not affect the structure and functionality of the spillway 5 and resists flooding due to the structure of the fish migration system.

2. The middle Bistra Mărului River, fish migration solution across the Poiana Mărului Dam.

The dam of Poiana Mărului Lake (Figs. 16a, b, c) was conceived from rockfill with clay core. The emptying of the reservoir is carried out through a pressure inlet manifold up to the house of the lake emptying valves and is equipped with two flat valves in the housing and a free-standing gallery after the house of the valves. The discharge rate is about 159 m³/s. A bypass duct leaves the house of the valves and provides a service flow of one m³/s which in turn feeds MHC from the base of the dam. (http://www.hidroconstructia.com/dyn/2pub/proiecte_det.php?id=38&pg=1)



a).

b) upstream.

c) downstream.

Figure 16a, b and c: Poiana Mărului Dam.

After feeding the MHC the water is discharged into a rectangular parallelepiped basin (Fig. 17) and from this basin the water returns to the river bed of Bistra Mărului (Fig. 17).

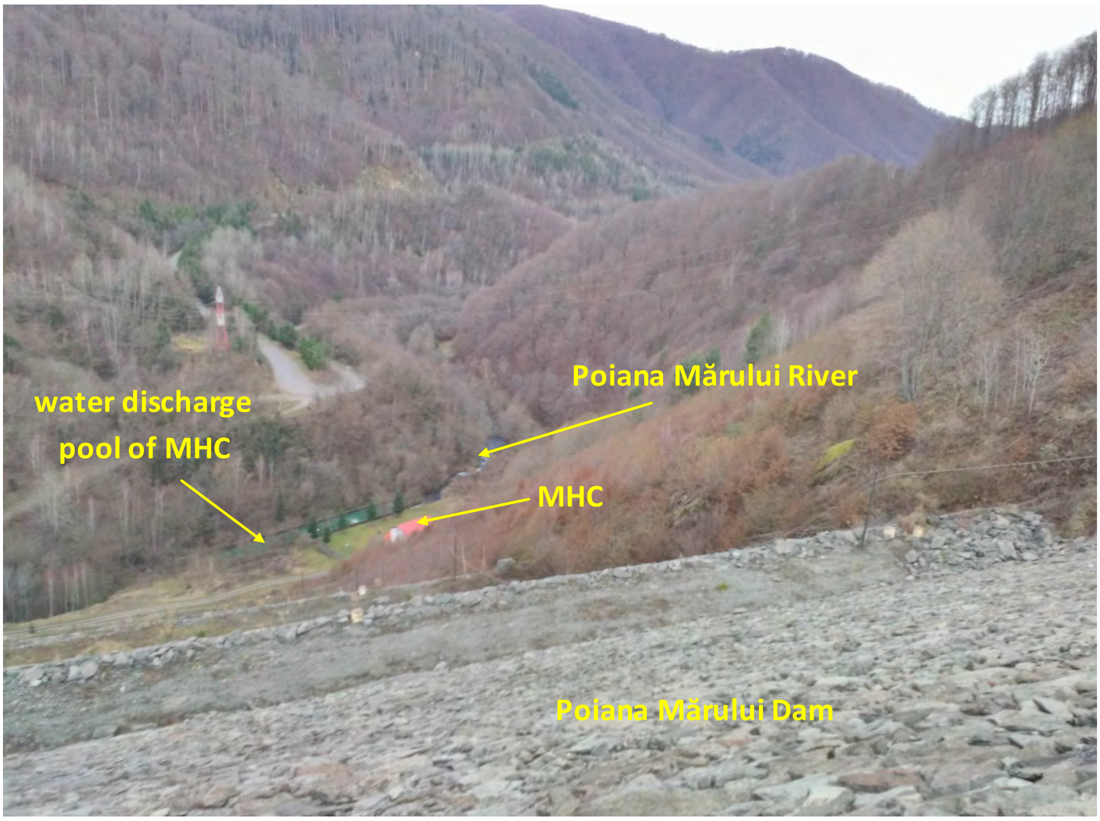


Figure 17: Positioning of the water discharge basin in MHC.

Downstream of the discharge basin (about five m), the river will be divided into half with a five cm thick concrete sheet pile and eight m long. In this basin must be a break in which a metal pipe with a manual or automatic valve must be fitted. On the left bank there will be a concrete sheet pile and a new concrete sheet pile will be attached on the first concrete sheet pile. The second concrete sheet pile will divide the river in half (Fig. 18). In the left side of the river divided by the concrete sheet pile, a rectangular parallelepiped basin of concrete (basin 1, quenching) will be built where the water discharged out of the pipe. The flow rate of the pipeline is about 0.5 m^3/s. River flow in the area is about one m^3/s. From the first basin, a hydraulic jump (40 cm) will connect a second basin (basin 2) (Fig. 18). The basin 2 will be parallelepiped and will be below the river level (Fig. 19).

