Ecological integrity assessment of four rivers in Macedonia affected by derivation hydropower schemes based on aquatic macroinvertebrates

FINAL REPORT

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Introduction

Europe's waters are affected by several pressures, including water pollution, water scarcity and floods, and by major modifications affecting morphology and water flow. A recent study prepared by the European Environment Agency (EEA) found that over 40% of European waters are affected by hydromorphological pressures.[1] Urban development, flood protection, power generation including hydropower, inland water navigation, river straightening and land drainage for agriculture are recognised as important pressures affecting the hydromorphological status of water bodies. The river flow regime (seasonal and inter-annual variation in flow) and water level fluctuations are two of the major determinants of ecosystem functioning of rivers. The main challenge in managing water flows and water levels is to meet the reasonable needs of different water users, while leaving enough water in the environment to maintain fluvial habitats and species.[2]

Among the biggest current threats affecting the hydromorphological status of rivers are hydropower plants. Their benefits as a renewable source of electricity production is well known, but there is also a need to recognise that they can significantly affect the ecological functions of rivers and adjacent habitats in which they are located.[3]

Derivation hydropower plants are considered to have lower environmental impacts than impoundment schemes. As they usually have a smaller power capacity, derivation projects are often exempted from conducting a full environmental impact assessment (EIA). Despite their perception as low-impact, small hydropower plants (SHPPs) are having significant detrimental effects on river ecosystems and the longitudinal continuum for living organisms. Results from Vaikasas et al. (2015)[4] as well as those presented in the EC's draft *Guidance document on hydropower development and Natura 2000,*[5] reveal that their biophysical impact may exceed even those of large hydropower, particularly with regard to habitat security and hydrologic change. This is particularly true in countries with weak environmental governance, where the so-called 'national competent authorities' are failing to carry out adequate permitting and monitoring of such schemes.

Overall, the kinds of impact fall into the following main categories[6]:

i) **Habitat changes:** the construction or renovation of a hydropower plant can impact in various ways on a river's ecosystem. These changes might include not just physical habitat loss but also its deterioration and degradation (through changes in its functionality and resilience), and habitat fragmentation.

ii) **Direct impacts on the species present:** animal species may be prevented from circulating because of the use of certain hydropower turbines and the existence of dams and

[1] European waters – assessment of status and pressures (2012) http://www.eea.europa.eu/publications/european-waters-assessment-2012

[2] Guidance document on hydropower development and Natura 2000. 4th draft European Commission, 2015, p. 33, https://circabc.europa.eu/sd/a/b194a383-8703-4dbc-a18f-e75407c9bd95/hydropower_guide_draft_consultation.pdf

[3] Schwarz U. (2012): Balkan Rivers – The Blue Heart of Europe. Hydromorphological Status and Dam Projects For ECA Watch Austria/Euronature Germany/MAVA Switzerland, 150 pp and 101 pp. Separate Annex („River Catalogue"). Vienna

[4] Vaikasas, S., Bastiene, N., & Pliuraite, V. (2015). Impact of small hydropower plants on physicochemical and biotic environments in flatland riverbeds of Lithuania. Journal of Water

[5] Guidance document on hydropower development and Natura 2000. 4th draft European Commission, 2015 https://circabc.europa.eu/sd/a/b194a383-8703-4dbc-a18f-e75407c9bd95/hydropower_guide_draft_consultation.pdf

[6] Ibid., p. 43

weirs which act as barriers to movement and migration. These impacts can include loss or injury of specimens, as well as displacement, disturbance and barrier effects, etc.

Among habitat changes such as disruption of ecological continuity by destruction of naturally flowing sections, sediment dynamics, water chemical changes etc., daily changes in river flow based on energy demand, known as ‘hydropeaking’, have the main negative impact on biological communities, especially fish and macroinvertebrates.[7,8]

Hydropeaking consists of variations in discharge and water level due to releases of water retained in a storage basin to generate electricity according to the market demand. These unnatural flow fluctuations create frequent and rapid variations in terms of flow magnitude, flow velocity, water depth, water temperature, wetted area and sediment transport which also can affect channel morphology. Such changes may lead to degradation of physical conditions and habitats in local ecosystems, which directly affect macroinvertebrates in the rivers. Dramatic rising and falling of water levels is a common experience for marine invertebrates adapted to life on the rocky coast – but not so for invertebrates living in rivers, at least historically. However, once an SHPP is built, a river’s flow no longer depends on the rhythm of the seasons, but is managed to accommodate the demand for electricity.

During the last decade, Balkan countries have experienced a wave of hydropower projects in protected areas. Macedonia, for example, is currently very active in awarding concessions for the construction of SHPPs in protected areas including national parks, Emerald sites and important plant and bird areas.[9]

In the present study, an ecological integrity assessment of four rivers in Macedonia affected by SHPPs based on aquatic macroinvertebrates is provided. The selected SHPPs are financed by international development banks such as the European Investment Bank (EIB) and the European Bank for Reconstruction and Development (EBRD).

Macroinvertebrates have been selected as the target group due to the fact that they play an important role in stream ecosystem function, providing an essential link in the food chain as they represent an important source of food for higher animals. They are less mobile than most other groups of aquatic organisms, they are easily collected, and most have relatively long periods of development in the aquatic environment.[10] Many macroinvertebrates are vulnerable to rapid diurnal changes in flow, and regulated river reaches below the SHPPs, with erratic flow pattern, are typically characterized by species poor macroinvertebrate communities.[11] Thus, macroinvertebrate species should reflect deleterious events that have occurred in the aquatic environment during any stage of their development, and therefore are often used as biological indicators.

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[7] Bunn, S. E., & Arthington, A. H. (2002). Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environmental management, 30(4), 492-507

[8] Kennedy, T. A., Muehlbauer, J. D., Yackulic, C. B., Lytle, D. A., Miller, S. W., Dibble, K. L., ... & Baxter, C. V. (2016). Flow management for hydropower extirpates aquatic insects, undermining river food webs. BioScience, 66(7), 561-575.

[9] Gallop, P., & Sikorova, K. (2015). Financing for hydropower in protected areas in Southeast Europe. RiverWatch & EuroNatur, 46 pp. https://bankwatch.org/sites/default/files/SEE-hydropower-financing.pdf

[10] Resh, V. H. R., David, M., & VH, R. (1993). Freshwater biomonitoring and benthic macroinvertebrates. Chapman and Hall, New York

[11] Bunn, S. E., & Arthington, A. H. (2002). Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environmental management, 30(4), 492-507

Chapter 1: Methodology

The field monitoring was carried out on five SHPPs in operation during the period of 11-15 September 2017 in Macedonia. Most of the SHPPs that were visited and checked are located within the boundaries of proposed or announced Emerald sites and national parks in Macedonia.

Overall, 21 selected monitoring stations along the Kamena river, the Bistrica river, the Tresonecka river, the Brajcinska river and its tributaries Kriva Kobila, Rzanska and the Stanisar river were visited during the field monitoring. In most cases, macroinvertebrates were collected above and below the intake and the powerhouse on SHPP Lipkovo, SHPPs Tearce 97, 98, 99, SHPP Tresonecka, SHPP Brajcino 1 and SHPP Brajcino 2, respectively. Dried river beds prevented the collection of macroinvertebrates below intake on the Kriva Kobila river and the Brajcinska river (SHPP Brajcino 1). More detailed information about the monitoring stations is given in Table 1.

Table 1. List of monitoring sites

SHPP	Monitoring station	Monitoring station code	GPS coordinates	Altitude (m.a.s.l.)	Water temperature (◦C)	Date	Notes
SHPP Lipkovo **In operation since 2015**	Kamena river above the intake	LAI	42.2232854, 21.5013728	827 m.a.s.l.	14.5	11.09.2017	
	Kamena river below the intake	LBI	42.2210830, 21.5037442	823 m.a.s.l.	15	11.09.2017	
	Kamena river below the powerhouse	LBP	42.1968623, 21.5248403	609 m.a.s.l.	15.6	11.09.2017	
SHPPs Tearce 97 **In operation since 2014**	Bistrica river above the intake of SHPP Tearce97	$T_{97}AI$	42.1132957, 21.0019270	1198 m.a.s.l.	11	12.09.2017	Working
SHPPs Tearce 98 **In operation since 2014**	Bistrica river above the intake of SHPP Tearce98	$T_{98}AI$	42.1074460, 21.0228033	1215 m.a.s.l.	13.5	12.09.2017	
SHPPs Tearce 98 **In operation since 2014**	Bistrica river below the intake of SHPP Tearce98	$T_{98}BI$	42° 6'24.61"N 21° 1'26.68"E	994 m.a.s.l .	12.7	12.09.2017	
SHPPs Tearce 99 **In operation since 2014**	Bistrica river below the intake of SHPP Tearce99	$T_{99}BI$	42.0876416, 21.0522790	613 m.a.s.l.	15.6	12.09.2017	
SHPP Tresonecka **In operation since 2013**	Tresonecka river above the intake	TAI	41.5669994, 20.7439667	1136 m.a.s.l.	8.5	13.09.2017	
	Tresonecka river below the intake	TBI	41.5671325, 20.7428286	1140 m.a.s.l.	9	13.09.2017	

