

## Assessment of the Ecological Potential of the Soła River Cascade on the Basis of the Selected Biological Indicators

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### ABSTRACT

The paper presents an assessment of the ecological potential of the Soła river based on the benthic macroinvertebrates and diatomaceous phytobenthos, according to the principles of the Water Framework Directive. The calculated values of Multimetric Diatom Index (IO) indicated class II of ecological potential, while the Multimetric Macroinvertebrate Index (MMI\_PL) – class III. The final classification of biological, physicochemical and hydromorphological elements showed that the examined section of the Soła river represents a moderate ecological potential which indicates a moderate disruption in the functioning of the water ecosystem as well as a violation of the hydrological regime and morphological conditions of the riverbed.

**Keywords:** biological indicators, ecological potential, water quality, MMI\_PL, IO

### INTRODUCTION

The quality of water is a very important issue for the life and functioning of all organisms in the world. Water is the basic component of the global ecosystem which provides people with different ecosystem services, i.e. supply in drinking water, regulating of climate (hydrological cycle) and non-material benefits (aesthetic values, tourism and recreation) [Millennium Ecosystem Assessment 2005].

In Europe, the surface water monitoring is currently carried out according to the principles of the Water Framework Directive (WFD), according to which the ecological and chemical status/potential of Surface Water Bodies is assessed. The biological elements are of fundamental importance in this assessment, while hydromorphological and the physicochemical elements have only an auxiliary function [Water Framework Directive 2000]. In Poland, the surface water monitoring is one of the subsystems of the State Environmental Monitoring. The Voivodship Inspectorates for Environmental Protection are responsible for conducting relevant tests in accordance with the guidelines set out in the Regulation of

the Minister of the Environment on the classification of the surface water bodies and environmental quality standards for priority substances [Journal of Laws, 2016, item 1187]. Monitoring of surface water bodies identified as artificial or heavily modified is particularly important. This group includes the cascade sections of rivers, i.e. the river and dam reservoirs formed on it. The Soła Cascade has many different functions, among which energy production (utilization of the energy potential of flows) and drinking water supply for people are the most important.

The main purpose of this work is to assess the ecological potential of the Soła river cascade based on benthic macroinvertebrates and diatomaceous phytobenthos according to the principles of the Water Framework Directive.

### MATERIAL AND METHODS

#### Study site

The studied section of the Soła river belongs to two heavily transformed Surface Water

Bodies identified as: the cascade of the Soła from the Tresna Reservoir to the Czaniec Reservoir (code RW2000021329553) and Soła from the Czaniec Reservoir to the estuary (code RW2000015213299). In terms of abiotic factors, it represents a medium-sized carbonate upland river [Hobot 2014]. Administratively, it is located in the Żywiec and Bielsko poviats in the Śląskie Voivodeship.

In order to assess of ecological potential of the Soła Cascade three sampling sites located in Porąbka (1), Czaniec (2) and Kobiernice (3) were selected (Fig. 1). Their choice was mainly determined by the diversity of habitat conditions, land use of adjacent areas, location relative to stagnant water bodies and anthropogenic buildings, as well as accessibility for the researcher. The selected points were similar in terms of these factors.

### Biological, physicochemical and hydromorphological analyses

The field studies were conducted from September 2018 to March 2019. The sampling of

benthic macroinvertebrates was carried out in accordance with the Multi Habitat Sampling (MHS) method [EN 16150:2012 European standard, Directive 2014/101/EU]. Diatomaceous phytobenthos were collected following the EN-PN 13946 standard. For the purification of diatoms, a hot hydrogen peroxide method was used. The cleaned silica frustules were mounted with Naphrax® resin on permanent slides. The taxonomic identification of the investigated organisms was carried out to the family level (in the case of macroinvertebrates) and to the species level (in the case of phytobenthos) by means of a Prolab stereoscopic microscope and a Nikon Eclipse E 200 optical microscope with a Delta Pix Invenio 5S digital camera. The abundance of families of zoobenthos was obtained by directly counting all observed individuals in the samples, whereas the abundance of diatom species was obtained by counting thecae in subsequent fields of view of the microscope along the transect on the permanent slides (until a total of 400 thecae was obtained).