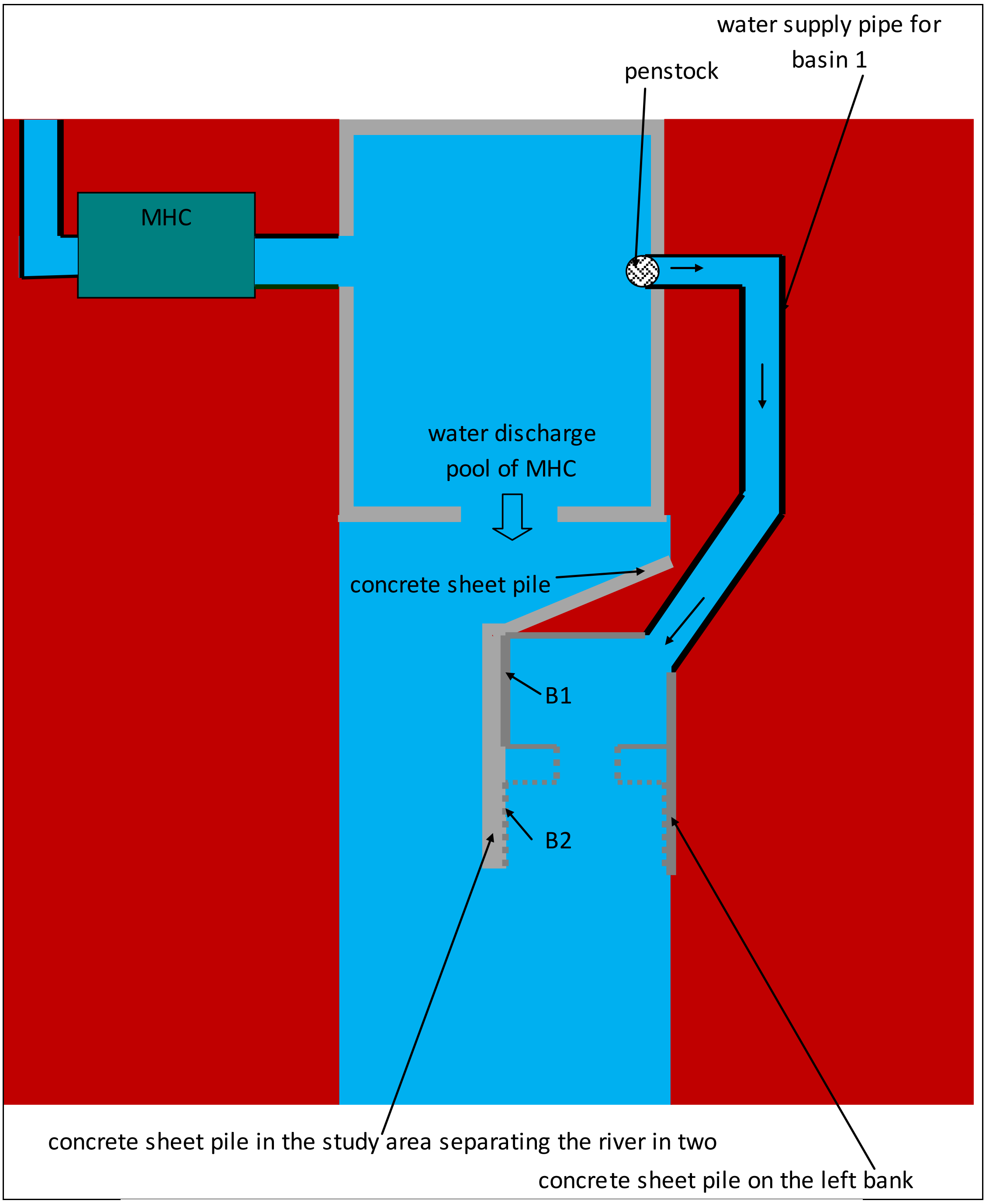


Figure 18: Positioning of the metallic pipe feeding the basins B1 and B2 and positioning of the two basins B1 and B2 – indicative scheme.

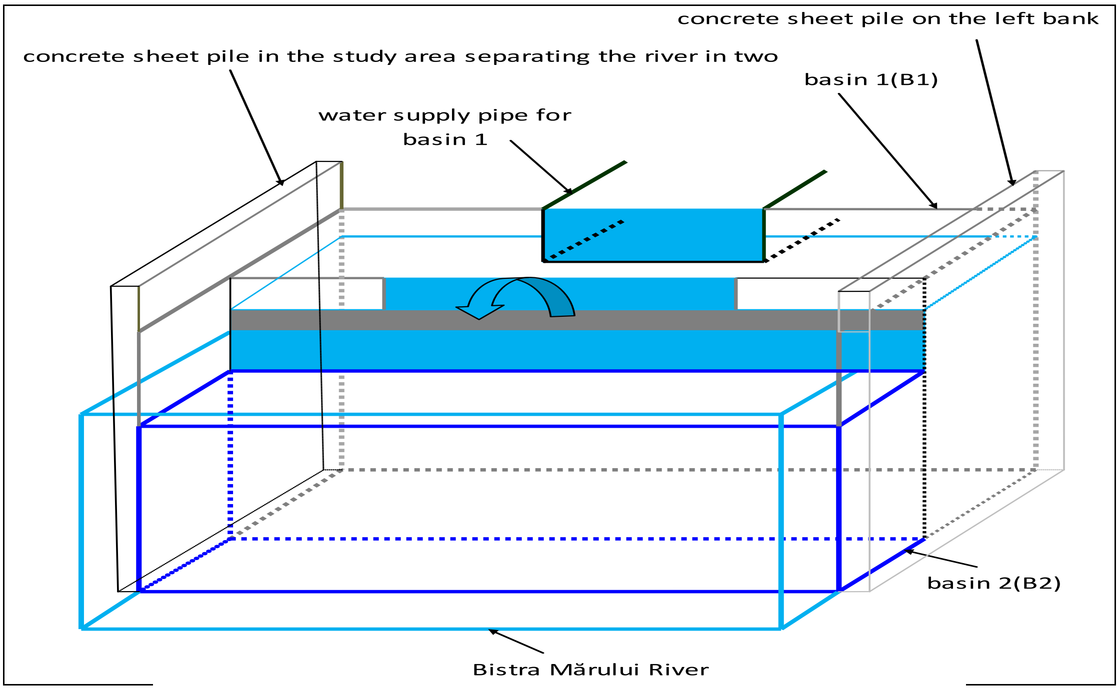


Figure 19: The link between basin 1 and basin 2 – indicative scheme.