	Tresonecka river above the powerhouse	TAP	41.5619852, 20.7312397	1020 m.a.s.l.	10.1	13.09.2017	
	Tresonecka river below the powerhouse	TBP	41.5619017, 20.7285260	1018 m.a.s.l.	10.5	13.09.2017	
SHPP Brajcino 1 **In operation since 2013**	Kriva kobila river above the intake	B_1KAI	40.92545, 21.21635	1348 m.a.s.l.	12.1	14.09.2014	Working
	Kriva kobila river below the intake	B_1KBI	40.9249042, 21.2165207	1357 m.a.s.l.	13.7	14.09.2014	
	Brajcinska river above the intake	B_1BAI	40.920060, 21.220865	1354 m.a.s.l.	11.7	14.09.2014	Working
	Brajcinska river below the intake	B_1BBI	40°55'14.75"N2 1°13'10.07"E	1326 m.a.s.l.	/	14.09.2014	
	Brajcinska river above the powerhouse of SHPP Brajcinska 1	B_1BAP	40.917816, 21.195804	1191 m.a.s.l.	13	14.09.2014	
	Rzanska river before the entrance in the pool below powerhouse of SHPP Brajcinska 1 and above the intake of SHPP Brajcinska 2	B_1R	40.9176233, 21.1950391	1140 m.a.s.l.	12.2	14.09.2014	
SHPP Brajcino 2 **In operation since 2014**	Stanisar river above the intake	B_2SAI	40.9202176, 21.1826575	1193 m.a.s.l.	13.5	14.09.2014	
	Stanisar river below the intake	B_2SBI	40.9161745, 21.1819384	1140 m.a.s.l.	10.5	15.09.2014	
	Brajcinska river above the powerhouse of SHPP Brajcinska 2	B_2BAP	40°54'38.45"N2 1°10'24.19"E	1101 m.a.s.l.	13	15.09.2014	
	Brajcinska reka river below the powerhouse of SHPP Brajcinska 2	B_2BBP	40°54'37.22"N 21°10'14.35"E	1065 m.a.s.l.	14.1	15.09.2014	

At each monitoring station macroinvertebrate samples were obtained using the 'Kick sampling' method, a technique in which submerged aquatic vegetation, stones and other hard substrate are disturbed to encourage organisms to flow downstream into a 500 µm mesh net. To allow semi-quantitative results to be calculated, as well as to catch the maximum numbers of taxa, samples were collected from all microhabitats with constant kicking (20 minutes of sampling at each monitoring site). Standard methodology for collection of bottom fauna (EN ISO 10870: 2012) was followed.[12] The next step was transferring the biological material into sample containers. Samples were preserved with ethanol with a final concentration of 70%. During the field monitoring water temperature was also measured using a portable digital thermometer.

Further processing of the material was conducted in the Laboratory of Invertebrates at the Faculty of Natural Sciences and Mathematics, which included the sorting of macroinvertebrates into groups for further identification, the preparation of numerous permanent slides, as well as adequate handling, labelling, and documentation of the sorted material. Macroinvertebrate specimens prepared for taxonomic work were identified under an Olympus SZX9 binocular microscope using the appropriate taxonomic keys[13,14,15,16,17,18,19,20] to the lowest possible taxonomic level. Subsequently, an identification list of detected taxa was produced. Detailed analyses on the composition and abundance of macroinvertebrate fauna were performed. Abundance was expressed as a number of individuals.

The obtained results on taxa composition and abundance were subjected to calculations on different indices or metrics which are usually employed to study the impacts of HPPs.[21,22] To provide data concerning community structure, Shannon-Wiener diversity index (H) and Margalef's diversity index (d) were calculated. Both indices are highly suited to assess the impact of organic pollution, degradation in stream morphology, as well as general degradation. Among them Margalef's diversity index (d) presents a common species richness index which incorporates the total number of taxa as well as total individuals. The index is informative about the health of the community through its diversity and increasing habitat diversity, suitability and water quality. The healthier the community is, the higher is the value of the index. The Shannon-Wiener Diversity index (H) is commonly used to calculate aquatic and terrestrial biodiversity. By taking relative abundances into account, a diversity index depends not only on species richness but also on the evenness, or equitability, with which individuals are distributed among the different species. As the number and distribution of taxa (biotic diversity) within the community increases, so does the value of H.

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12 EN ISO 10870: 2012. Water quality – Guidelines for the selection of sampling methods and devices for benthic macroinvertebrates in fresh waters.

13 LILLEHAMMER, A. 1988. Stoneflies (Plecoptera) of Fenoscandia and Denmark. Fauna En-tomologica Scandinavica. Vol 21, 1-165.

14 ELLIOTT, J.M. 1996. A key to the larvae and adults of British freshwater Megaloptera and Neuroptera. Freshwater Biological Association. Scientific Publication No. 54, 68 pp

15 FRIDAY, L.E. 1988. A key to the adults of British water beetles. Field studies 7(1), 151 pp.

16 REYNOLDSON, T.B. 1978. A key to the British species of Freshwater Triclads (Turbellaria, Paludicola). Freshwater Biological Association. Scientific Publication No. 23, 26 pp.

17 M. Karaman, Faune de Macedoine, II (Decapoda), Musée D'histoire Naturalle de Skopje, Skopje, 1976. (In Macedonian)

18 NILSSON, A.N. (ed.) 1996. Aquatic Insects of North Europe. A Taxonomic Handbook. Vol-ume 1. Apollo Books, Stenstrup, 274 pp.

19 Wallace, I. D., Wallace, B. & Philipson, G. N. (2003): Keys to the Case-Bearing Caddis Larvae of Britain and Ireland. Scientific Publication 61. Freshwater Biological Association: Ambleside

20 Waringer, J. & Graf, W. (2013): Key and bibliography of the genera of European Trichoptera larvae. Zootaxa, 3640 (2): 101-151

21 Principe, R. E. (2010, January). Ecological effects of small dams on benthic macroinvertebrate communities of mountain streams (Córdoba, Argentina). In Annales de Limnologie-International Journal of Limnology (Vol. 46, No. 2, pp. 77-91). EDP Sciences.

22 Bredenhand, E., & Samways, M. J. (2009). Impact of a dam on benthic macroinvertebrates in a small river in a biodiversity hotspot: Cape Floristic Region, South Africa. Journal of Insect Conservation, 13(3), 297-307.

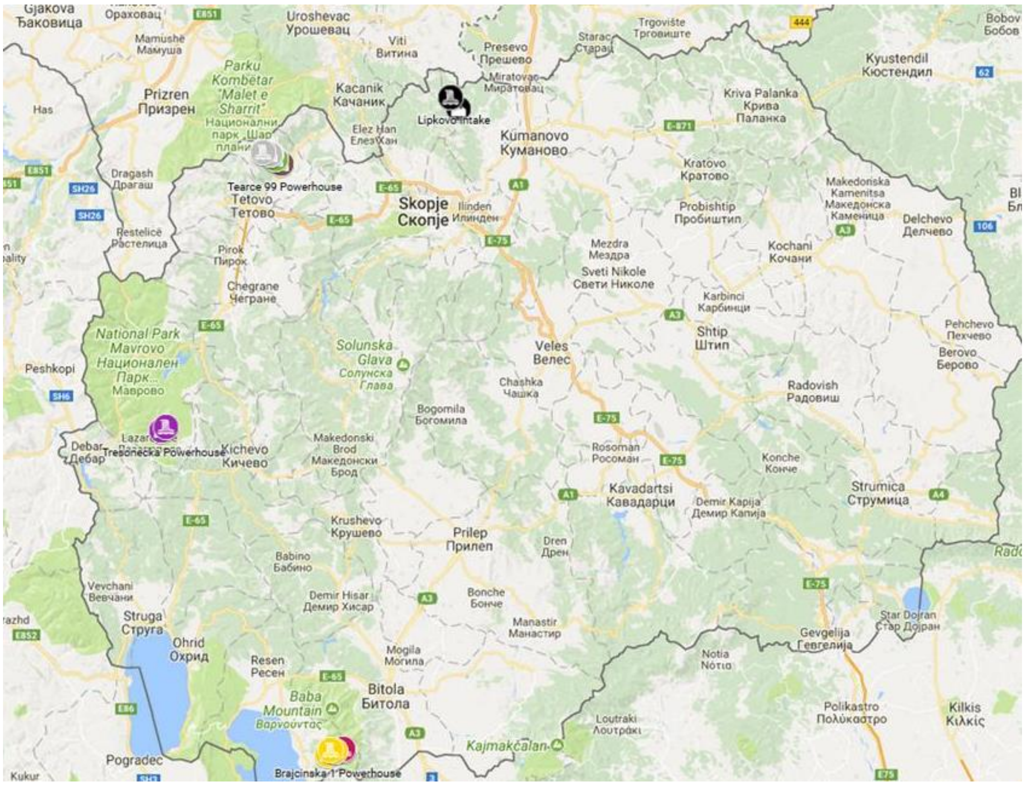

Figure 1. Sampling stations monitored during the field campaign.

Furthermore, the most represented biotic indices or metrics, such as the number of Ephemeroptera, Plecoptera, and Trichoptera taxa (number of EPT taxa), the Biological Monitoring Working Party (BMWP) Score and Average Score Per Taxon (ASPT), were used in the assessment of the ecological status of the monitoring stations. The BMWP (Armitage et al., 1983)[23] provides single values, at the family level (with the exception of Oligochaeta, which is at the order level), representative of the organisms' tolerance to the environmental stressors. The greater their tolerance, the lower the BMWP scores. The ASPT (Armitage et al., 1983)[24] represents the average tolerance score of all taxa within the community, and was calculated by dividing the BMWP by the number of families represented in the sample. The number of EPT taxa (Plafkin et al., 1989)[25] index displays the EPT taxa richness within the insect groups which are considered to be sensitive to pollution, and therefore should increase with increasing water quality. These three indices are most suited for assessing the impact of degradation in stream morphology, acidification, as well as general degradation.[26] Class boundaries for different biotic indices and water classification are given in Table 2. Categorization of the ecological status was made according to the classification of surface water given in Annex V of Water Framework Directive (WFD).

ASTERICS software (version 3.0; www.aqem.de) was used to calculate all the above mentioned indices, as well as metrics such as: the number of taxa, the number of sensitive

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23 Armitage, P. D., Moss, D., Wright, J. F., & Furse, M. T. (1983). The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites. Water research, 17(3), 333-347.

24 Ibid.

25 Plafkin, J. L., Barbour, M. T., Porter, K. D., Gross, S. K., & Hughes, R. M. (1989). Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. In Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish. EPA.

26 AQEM CONSORTIUM (2002). Manual for the application of the AQEM system. A comprehensive method to assess European streams using benthic macroinvertebrates, developed for the purpose of the Water Framework Directive. Version 1.0, February 2002.

taxa, the percentage of Ephemeroptera, Plecoptera, Trichoptera (%EPT) and the percentage of Diptera which contribute to the biodiversity assessment.

The valorization of aquatic macroinvertebrates was produced according to the national and international conventions and laws for the protection of endangered species at the European and global level. The list includes: the EU Habitats Directive 92/43/EEC[27], the IUCN Red List of Globally Threatened Species[28], the European Red List of Non-marine Molluscs[29], the European Red List of Dragonflies[30] and the Lists for Designation of Strictly Protected and Protected Wild Species in the Republic of Macedonia[31]. Within the scope of the present report, endemism, and the presence of rare species with restricted distribution range in Macedonia, were taken into consideration.

27 EU Habitats Directive (92/43EEC): Council Directive 92/43/ EEC on the Conservation of natural habitats and of wild fauna and flora; OJ L 206/7, 22.7.92.
28 UCN 2017. The IUCN Red List of Threatened Species. Version 2017-2. <http://www.iucnredlist.org>. Downloaded on 14 September 2017
29 Cuttelod, A., Seddon, M. and Neubert, E. 2011. European Red List of Non-marine Molluscs. Luxembourg: Publications Office of the European Union
30 V.J. Kalkman, J.-P. Boudot, R. Bernard, K.-J. Conze, G. De Knijf, E. Dyatlova, S. Ferreira, M. Jović, J. Ott, E. Riservato and G. Sahlén. 2010. European Red List of Dragonflies. Luxembourg: Publications Office of the European Union.
31 Lists for Designation of Strictly Protected and Protected Wild Species in the Republic of Macedonia, 2011, Official Gazette of the Republic of Macedonia no. 139/2011

Chapter 2 Findings

2.1 Lipkovo (also MHEC Kamena reka 125) financed by the EIB

The Lipkovo SHPP is situated in the border area of the designated Important Plant Area (IPA)[32]. During the field trip material was collected at three monitoring stations on the Kamena river affected by the Lipkovo SHPP. Macroinvertebrate assemblage indicated a 'healthy' river sector on the Kamena river **above the intake (LAI).** The monitoring site is characterized by high biological diversity (high number of taxa, a number of EPT taxa, and a number of sensitive taxa), as well as dominance of sensitive EPT taxa (60.2%) such as mayfly (*Ecdyonurus venosus)*, stonefly (*Perla marginata)* and caddisfly (*Hydropsyche instabilis)* (Fig. 11, Tab. 4).

Additionally, the research showed the occurrence of good populations of stone crayfish (*Austropotamobius torrentium)* and the Balkan goldenring dragon fly (*Cordulegaster heros),* whose conservation requires the designation of Special Areas of Conservation (SACs) within the Natura 2000 network.

Obviously, well conserved habitat (Fig. 2a) provides quality conditions for obtaining good populations of the stone crayfish and the Balkan goldenring dragon fly whose conservation requires designation of Special Areas of Conservation (SACs) within the Natura 2000 network. Both species are listed in Annex II of the Habitats Directive and the stone crayfish is a priority species, which provides an even higher protection status. Further, *A. torrentium* and the *C. heros* present protected wild species in Macedonia[33,] while the latter is ranged as "Near Threatened" on the IUCN Red List of Globally Threatened Species and the European Red List of Dragonflies[34].

These two species are not tolerant of environmental change, so threats such as domestic and industrial pollution, agriculture, sedimentation, eutrophication, damming, water abstraction, and channelization have an extremely negative impact on them.[35]

Overall, we have two species whose habitat should not be altered and which require protection, particularly because this area is not yet recognized as an area with a high conservation value. Unfortunately, their monitoring was omitted or ignored in both the environmental elaborate[36] and the Strategic Enviromental Assesment[37] before the construction of this SHPP, despite the fact that there is literature data confirming their occurrence in the area.[38,39] In summary the high ecological status (Table 2) and non- existence of signs of fragmentation of the populations indicate that the Lipkovo SHPP has no impact on the Kamena river above **the intake.**

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32 Melovski, Lj., Matevski, V., Kostadinovski, M., Karadelev, M., Angelova N. & Radford, E. A. (2010): Important Plant Areas in Republic of Macedonia. Special Edition of Macedonian Ecological Society. 9. 100-101

33 Lists for Designation of Strictly Protected and Protected Wild Species in the Republic of Macedonia, 2011, Official Gazette of the Republic of Macedonia no. 139/2011

34 Boudot, J.-P. 2010. Cordulegaster heros. The IUCN Red List of Threatened Species (2010), pp. 1-11.

35 Slavevska-Stamenkovic, V., Rimceska, B., Stojkoska, E., Stefanovska, N., Hinic, J., & Kostov, V. (2016). The catalogue of freshwater Decapoda (Decapoda: Potamonidae, Astacidae, Atyidae) from the Republic of Macedonia in the collection of Macedonian Museum of Natural History. Contributions. Section of Natural, Mathematical & Biotechnical Sciences, 37(2).

36 Environmental Elaborate SHPP 125 "Kamena reka" Lipkovo. February 2013

37 Strategic Enviromental Assesment SHPP 125 "Kamena reka" Lipkovo. October 2012

38 Jović, M., & Mihajlova, B. (2009). Catalogue of the Odonata collection in the Macedonian Museum of Natural History. Acta entomologica serbica, 14(2), 133-146.

39 M. A. Subchev, Branchiobdellidans (Annelida: Clitellata) found in the crayfish and annelid collections of the Natural History Museum of Humboldt University, Berlin, Germany, Acta zoologica bulgarica, 59 (3) (2007), pp. 275–282.

Below the intake of the Kamena river the situation is not very similar with the one above the intake. It was apparent that the construction activities had resulted in the extreme loss of riparian vegetation and contributed to the deposition of sediment in the riverbed (Fig. 2c). The noticeable eutrophication in the lake above the intake (methane bubbles were present) probably contributed to changes in water quality and the mass occurrence of algae.

During the monitoring, reduced water level in the riverbed below the intake was noticed and, according to local people, the river often becomes dry, providing conditions for the occurrence of the eurivalent species such as aquatic snails from the Lymnaeidae family. Due to the accumulation of thinner sediments and the possible hydropeaking effect, the abundance of filter feeding Tanytarsinae (Chironomidae) increase, which results in a shift from a macroinvertebrate community dominated by EPT taxa (34%) to a community dominated by Dipterans (51%), mainly Chironomids (Fig 11).

It is widely recognized that insects such as mayflies, caddisflies and stoneflies, which lay their eggs on rocks at the river's edge, are significantly affected by the hydropeaking effect, while Chironomids, which lay eggs in open water, are mostly unaffected.[40]

Furthermore, the density of the macroinvertebrates and the number of sensitive taxa (4), as well as the values of the diversity indices (Fig. 13), moderately decreased confirming the less favourable conditions. The absence of species of Community interest most likely is a result of the loss of their habitats. Clausnitzer et al. (2009)[41] have emphasized that, for the endangered Balkan Golden ring, altering habitats surrounding headwater stream sections can strongly modify emergence behavior. Changes in vegetation may affect the number of individuals of the next generation and ultimately the survival of the population, so the conservation of forest habitats at *C. heros* sites seems to be crucial to their long-term persistence. Concerning the stone crayfish, the deposition of sediment in the riverbed and the loss of the riparian vegetation at this part of the river do not provide appropriate shelter to protect the crayfish protection from predation or to prevent drift.

a)

b)

[40] Guidance document on hydropower development and Natura 2000. 4th draft European Commission, 2015

[41] Clausnitzer, V., Kalkman, V. J., Ram, M., Collen, B., Baillie, J. E., Bedjanič, M., ... & Karube, H. (2009). Odonata enter the biodiversity crisis debate: the first global assessment of an insect group. Biological Conservation, 142(8), 1864-1869.

c) d)

Figure 2. a), b) The Kamena river above intake; c) the Kamena river below intake; d) the Kamena river below the powerhouse of the Lipkovo SHPP

Contrary to the already mentioned changes in the community, the number of taxa (19) and number of EPT taxa (8) is still relatively high and almost the same taxa as above occurred below the intake, although in lower number. Thus, the metrics values (BMWP, ASPT and EPT taxa) indicate good ecological status.