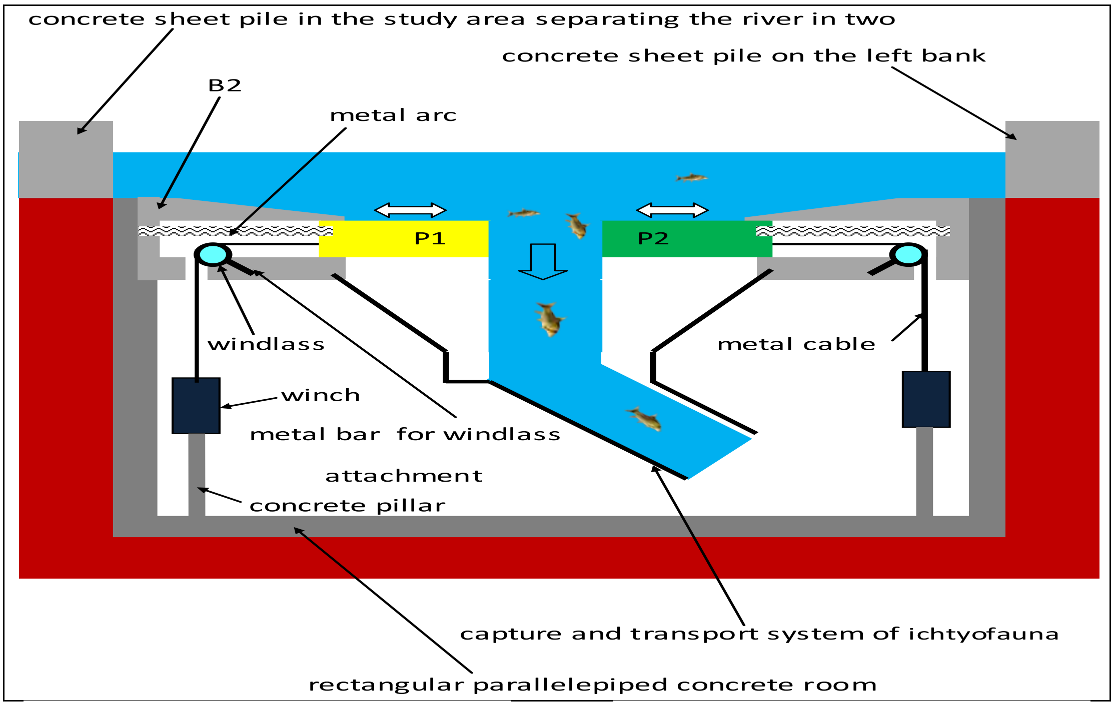


Figure 20: Placing of moving P1 and P2, windlass and trolleys inside the rectangular space – indicative scheme.

Approximately 20 cm of water is above the basin 2, in fact the Bistra Mărului River level is in the study area. The base of the basin 2 should be approximately 30 cm thick and include two moving concrete slabs in a horizontal plane. The upper part of the basin 2 is shaped like a funnel for water capture. A parallelepiped rectangular special room must be constructed under the base of the basin 2. There is an electric winch next to the downstream end of the P2 concrete sheep pile. There is an electric winch next to the upstream end of the P1 (concrete sheep pile). Next to each electric winch is a metal bar on which a windlass is welded. Over the two windlass are placed the two wires of the electric winches that will be fastened by the two mobile plates P1 and P2 (Fig. 20).

The metallic springs are fixed to the concrete sheet piles P1 and P2 and to the walls of the underground rectangular space (Figs. 20 and 21). At the moment when the windlass is moved due to an ichthyofauna sensor, the concrete plates are moved with horizontal movement. During the plate movements, the springs contract and de-contract when the concrete sheet piles P1 and P2 return to the original position. The downstream end of the underwater capture and transport system of the ichthyofauna will be directly linked to a horizontal parallelepiped subterranean basin located horizontally. This does not have a vertical surface (Fig. 22). The downstream end of the underground capture and transport system of the ichthyofauna fixes on a metal arch a thin transparent and resistant plastic sheet pile that allows the water and the ichthyofauna to penetrate into the horizontal rectangular parallelepiped basin located in the horizontal plane (Fig. 22).

Inside the rectangular parallelepiped basin located horizontally, a parallelepiped of resistant rubber slides into the horizontal rectangular parallelepiped basin. Between the rubber parallelepiped and the top of the right (underground) basin located in the horizontal plane remain approximately 20 cm. These 20 cm remain the full length of the rectangular parallelepiped basin in the inclined plane. From the upper surface of the rectangular parallelepiped basin located horizontally, a metal reinforced bar is fastened. From this bar through two metal rings, the movable parallelepiped of rubber is fixed. The rectangular parallelepiped basin located horizontally will be extended also in inclined plane (Fig. 22). A metal cable (Fig. 22) should be attached to the rubber parallelepiped. The right-angled (subterranean) parallelepiped basin located in the horizontal plane will exit the underground and be fixed on concrete pillars and extend in an inclined plane and then horizontally up to the dam (Fig. 23). The upstream end will be secured by a concrete pillar (Fig. 23). The movable rectangular parallelepiped of rubber will be towed up to the upstream end of the rectangular parallelepiped basin located horizontally by a winch located on a concrete pillar on the bank of the accumulation lake Poiana Mărului (Fig. 23). At the moment of closing the transparent and resistant plasterboard with a sensor, the winch is automatically placed on a concrete pillar on the bank of the accumulation lake Poiana Mărului. Detaching the water from the fish migration system will be done through a free-standing rectangular canal.

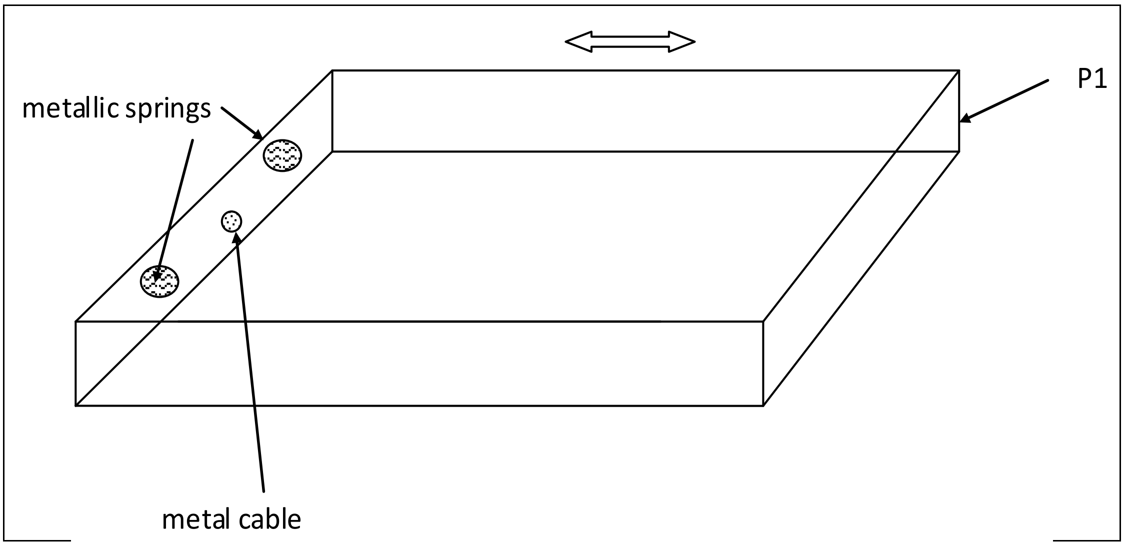


Figure 21: Positioning the metallic springs and the metal cable – indicative scheme.