Based on expert opinion and judgment it is possible that, in fact, the intensity of the influence of the intake is stronger and the ecological status is worse (at least **moderate**). Namely the adults of the aquatic insects whose larvae inhabited the upper part of the river apparently laid their eggs in the water below the intake. Moreover, it cannot be ruled out that the hydropeaking effect contributed to this condition. Namely, a sudden increase in flow can cause the downstream drift of small insect larvae which are not able to tolerate high velocities and are often underrepresented in downstream reaches.[42] Regardless, for a more precise assessment of the impact of this SHPP and determination of the actual condition, further investigation should be focused on this river sector.

a) b)

Figure 3. Species of Community interest: a) *Austropotamobius torrentium*; b) *Cordulegaster heros* (larvae)

[42] Wang, X., Cai, Q., Jiang, W., & Qu, X. (2013). Assessing impacts of a dam construction on benthic macroinvertebrate communities in a mountain stream. Fresenius Environmental Bulletin, 22(1), 103-110.

The findings of the biological monitoring show that the biodiversity condition on Kamena river **below the powerhouse** is better than below the intake. The Kamena river powerhouse wasn't working during the field visit and the river was running with its natural flow, contributing to an increasing number of taxa (18), number of EPT taxa (52,5%) as well as the number of sensitive taxa (7). The presence of a stone crayfish should be indicative of a better quality ecosystem in this part of the river.

However, because it is a very young individual, it has perhaps arrived there along with the waterflow. The only way to confirm if the stone crayfish really inhabits this part of the river is with further thorough investigation. If it really does, it would mean that this part of the Kamena river is not yet influenced by the construction of the HPP (given that the operation phase started in 2015) or if it was, it has fully recovered. Additionally, the sampling site was after the confluence of the Brestajnska river, so the possibility that the stone crayfish actually inhabits Brestjanska and was found here in Kamena by chance (arriving from Brestajnska with the waterflow) cannot be discounted.

The fact that the presence of the Balkan golden ring wasn't noted suggests the light but still existing impact of the Lipkovo SHPP towards the Kamena river's biodiversity, which corresponds with the results of the biological assessment which indicate that the LBP is slightly altered (**good** ecological status, Tab. 3)

2.2 Tearce 97-99 (also Bistrica 97-98) financed by the EIB

In order to identify the influence of the Tearce 97, 98, and 99 SHPPs, located in the Shar Mountains, aquatic invertebrates were collected at four monitoring stations on the Bistrica river. The Tearce 97, and 98 SHPPs are situated in an area protected within the Emerald network.

The Bistrica river **above the first intake (Tearce 97)** is in pristine, natural condition, with well developed riparian vegetation. The monitoring site is characterized by high biological diversity, which also means a high number of taxa (23), a number of EPT taxa (16), and a number of sensitive taxa (11), as well as the dominance of sensitive EPT taxa (68.7%) such as mayflies *Ecdyonurus helveticus*, *Habroleptoides confusa*, *Baetis rhodani,* stonefly *Dinocras megacpheala, Isoperla grammatica, Protonemura praecox* and caddisfly *Hydropsyche saxonica, Philopotamus montanus, Drusus discolor* (Figs.11, 12; Tab. 4).

The presence of adult specimens of sensitive, cold stenothermic *Limnius volckmarii* (Coleoptera) additionally indicate the favourable, undisturbed conditions of the Bistrica river above the first intake.

a) b) c) d)

Figure 4. a) The Bistrica river above the intake of Tearce 97 SHPP; b) the Bistrica river above the intake of Tearce 98 SHPP; c) the Bistrica river below the intake of the Tearce 98 SHPP; d) the Bistrica river below the intake of the Tearce 99 SHPP

This correlates with the results from the biological assessment based on indices BMWP, ASPT and EPT taxa richness (**high** ecological status).

The density of the macroinvertebrates, the number of sensitive taxa (5 and 5), as well as the values of diversity indices (Fig. 11), moderately decreased referring to the less favourable conditions on the Bistrica river **above and below the second intake** (Tearce 98). However, the number of taxa (20 and 18) and the number of EPT taxa (12 and 11) is still significantly high, and most of the taxa inhabiting the Bistrica river above the first intake (Tearce 97) occurred above and below the second intake, although in lower number.

It is possible that the composition of the community is due to sudden changes in water discharge from the Tearce 97 powerhouse which was working during the field visit. Populations in this impacted stretch were presented by early larval stages of aquatic insects, more prone to drift and thus to colonize downstream areas. Therefore, it is completely understandable why the biological metrics values indicate that the river reach is slightly altered (good ecological status, Tab. 3). Based on expert opinion and judgement, it is possible that the intensity of the influence of the intake of Tearce 98 is stronger and that the ecological status is actually worse (at least **moderate**). However, for a more precise assessment of the impact of this SHPP and determination of the actual condition, further investigation should be focused on this river sector.

The worst condition concerning biological diversity and ecological status (**poor**) was noted **below the third intake (Tearce 99).** The drastic reduction of aquatic invertebrate species (10), number of EPT taxa (4) and number of sensitive taxa (3), as well as the severe drop in the abundance of the benthic community (three to five times lower than the upper part of the river) may be a result of the cumulative effect from the the HPP cascade system and of the deteriorated water quality caused by the settlement.

2.3 Tresonecka (Mavrovo National Park) (EBRD)

A biodiversity impact assessment was carried out on four monitoring stations on the Tresonecka river affected by the Tresonce SHPP. This SHPP is located within the boundaries of the National Park Mavrovo, part of the Emerald network in Macedonia (non-EU country), which represents a future Natura 2000 site.

The highest biodiversity (25 taxa) and the best conserved habitats (Fig. 5a) were noticed **above the intake**. The results showed that this part of the river is inhabited with macroinvertebrates, characteristic for cold (8.5°C; see Table 1), fast flowing and well oxygenated streams (Fig 5a). The benthic community is characterized by a high EPT taxa richness (16), a high number of sensitive taxa (11), as well as high values of diversity indices.

From the quantitative point of view, the most numerous species were oligosaprobic aquatic insects such as: *Ecdyonurus helveticus*, *Rhithrogena gratianopolitana,* (Ephemeroptera), *Isoperla grammatica*, *Protonemura praecox* (Plecoptera), *Oecismus monedulla*, *Thremma anomalum* (Trichoptera), *Lymnius volckmarii* (Coleoptera) – this indicates pristine conditions. Biological assessment, based on BMWP, ASPT and EPT taxa richness, indicated a 'healthy' sector of the Tresonecka river (**high** ecological status).

Furthermore, species of Community interest, such as *Austropotamobius torrentium* and *Cordulegaster heros* were not recorded (the same situation was noticed at the Bistrica river above the first intake), however TAI contains enormous biodiversity and important species for protection. The significant members in the macroinvertebrate fauna from the Tresonecka river above the intake were the caddisfly (*Thremma anomalum,* Fig. 6)*,* a subendemic species for the Balkan Peninsula, Carpathians and Caucasus, and the Balkan endemic hydrobiid snail (*Bythinella drimica drimica*) inhabiting only fast flowing waters in western Macedonia, eastern Albania and Kosovo. The latter is ranged as "Least concern" on the IUCN Red List of Globally Threatened Species[43] and on the European Red List of Non-marine Molluscs[44]. *B. d. drimica* present rare species with restricted distribution range only in

[43] IUCN 2017. The IUCN Red List of Threatened Species. Version 2017-2. <http://www.iucnredlist.org>. Downloaded on 14 September 2017
[44] Cuttelod, A., Seddon, M. and Neubert, E. 2011. European Red List of Non-marine Molluscs. Luxembourg: Publications Office of the European Union

a few localities in western Macedonia and present protected wild species in the country[45]. The taxonomic identification of macroinvertebrates showed the presence of still undescribed representatives of leeches (*Dina* sp. nov. 1) which additionally reflects the well known high conservation value of the area.

a) b)

c) d)

Figure 5. a) The Tresonecka river above intake; b) the Tresonecka river below intake; c) the Tresonecka river above the powerhouse of the Tresonce SHPP; d) the Tresonecka river below the powerhouse of the Tresonce SHPP

Although the habitat seems well conserved, the field monitoring and biodiversity assessment show that the SHPP has the strongest impact at the river stretch **between the intake and the powerhouse** (TBI and TAP). Below the intake, the black line seen on the stones suggested that the water level in the previous period was around 10-15 cm lower than during the field monitoring and that water fluctuations are common, or that the riverbed is dry in a certain part of the year. The mass occurrence of algae on stones as well as the presence of

[45] Lists for Designation of Strictly Protected and Protected Wild Species in the Republic of Macedonia, 2011, Official Gazette of the Republic of Macedonia no. 139/2011

the eurivalent species such as aquatic snails from the Lymnaeidae family at the part of the river above the powerhouse confirms this presumption.

Additionally, the composition and structure of macroinvertebrate fauna significantly changed. The drastic reduction of aquatic invertebrate species (9 and 7), and the severe drop in the number of EPT taxa (4 and 2) and in the abundance of the benthic community (ten times lower) at TBI and TAP, as well as the disappearance of sensitive taxa (2 and 0) and endemic species (caddisfly *Thremma anomalum* and aquatic snail *Bythinella drimica drimica*) could be the result of a hydropeaking event or long-term dry condition. According to an analysis of threatened freshwater fish and molluscs in the Balkans and the potential impact of hydropower projects, many threatened hydrobiids are highly vulnerable to the construction of dams and the habitat alterations which ensue[46]. Also, it cannot be discounted that some other stressors linked to the construction or the operational phase (higher water temperature, the deterioration of water quality, lower oxygen concentration etc.) exist which prevent macroinvertebrate fauna recolonizing the river. The absence of the still undescribed leech *Dina* sp. nov. 1 is further evidence that this area, recognized as a biodiversity hotspot, is at risk of destruction and that many species may become extinct without ever being discovered. It is evident that the community structure indicates a high level of ecosystem stress – or **poor** towards **bad** ecological status – of the sector between the intake and the powerhouse. The biological metrics values provided in Table 3 confirm this statement.

a) b)

Fig. 6. a) *Thremma anomalum;* b) *Bythinella drimica drimica*

Regarding the Tresonecka river, below the powerhouse the situation with water flow condition is improved and consequently the abundance of macroinvertebrates, number of taxa (16) and EPT taxa (10) has moderately increased. However, a more detailed biological assessment indicates that the ecosystem did not fully recover, and the ecological status is **moderate**. Namely, the values of diversity indices increased only slightly, while the number of sensitive taxa remains low (3). Although a good population of caddisfly *T. anomalum* still exist, the stenothermic cold water endemic aquatic snail *Bythinella drimica drimica* and the unknown *Dina* sp. nov. 1 are absent.

[46] Freyhof, J. (2012): Threatened freshwater fish and molluscs of the Balkan. Report for the ECA-Watch/Euronature project “Balkan Rivers - The Blue Heart of Europe”. In print. Berlin

2.4 Brajcinska reka 1 (also Brajcino 1) financed by the EBRD

The Brajcinska reka 1 SHPP is located in the boundaries of the Pelister National Park.

a) b) c) d)

Figure 7. a) The Kriva kobila river above the intake; b) The Kriva kobila river below the intake; c) The Brajcinska river above the intake; d) The Brajcinska river below the intake

Observations conducted on the Brajcinska and Kriva Kobila rivers **above the intake** on Brajcinska 1 SHPP (Figs. 7a, 7c) as well as on the Rzanska river showed well conserved and undisturbed habitats. Macroinvertebrate assemblage on these three sampling sites was characterized by the greatest species diversity (25, 21 and 19 taxa), a high number of sensitive taxa (10, 9, 7) and high EPT taxa values (13, 13 and 10). The watercourses were inhabited by macroinvertebrates typical of clean, fast flowing and well oxygenated streams, and were mostly composed of xeno- and oligosaprobic aquatic insects such as: *Ecdyonurus helveticus*, *Epeorus assimilis* (Ephemeroptera), *Dinocras megacephala*, *Protonemura praecox*, *Leuctra nigra* (Plecoptera), *Philopotamus montanus*, *Oecismus monedulla, Rhyacophila nubila, Rhyacophila tristis* (Trichoptera) and adult specimens and larvae of sensitive cold stenothermic *Limnius volckmarii* (Coleoptera), indicating high water quality. *Crenobia alpina* and *Dugessia gonocephala* (Turbellaria), *Gammarus balcanicus* (Amphipoda) as well as Orthocladiinae spp. larvae (Chironomidae) significantly contributed to the benthic community.

Furthermore, species of Community interest, such as the Balkan goldenring dragon fly *Cordulegaster heros,* was recorded in the Kriva kobila river above the intake. As protected wild species in Macedonia, listed in Annex II of the Habitats Directive, and rated as “Near Threatened” on the IUCN Red List of Globally Threatened Species and European Red List of Dragonflies, *C. heros* additionally confirm the high conservation value of the area. In summary, the macroinvertebrate assemblage as well as the metrics values (BMWP, ASPT, EPT taxa richness given in Table 3) indicated “healthy” river sectors on B_1KAI, B_1BAI and B_1R (**high** ecological status).

During the field visit it was noted that the Brajcinska and Kriva Kobila rivers are strongly affected by the operations of Brajcinska 1 SHPP. The riverbed of both rivers **below the intake** was dry, and macroinvertebrate fauna had completely disappeared (**bad** ecological status).

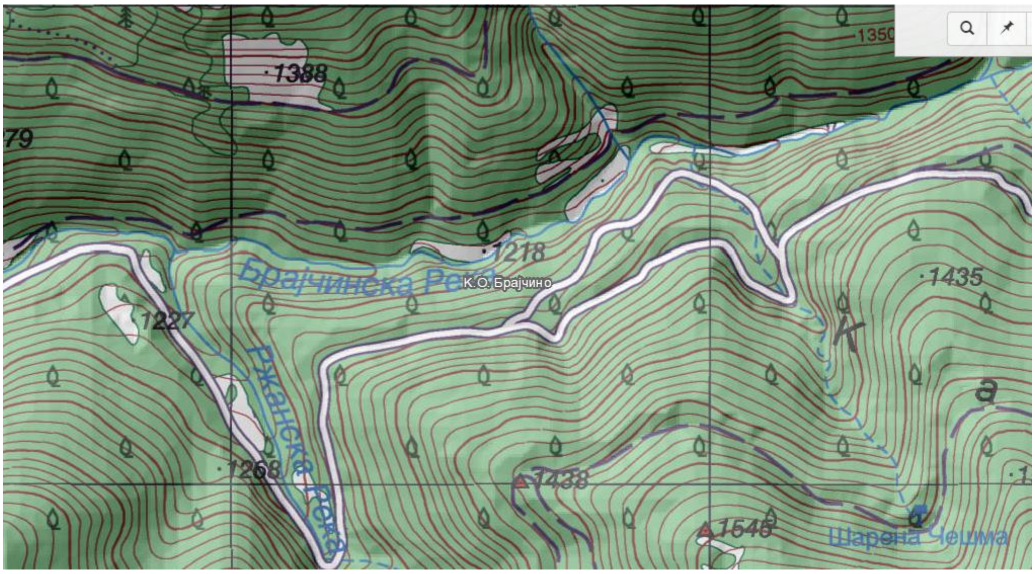


Figure 8. Tributaries of the Brajcinska river

Regarding the Brajcinska river, above the powerhouse a small quantity of water was noticed and probably the water is derived from small tributaries before this stretch (Fig. 8). A biodiversity assessment shows that the abundance of filter feeding Tanytarsinae (Chironomidae) has increased, which has resulted in a shift from a macroinvertebrate community dominated by EPT taxa (20%) to a community dominated by Dipterans (77%), mainly Chironomids (Fig. 12).

It is widely recognized that insects such as mayflies, caddisflies and stoneflies which lay their eggs on rocks at a river's edge are significantly affected by the hydropeaking effect, while Chironomids that lay eggs in open water are mostly unaffected.[47] At the same time, however, in comparison with the Brajcinska and Kriva Kobila rivers **above the intake** at the Brajcinska 1 SHPP, the number of sensitive taxa (6) as well as the values of the diversity indices (Fig. 13) moderately decreased, confirming less favourable conditions. The absence of species of Community interest is most likely the result of the loss of their habitats. However, the density of the macroinvertebrates, the number of taxa (17) and the number of EPT taxa (8) is still relatively high and the metrics values (BMWP, ASPT, EPT; Tab. 3) indicate good ecological status, which is probably the result of the minimized impact of the hydropeaking by additional water derived from the tributaries. Based on expert opinion and judgement, it is possible that the intensity of the influence of the Brajcino 1 SHPP is stronger and that the ecological status is actually worse (at least **moderate**). However, for more precise assessment of the impact of this SHPP and determination of the actual condition, further investigation should be focused on this river sector.

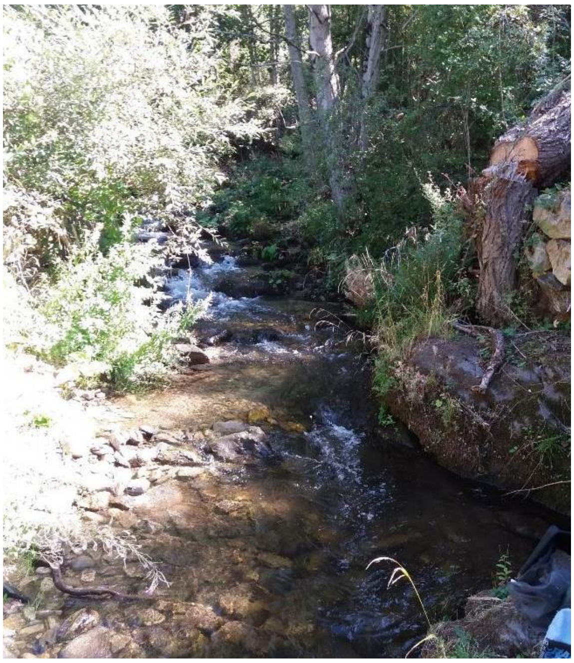
[47] Guidance document on hydropower development and Natura 2000. 4th draft European Commission, 2015