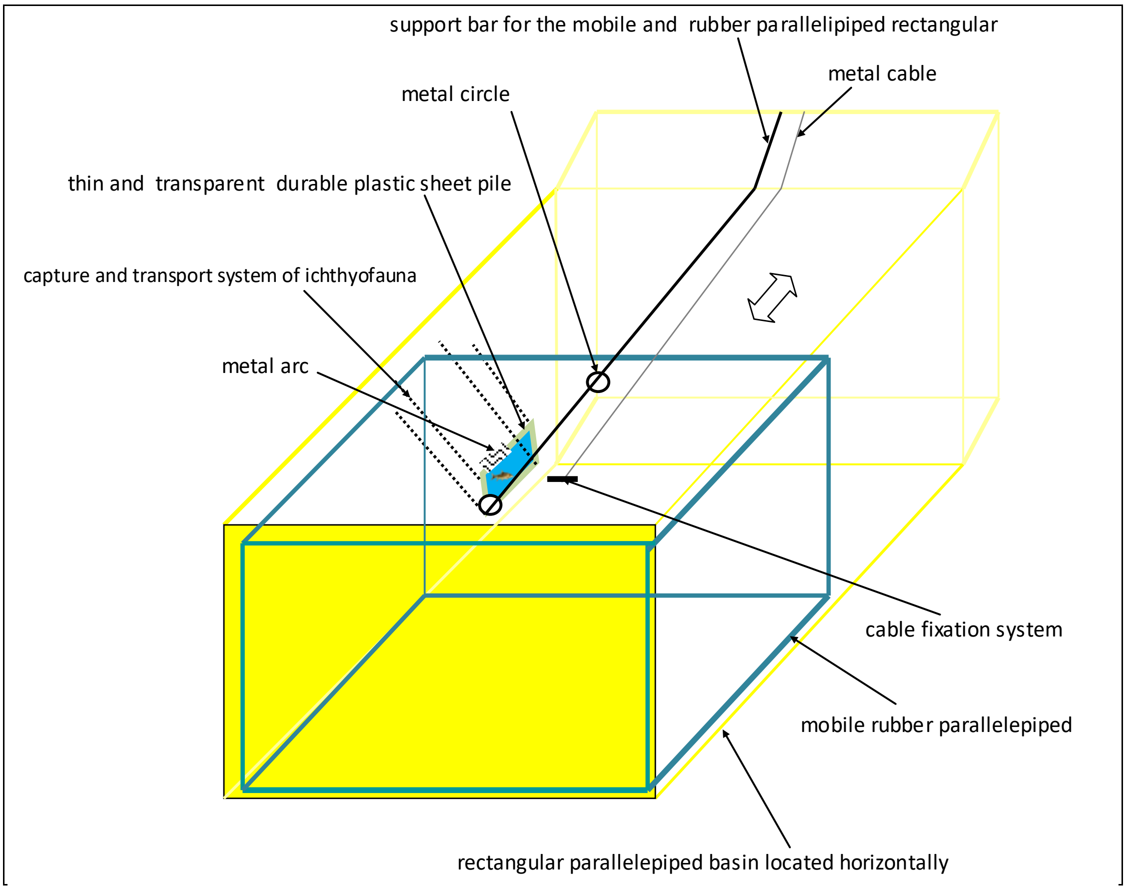


Figure 22: Positioning of the mobile rectangular parallelepiped from rubber – indicative scheme.

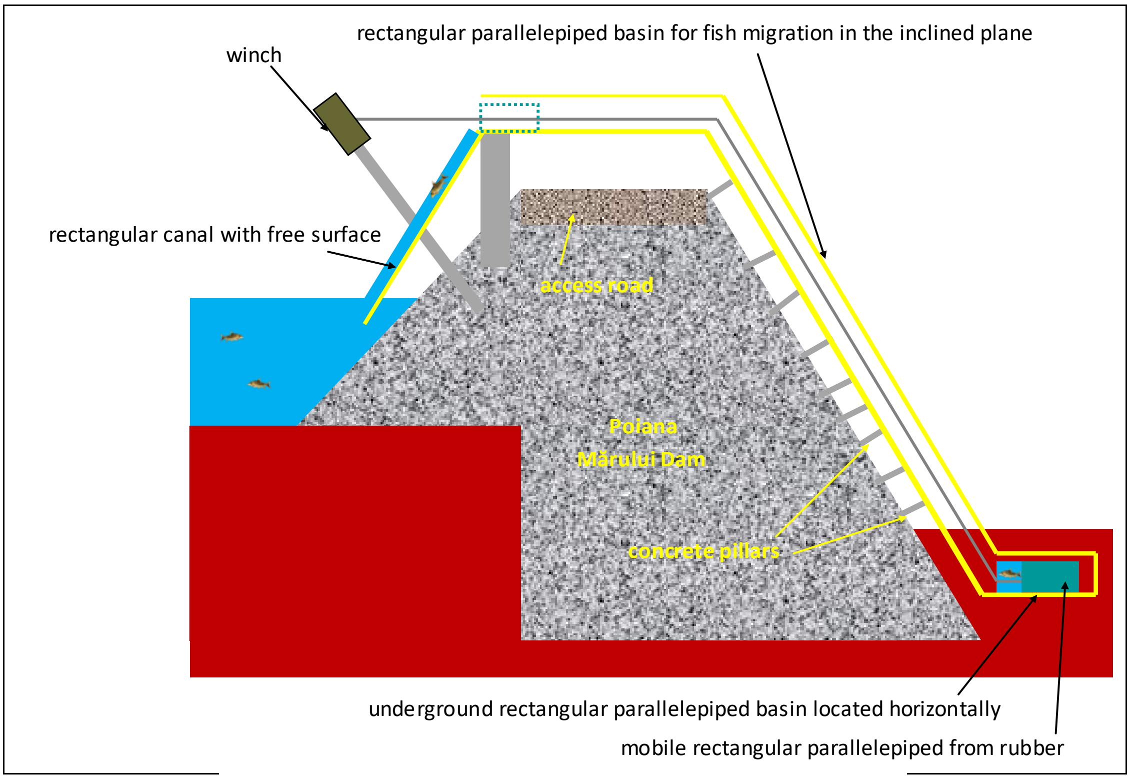


Figure 23: Positioning the rectangular parallelepiped basin on the Poiana Mărului Dam – indicative scheme.

From the back surface of the rubber parallelepiped that pushes the fish into the reservoir Poiana Mărului, a metal cable is attached which belongs to a winch inside the right-hand parallelepiped located horizontally. After the caulking parallelepiped reaches the maximum level and pushes the fish into the reservoir, this winch pulls the mobile parallelepiped in the initial position after five seconds after running the entire length of the fish migration system.

The hydraulic jump between basin B1 and B2 draws the ichthyofauna before the water is discharged from MHC, which is an important fact. For redirecting fish, low amperage systems (generators) can also be fixed in the riverbed as the safety of reaching the fish above basin B2 is maximum. The fish will want to jump over the fall of water between B1 and B2 which makes them stay in the area. Under these conditions, the system is started even with a single specimen (fish). The two mobile pallets will be folded for a maximum of five seconds afterwards automatically closing due to the winches and metal springs. There are visiting chambers for both the rectangular parallelepiped room below B2 and the space where the rectangular parallelepiped basin is located horizontally. All components of the system must be non-corrosive and of good quality. In winter the ichthyofauna sensor can be de-energized which will cause system shutdown. To clean or repair the system, close the valve. Also in winter this system may close. This system is fully automatic and can be applied to other dams of other structures and design.

3. The lower Bistra Mărului River is significantly fragmented by a four m high spill threshold (Fig. 24).

Figure 24: The discharge sill
of the lower Bistra Mărului River sector.