2.5 Brajcinska reka 2 (also Brajcino 2) financed by the EBRD and KfW

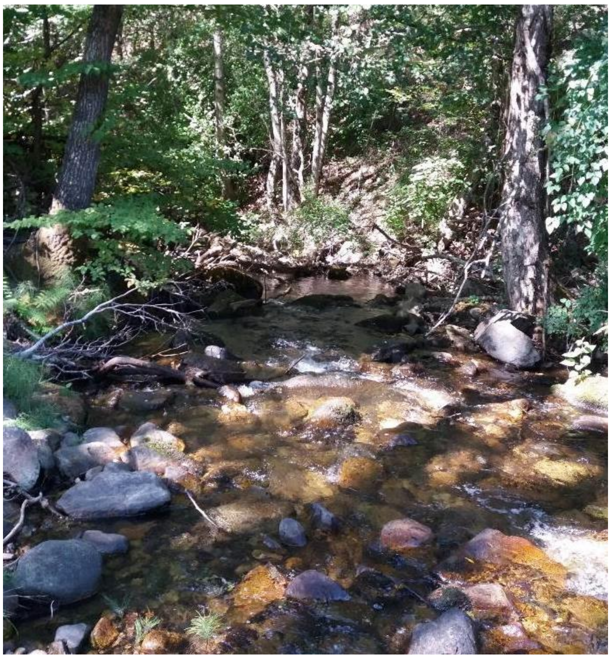
The Brajcinska reka 2 SHPP is also located in the boundaries of the Pelister National Park, a potential Natura 2000 site. During the field visit this SHPP wasn't working and intakes on the Brajcinska river and on its tributary – the Stanishar river – didn't take any water. In order to identify the influence of the Brajcinska reka 2 SHPP, aquatic invertebrates were collected at four monitoring stations.

a)

b)



c)



d)

Figure 9. a) The Stanisar river above the intake; b) The Stanisar river below the intake; c) The Brajcinska river above the powerhouse of the Brajcino 2 SHPP; d) The Brajcinska river below the powerhouse of the Brajcino 2 SHPP

The investigation showed that habitats at all monitoring stations (B_2SAI, B_2SBI, B_2BAP, B_2BBP) are well conserved or only slightly altered, and support the presence of rich macroinvertebrate fauna with numerous populations of EPT taxa and a high diversity of sensitive taxa (11, 12, 9 and 9). The Stanisar river above the intake supports the existence of the Balkan goldenring dragonfly (*Cordulegaster heros*). Additionally, the priority species *Austropotamobius torrentium* inhabits the Stanishar river above and below the intake, and the Brajcinska river below the powerhouse (HEC Brajcinska reka 2). Although it wasn't caught during the macroinvertebrate sampling at B_2BBP, its presence there is guaranteed since its leftovers were noticed in otter scats. Additionally, this species monitoring was omitted or ignored in the Environmental elaborate before the construction of this HPP, despite the fact that there is literature data confirming their occurrence in the area.[48,49]

Finally, the metrics values provided in Table 2 indicate "healthy river sectors" or **high** (B_2SAI and B_2SBI) toward **good** (B_2BAPand B_2BBP) ecological status (Table 3). The question is are these ecosystems not yet influenced by the construction of the Brajcinska reka 2 SHPP given that the operational phase started in 2014, or is it a result of good work practices which follow international standards? Nevertheless, it cannot be discounted that the additional water inflows from the Kalmar stream actually minimize the impact from the SHPP, especially towards B_2BAP and B_2BBP. However, biological monitoring is required in the future to confirm whether this favourable ecological state is permanent and obtainable, or if after all the cascade has a negative impact on aquatic macroinvertebrates, especially on species of Community interest.

48 Germanos, A. (2009). Development of a Transboundary Monitoring System for the Prespa Park Area. Prespa, November 2009
49 Studies on Environmental and Applied Geomorphology, Edited by Tommaso Piacentini
and Enrico Miccadei. March, 2012. 1-292

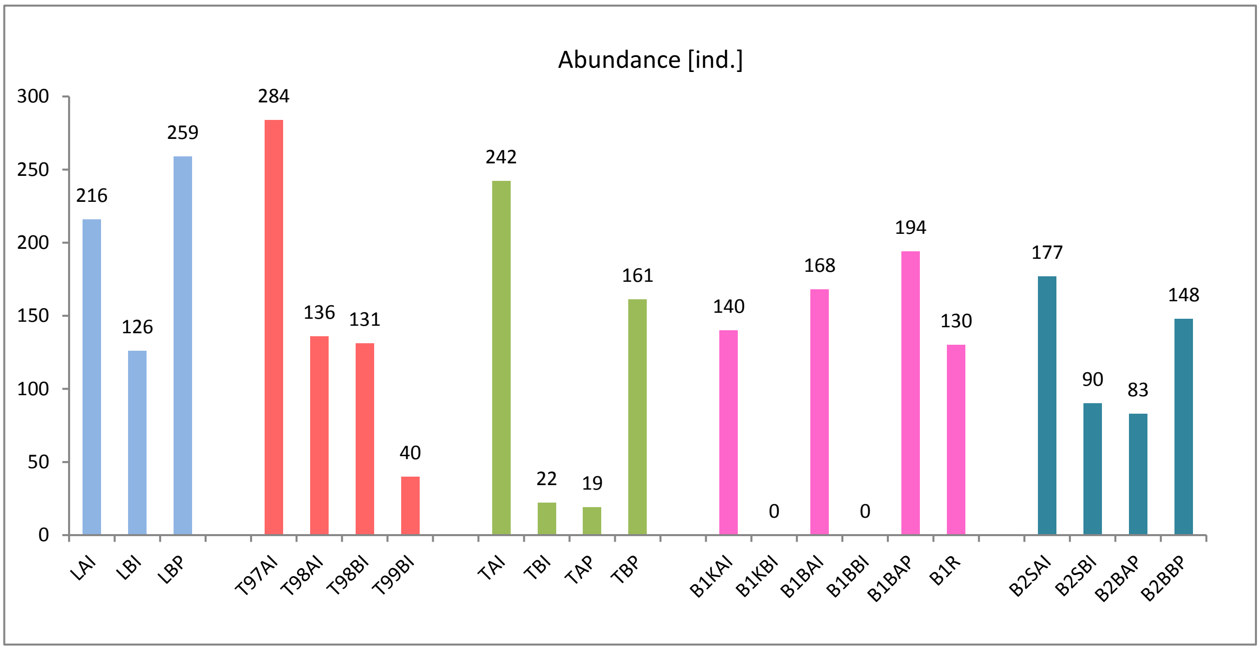


Figure 10. Abundance of the macroinvertebrate fauna

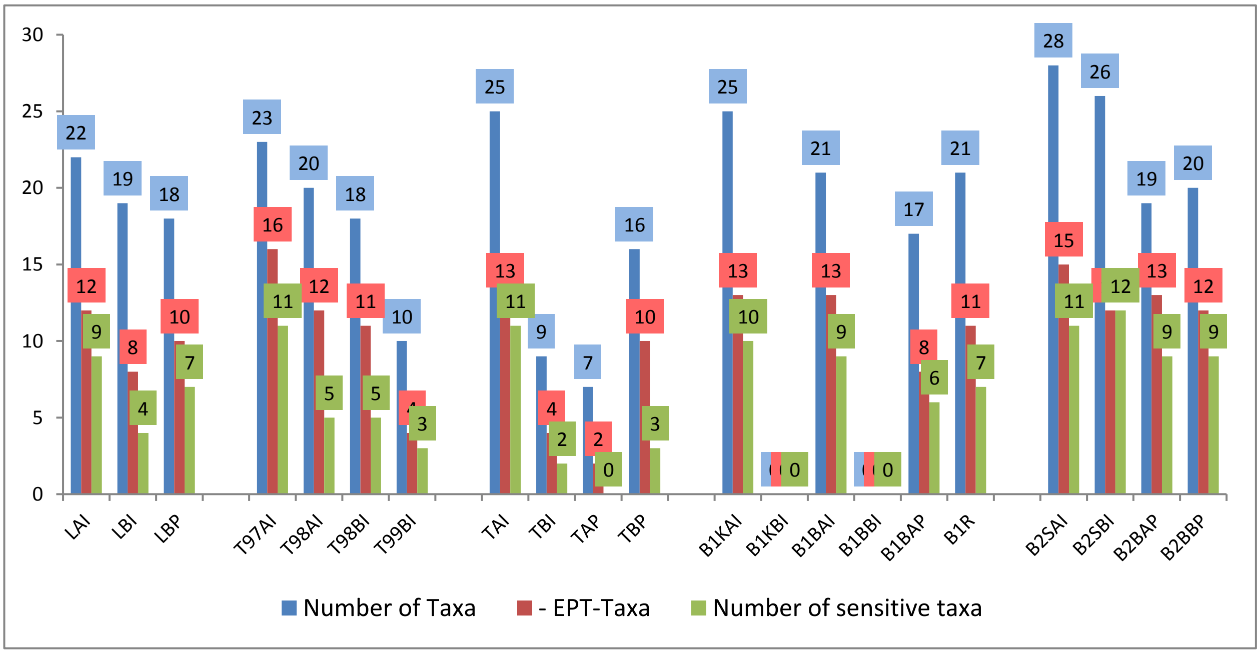


Figure 11. Number of taxa, EPT taxa and Number of sensitive taxa

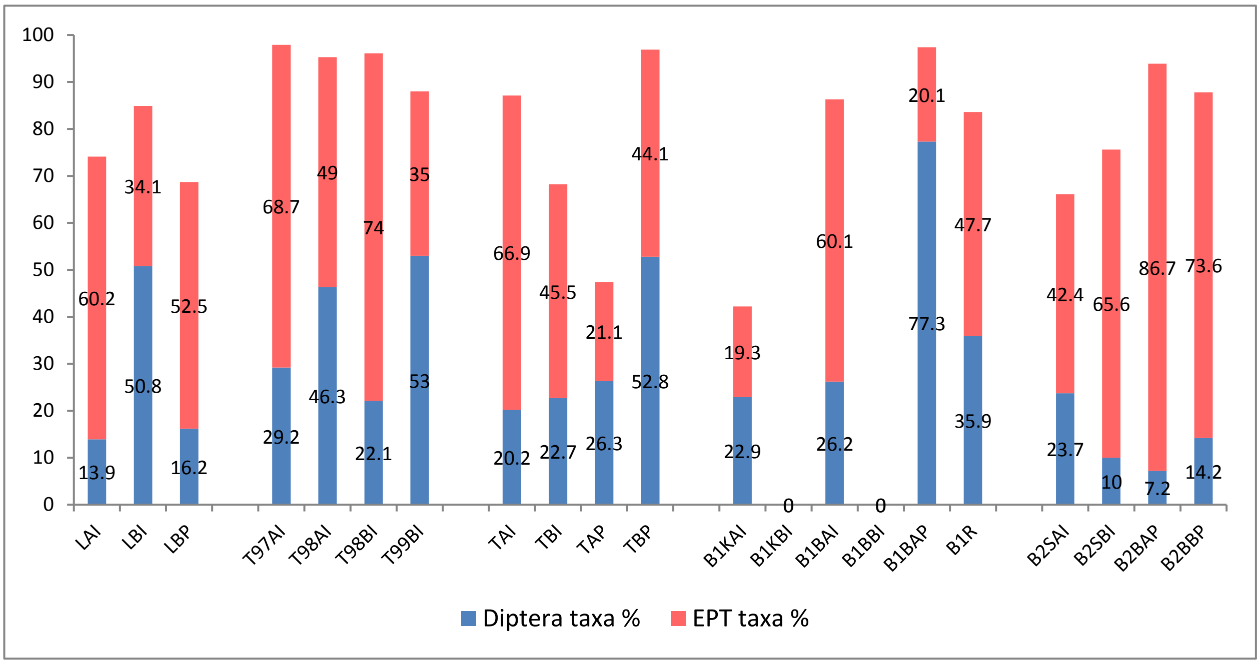


Figure 12. Relative contribution (%) of EPT taxa and Diptera taxa

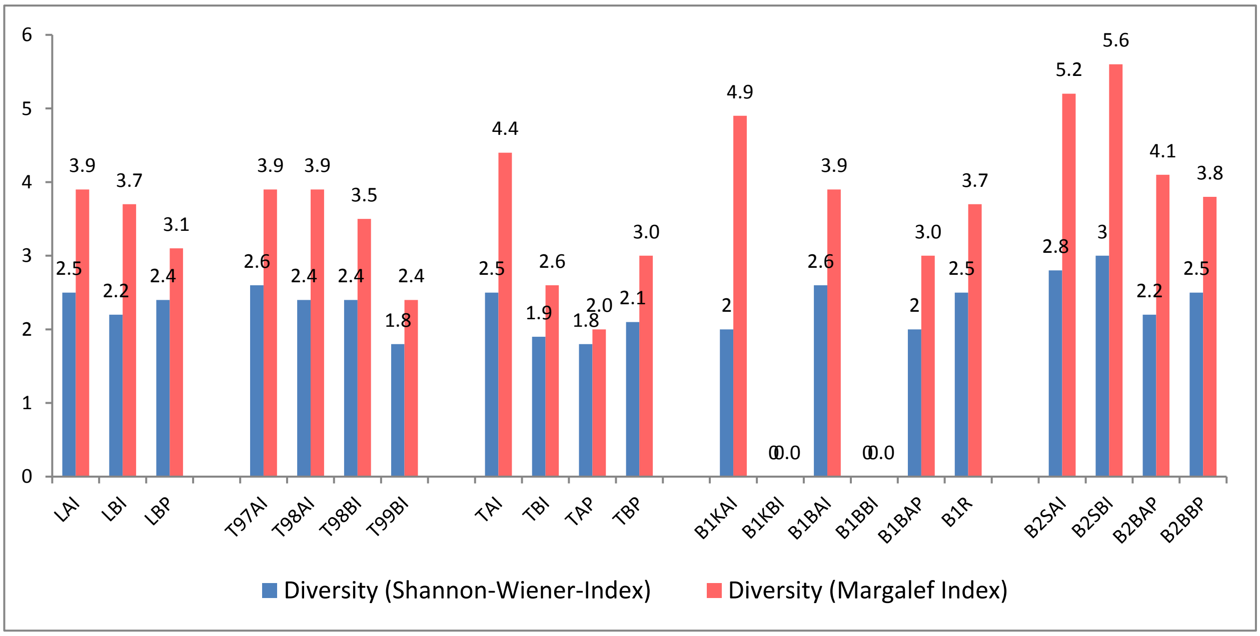


Figure 13. Shannon-Wiener and Margalef index

Chapter 3 Conclusion and recommendations

This study is the first comprehensive attempt to provide an overview of the impact of SHPPs financed by the EIB and the EBRD on four rivers in Macedonia. Most of the SHPPs are in areas with high ecological importance, such as Emerald sites, IPA and national parks. All the investigated SHPPs are built on water courses in pristine condition which provide well conserved habitat for the occurrence of endemic and rare species, as well as species listed in Annex II of the Habitats Directive whose conservation requires designation of Special Areas of Conservation (SACs) within the Natura 2000 network.

In these areas, it is highly recommended to examine all potential restoration measures that could not only mitigate the existing impacts on the rivers in question, but also improve the conservation status of the EU protected species and habitats present. Furthermore, there is also some other legislation, such as the Water Framework Directive (WFD)[50], which are strongly connected to the Birds and Habitats Directives. Both operate at least in part on the same environment. They also have broadly similar ambitions in terms of aiming to ensure the non-deterioration of rivers and enhancing the ecological condition of aquatic ecosystems. According to the WFD, in protected areas it is not allowed for the water bodies to have less than 'good' ecological status.

Detailed review of the poor quality Strategic Enviromental Assessments and the project EIAs revealed that no significant impacts on the biodiversity and the ecological integrity of the area have been reported that could not be mitigated through the proposed measures. Concerning the macroinvertebrate species, whose habitats should not be altered and require protection, they were: (i) not mentioned, even though there is literature data confirming their occurrence in the area, or; (ii) were listed, but any proposal for their monitoring was omitted or ignored. Thus, the banks (the EIB and the EBRD) didn't consider all available data, didn't conduct an early screening and scoping process, and failed to determine the biodiversity footprint of the projects and whether there are any no-go areas. Clearly, therefore, the banks' investments are not in line with their own standards.[51,52]

The results presented in this report confirm that the sampling sites above the intakes remained in favourable and undisturbed conditions. Biodiversity and ecological status assessment clearly show that almost all the investigated SHPPs have caused alteration to the composition and structure of macroinvertebrate communities downstream. It is possible that the hydropeaking event, long-term dry condition or activities during the construction and the operational phase have caused the moderate or drastic reduction of macroinvertebrate richness, the moderate or severe drop in the abundance of the benthic community, the disappearance of endemic and still undescribed species, as well as the disappreance of species of Community interest. The significant reduction in the ecological status (poor or bad) of the Tresonecka, Kriva Kobila and Brajcinska (SHPP Brajcino 1) rivers below the intake and above the powerhouse, confirms the harmful impact of the investigated SHPPs. *The*

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50 Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy

51 European Investment Bank (2013). Environmental and Social Handbook. VOLUME I: EIB ENVIRONMENTAL AND SOCIAL STANDARDS

52 European Bank for Reconstruction and Development (2014). Biodiversity Conservation and Sustainable Management of Living Natural Resources. Performance Requirement 6

occurrence of rivers with moderate, poor or even bad ecological status in a protected area contraveness the principles of non-deterioration status in the WFD.

The negative effects of small hydropower plants on macroinvertebrate biodiversity and biomass can affect many aquatic, semi-aquatic and riparian species that depend on this fauna as a food base, such as trout and otter. Bearing in mind that the SHPPs also have direct adverse effect on both species, further monitoring of the population status is not just recommended but necessary.

In a few cases – the Kamena river below the powerhouse of the Lipkovo SHPP, the Brajcinska river above the powerhouse of the Brajcino 1 SHPP and the Brajcinska river above the powerhouse of the Brajcino 2 SHPP – there are doubts over whether additional water coming from tributaries probably minimizes, and therefore disguises, the real intensity of the SHPPs' impact. *Therefore, for better screening of the impacts, during future field monitoring more time for appropriate selection of the sampling sites is recommended.*

On the other hand, it is suspected that the intensity of the influence of the intake Tearce 98 is stronger and the ecological status is worse (at least moderate) than the biological metrics values showed (good ecological status). The composition of the community, as well as the presence of early larval stages of aquatic insects above and below the second intake (SHPP Tearce 98), more prone to drift, is possibly due to sudden water discharge from Tearce 97 which was working during the field trip and doesn't make the river reach slightly altered. *Therefore, for more comprehensive assessment of the impact of the SHPPs on biological diversity and ecological integrity, further monitoring should involve a full year survey.* Some species, such as endemic, priority, endangered and rare species, may not be detectable at certain times of the year, for example when they have emerged as flighted adults, are present as eggs attached to vegetation, or as early instar stages.