Two rectangular breaches of 40 cm width and 60 cm height must be made, one made in the barrage near the supporting and watering wall, and the other in the water support and guide wall (Fig. 25). Between the two breaches on the support wall and the water direction, a rectangular channel (module 1) of concrete piles of three cm thick (Fig. 25) is fastened by means of metal dowels and horizontal bars. Thus the two breaches are directly related. The water from the first breech reaches the second bay through module 1 (Fig. 25). A second rectangular channel (module 2) is also attached to the downstream end of break 2 by three cm thick concrete sheet pile and having the same dimensions as the first module (Fig. 25).

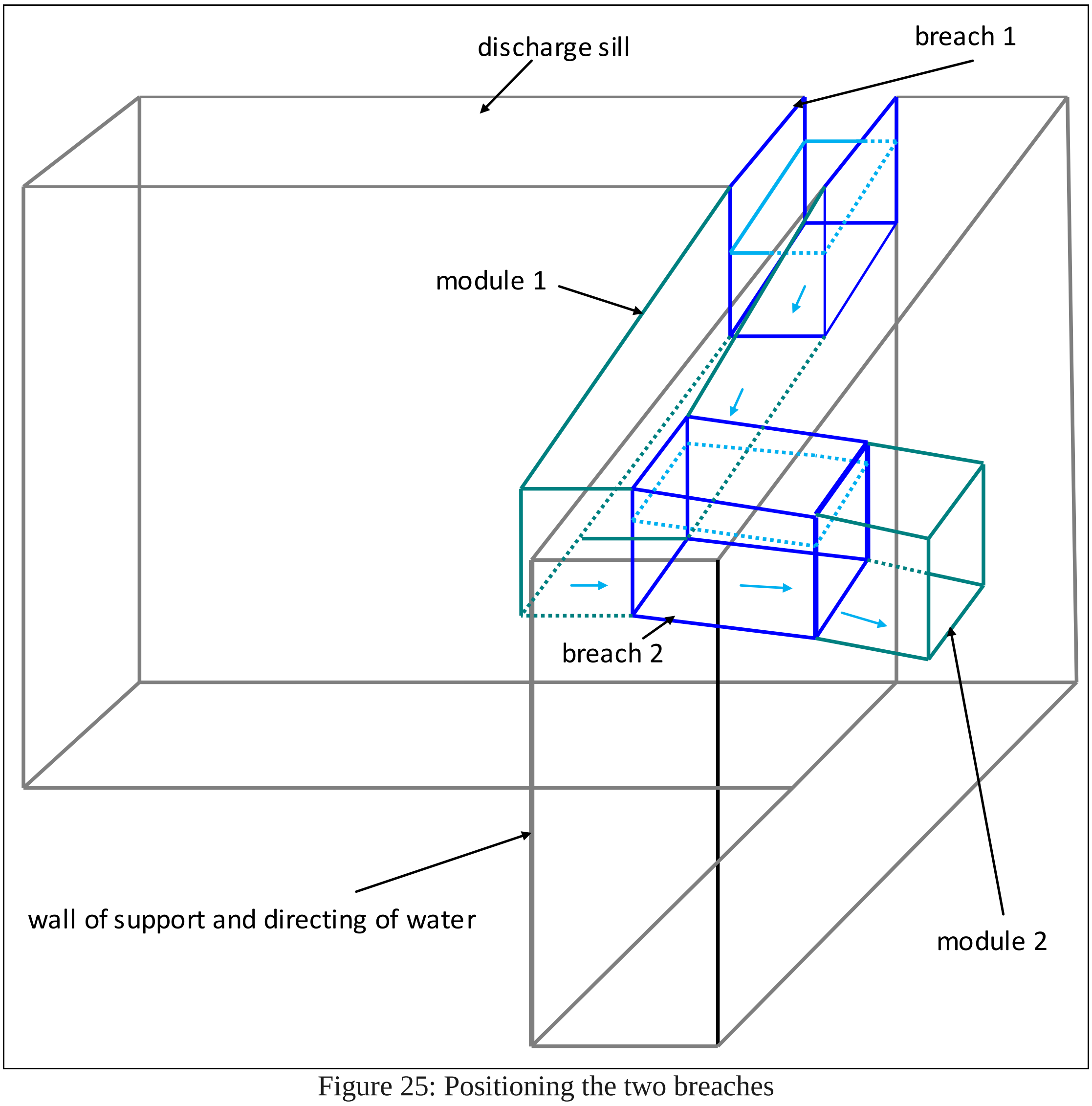


Figure 25: Positioning the two breaches
and the two modules.

Module 2 continues to the right bank. On the right bank concrete module 2 connects to module 3 (Fig. 26).