Furthermore, the presented results show that the Brajcino 2 SHPP has the lowest detectable impact on the macroinvertebrates, especially on the species of Community interest (the stone crayfish and the Balkan goldenring). Questions remain over whether the ecological integrity of the Stanisar and Brajcinska rivers is undisturbed and whether these ecosystems are capable of supporting and maintaining ecological processes and a diverse community of macroinvertebrates. And, does good work practice at the Brajcino 2 SHPP, which follows international standards, contribute to this condition? *Clearly, long term biological monitoring is required in the future to confirm whether this favourable ecological state is permanent and achievable or that after all the cascade has a negative impact on the aquatic macroinvertebrates.*

Finally, Macedonia, as with all accession countries from the Balkan region, sooner or later will become a member of the European Union and will have to comply fully with the Water Framework Directive and the Habitats Directive. Preventing damage to river systems today will save future costs for measures to improve the ecological status, and will preserve its unique and remarkable biodiversity for generations to come.

Table 2. Class boundaries for different biotic indices and water classification based on macroinvertebrates

BMWP (Serbian version)	**ASPT** (Serbian version)	**EPT** (Original version)	**No.of taxa** (Serbian version)	**Ecological status**
> 90	≥ 6.9	> 10	> 20	high (H)
71 - 90	5.1 - 6.8	6 - 10	16 - 20	good (G)
51 - 70	4.1 - 5.0	2 - 5	11 - 15	moderate (M)
30 - 50	3.1 - 4.0	< 2	5 - 10	poor (P)
< 30	< 3	< 2	< 5	bad (B)

Table 3. Biological assessment of the ecological status of the monitoring stations

	SHPP Lipkovo			SHPP Tearce 97,98,99				SHPP Tresonecka reka				SHPP Brajcino 1						SHPP Brajcino 2			
	LAI	LBI	LBP	T97AI	T98AI	T98BI	T9 9BI	TAI	TBI	TAP	TBP	B1K AI	B1K BI	B1B AI	B1B BI	B1B AP	B1R	B2S AI	B2S BI	B2B AP	B2B BP
BMWP	136	106	102	121	99	79	54	121	42	29	51	128	0	104	0	92	105	154	162	122	108
ASPT	7.2	6.6	6.8	7	6.6	6.6	6	6.5	5.3	4.8	5.5	7	0	7.4	0	7.1	7.5	7	7	7.2	6.8
EPT-Taxa	12	8	10	16	12	11	4	13	4	2	10	13	0	13	0	8	11	15	12	13	12
Number of Taxa	22	19	18	23	20	18	10	25	9	7	16	25	0	21	0	17	21	28	26	19	20
	H	G	G	H	G	G	P	H	P	B	M	H	B	H	B	G	H	H	H	G	G

Table 4. Abundance (ind.) of the macroinvertebrate taxa

Taxa (ind.)	LAI	LBI	LBP	T97A I	T98A I	T98B I	T99B I	TA I	TB I	TA P	TB P	B1KA I	B1KB I	B1BA I	B1BB I	B1BA P	B1 R	B2SA I	B2SB I	B2BA P	B2BB P
<u>Turbellaria</u>																					
Crenobia alpina	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	5	1	0	0	0
Dugesia gonocephala	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	5	0	0	0	0
Planaria torva	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<u>Nematomorpha</u>																					
Gordius aquaticus	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MOLLUSCA																					
<u>Gastropoda</u>																					
Ancylus fluviatilis	18	3	63	1	0	0	1	0	0	2	0	1	0	0	0	3	1	6	4	2	3
Bythinella drimica drimica	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0
Galba truncatula	0	0	0	0	0	0	1	0	0	2	1	0	0	0	0	0	0	0	0	0	0
Radix balthica	0	2	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	1	0	0
<u>Bivalvia</u>																					
Sphaerium sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
<u>Oligochaeta</u>																					
Lumbricidae	0	0	0	0	4	5	3	2	1	5	1	1	0	0	0	0	0	0	0	1	0
<u>Hirudinea</u>																					
Dina lineata	0	0	0	0	0	0	0	13	6	0	0	0	0	0	0	0	0	0	0	0	0
<u>Amphipoda</u>																					
Gammarus balcanicus	22	10	10	0	0	0	0	5	0	0	0	72	0	0	0	0	1	35	0	0	9
<u>Decapoda</u>																					
Austropotamobius torrentium	10	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	6	0	5
INSECTA																					

Ephemeroptera																					
Baetis alpinus	0	0	0	0	0	0	0	2	0	0	1	1	0	0	0	0	1	0	0	0	0
Baetis melanonyx	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baetis rhodani	12	20	39	27	6	0	0	23	5	0	21	0	0	0	0	0	0	2	0	2	4
Caenis pseudo rivulorum	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ephemera danica	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	2	2	3
Serratella ignita	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Ecdyonurus helveticus	0	0	0	10	0	2	0	4	0	0	1	1	0	2	0	8	5	10	4	0	0
Ecdyonurus venosus	56	6	35	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	7	12
Habroleptoides confusa	0	2	0	3	0	0	0	0	0	0	0	0	0	2	0	2	0	6	6	1	2
Epeorus assimilis	7	0	10	4	0	1	0	0	0	0	0	2	0	2	0	0	0	0	0	0	4
Rhithrogena gratianopolitana	0	0	0	0	0	0	0	4	1	0	1	0	0	0	0	0	0	0	0	0	0
Odonata																					
Calopteryx virgo	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Cordulegaster heros	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
Plecoptera																					
Dinocras megacephala	0	0	0	4	3	3	0	0	0	0	0	3	0	10	0	0	1	2	0	0	0
Perla marginata	15	2	10	2	0	0	1	0	0	0	0	4	0	0	0	0	0	9	9	0	0
Isoperla grammatica	0	0	0	13	2	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0
Perlodes microcephalus	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leuctra hippopus	2	7	10	0	2	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
Leuctra nigra	0	0	0	0	0	0	0	0	0	0	0	2	0	9	0	11	7	12	9	7	7
Protonemura praecox	1	0	4	60	15	15	1	56	3	0	14	1	0	41	0	7	24	7	5	33	37
Trichoptera																					
Hydropsyche instabilis	22	4	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5

Hydropsyche peristerica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	10	1	1
Hydropsyche saxonica	0	0	0	11	15	20	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0
Philopotamus montanus	2	0	0	16	2	6	0	8	0	0	0	4	0	12	0	7	2	0	0	11	22
Philopotamus variegatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0	0
Rhyacophila nubila	0	0	1	4	12	28	0	0	0	0	0	0	0	1	0	0	0	0	0	2	10
Rhyacophila tristis	0	0	0	5	1	1	0	0	0	0	0	0	0	2	0	0	0	1	4	0	2
Brachycentrus montanus	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	2	0	3	1	0
Drusus discolor	0	0	0	22	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Drusus plicatus	0	0	0	0	0	0	0	1	0	0	6	0	0	0	0	0	0	0	0	0	0
Limnephilus lunnatus	0	0	0	0	0	0	0	0	0	1	4	1	0	0	0	0	0	0	0	0	0
Potamophylax cingulatus	7	0	2	3	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
Anabolia nervosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0
Odontocerum albicorne	0	0	0	2	5	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Silo pallipes	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Oecismus monedula	0	0	0	0	2	0	0	38	0	0	5	2	0	8	0	2	15	5	0	0	0
Sericostoma flavicorne	0	0	0	9	1	8	11	0	0	3	10	0	0	9	0	0	1	8	3	0	0
Thremma anomalum	0	0	0	0	0	0	0	14	0	0	8	0	0	0	0	0	0	0	0	0	0
Megaloptera																					
Sialis fuliginosa	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	2	0	0	0
Diptera																					
Chironomidae																					
Orthocladinae	19	18	15	17	6	5	7	15	1	5	63	9	0	7	0	39	14	27	2	0	8
Tanytarsinae	0	42	0	19	11	11	13	0	2	0	17	15	0	7	0	69	9	9	4	0	0
Tanypodinae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	6	0	2	0

Chironominae	0	0	24	0	0	8	0	0	0	0	0	0	0	0	0	32	0	0	0	1	0
Prodiamesa olivacea	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Athericidae																					
Ibisia marginata	5	0	0	41	43	3	0	0	0	0	5	5	0	16	0	3	0	0	0	5	8
Atheryx ibis	3	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	22	0	0	0	0
Pediciidae																					
Dicranota sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Limoniidae																					
Eloeophila mundata	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Simuliidae																					
Prosimulium sp.	0	2	0	0	1	0	0	2	2	0	0	0	0	0	0	6	0	0	2	0	2
Tabanidae																					
Tabanus sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tipulidae																					
Tipula sp.	3	1	0	6	2	1	1	7	0	0	0	3	0	14	0	1	0	2	1	0	3
<u>Coleoptera</u>																					
Cyphon sp. (larvae)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Dytiscidae (adult)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Hydraena sp. (adult)	0	0	0	3	0	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0
Pomatinus substriatus (adult)	1	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oreodytes sanmarkii (adult)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Limnius volckmari (adult)	0	0	4	2	0	0	0	2	0	0	0	2	0	13	0	0	5	4	1	1	1
Limnius volckmari (larvae)	0	0	0	0	2	0	0	0	0	0	0	0	0	8	0	0	5	1	2	1	0
Elmis aenea (adult)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elmis aenea (larvae)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0