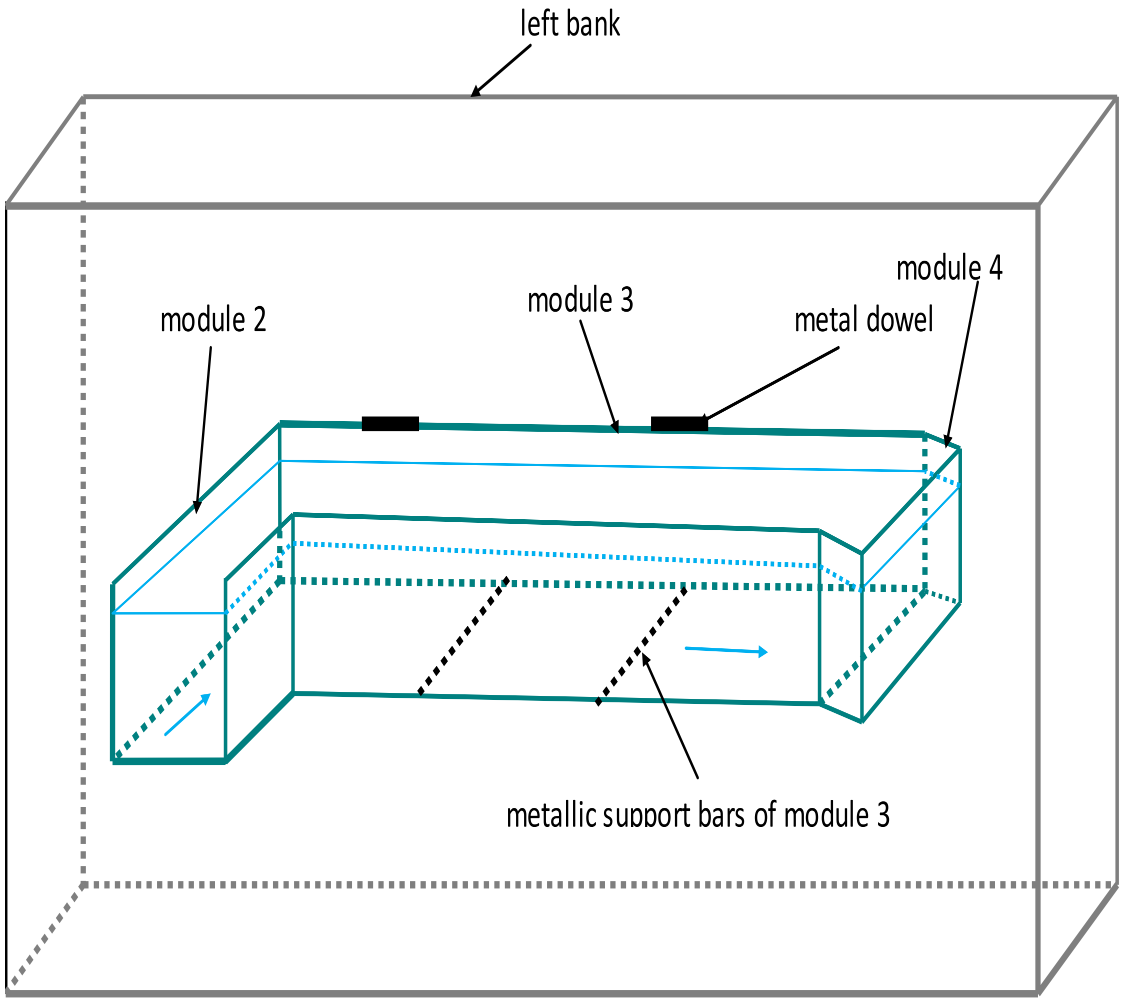


Figure 26: Positioning modules 2, 3 and 4.

From the downstream end of Module 3 will start Module 4 which will have the downstream end in two hydraulic junction basins of five cm (Fig. 27). The slope of all modules is smaller than the river slope in the study area. At the upstream end of the beam 1, a metallic grid in the semicircle, which stops the pet or floating wood material, will be fixed to the spill threshold. The grill will be 40 cm thick and will rise above the water at least five cm. The system has a durable structure and can withstand flooding.

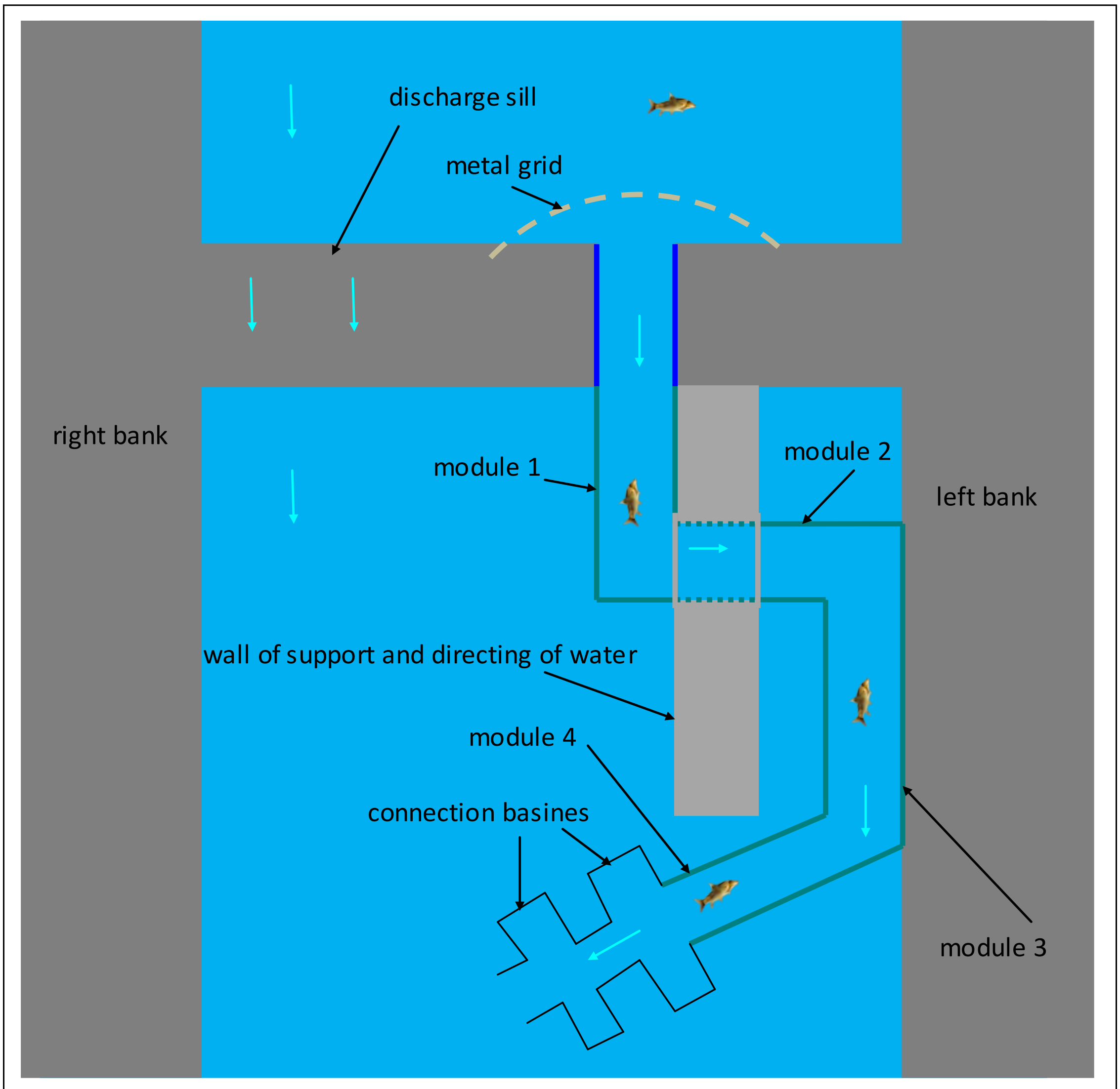


Figure 27: Positioning of the two connecting basins.

CONCLUSIONS

In a significant valuable from ichthyofauna conservation point of view basin of Timiş River, the Bistra Mărului River lotic habitats were heavily fragmented in the last 40 years by a large variety of hydrotechnical works categories (small – 0.20 cm to two m high, medium – two to four m high and big – four to 125 m high), all of them builded in the communist period of Eastern Eurpe when river fragmentation and natural conservation values were concepts almost totally missing in the field of these works construction.

The Carpathian Fish Index of Biotic Integrity (CF-IBI) values variation in space and time reveal athropogenic induced negative effects on characteristic fish fauna integrity, from past (natural) to present (deteriorated) and from upstream (still natural from some points of view) to downstream (deteriorated). The Carpathian Fish Index of Biotic Integrity values decreased in the big majority of the river, often significantly and with a continuous decreasing trend.

The most valuable and key fish species (*Salmo trutta fario, Cottus gobio, Thymallus thymallus, Eudontomyzon danfordi, Eudontomyzon vladykovi, Gobio uranoscopus, Barbus meridionalis,* and *Condrostoma nasus*) of Bistra Mărului River have declined significantly over the past two decades to the river fragmentation and water flow diminishing. Among them *Thymallus thymallus* and *Gobio uranoscopus* are now locally extinct (in Mara, Bistra Bouţarului and Bistra rivers is still present), and *Eudontomyzon vladykovi* is critically endangered.

Among the selected key fish species decreasing trend, the appearance, colonization and thrive of some not sensible fish species (e.g. *Squalius cephalus* and *Gobio gobio*) populations underline too the “sad story” of an extremely valuable Carpathian river ichthyofauna from conservative point of view.

All the three ichthyological zones for Bistra Mărului River suffer significant structural changes and an obvious major shifting, with an obvious advance from downstream to upstream of numerous uncharacteristic fish species.

The lack of proper scientific and practical knowledge in aquatic ecology in general and of ichthyology in special, the economic past and present very high and sometimes not moral and legal pressure on local administrations and environmental agencies, the so called political decisions and some inabilities in manage natural resources and services determine a continuous qualitative and quantitative degradation of habitats and related biocoenoses components, including obviously the fish.

All the technical solutions proposals of this research paper for the present hydro-technical work negative effects diminishing are both functional and aesthetic in the hydro-technical constructions in the study. These engineering solutions are designed to have a minimal negative impact during construction, designed to function without human intervention over a long period of time and without electricity consumption (for the three spill thresholds) and with minimal energy consumption for the system at the Poiana Mărului Dam. All the proposed solutions do not affect the structure of the hydro-technical constructions in the study area. The proposed solutions will make an important contribution to the recovery of local fish habitats and communities.

For the conservation of all key species (*Salmo trutta fario, Cottus gobio, Thymallus thymallus, Eudontomyzon danfordi, Eudontomyzon vladykovi, Gobio uranoscopus, Barbus meridionalis,* and *Condrostoma nasus*), the ecological status can be improved only if fish passage is improved. Furthermore, no other human constructed obstacles should be constructed (overfishing, mineral exploitation of the riverbed, pollution, banks and riverbed modifications, riverbanks ligneous vegetation deterioration, etc.).

The Bistra Mărului Basin ichthyofauna remains one of the most threatened in the Carpathians and urgent professional management care should be implemented!

ACKNOWLEDGEMENTS

The first author of this research paper is grateful for the chance to spend a wonderful childhood and teenaging in Bistra River Basin, and hope that a proper future ecological management of this basin will offer a similar chance for the coming generations of kids and not only.

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