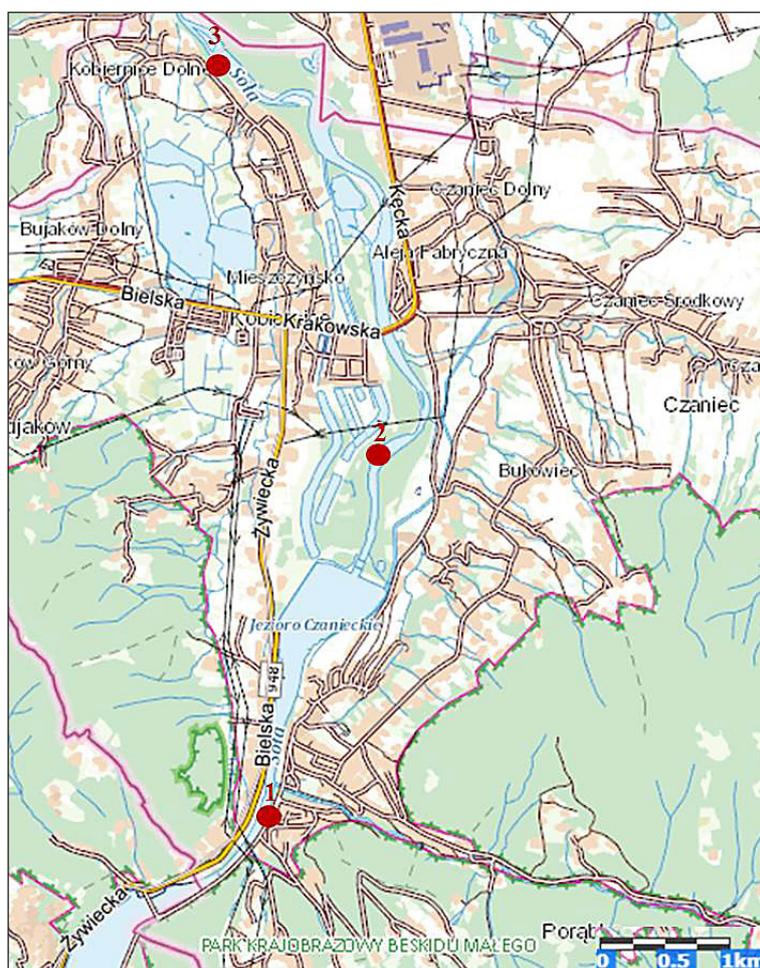


Fig. 1. Map of the study area (www.geoportal.gov.pl)

The collected data on the diversity of macroinvertebrates and phytobenthos of the Soła river were used to calculate the Multimetric Macroinvertebrate Index (MMI\_PL) based on the algorithm developed by Bis, Mikulec [2013] and the Multimetric Diatom Index (IO) according to the formula given by Zgrundo et al. [2018].

In addition, the physicochemical analyses of water were performed (Table 3). Some of them (temperature, conductivity and pH) were measured in situ using a CX-401 multifunction meter. For the remaining analyses, the water samples were taken in accordance with the guidelines for sampling from rivers and streams [PN-ISO 5667–6]. For this purpose, the plastic bottles were immersed under the surface of the water, to a depth enabling the water to be taken in from the zone above the benthic zone. The water samples were delivered to the laboratory tightly closed, described and with limited light access. Until the determinations were carried out, they were stored in a refrigerator at 4°C. Individual parameters were determined according to the methods specified in the following PN-EN standards: concentration of nitrite – spectrophotometric method PN-EN 26777; concentration of nitrate – spectrophotometric method with sodium salicylate in a sulfuric acid medium PN-82 C-04576.08; concentration of ammonia – spectrophotometric method PN-ISO 7150–1; dissolved oxygen – iodometric method PN-EN 25813, PN-ISO 5813; BOD<sub>5</sub> – PN-EN 18991–2; alkalinity – in the presence of phenolphthalein indicator PN-EN ISO 9963–1.

The assessment of hydromorphological elements and final classification of ecological potential of Soła river was carried out in accordance with the guidelines set out in Annex 8 to the Regulation...2016 [Journal of Laws, 2016, item 1187].

## RESULT AND DISCUSSION

### Biodiversity of macrofauna and phytobenthos

In total, nine macroinvertebrate taxa were found on the examined section of the Soła river (Table 1). Two of them: amphipods from the *Crangonyctidae* Bousfield family and isopods from the *Asselidae* Latreille family were dominant. Their highest density was recorded on the first investigated station, where it reached the values of almost 494 and 282 ind./m<sup>2</sup>, respectively. The most sensitive taxa were two families of the caddisflies: *Limnephilidae* Kolenati and *Rhyacophilidae* Stephens which were assigned 7 scores in the BMWP-PL scoring system [Kownacki, Soszka 2004]. During the field study, two individuals of the species *Orconectes limosus* (Raf.) (family *Cambaridae*) were found. It is an invasive species, whose natural area of occurrence is North America [Hamr 2002]. Its presence in the studied rivers is unfavorable, because it can displace the native species of crayfish [Schulz et al. 2006]. The fast water current and the unevenness of flows, associated with the operation of hydroelectric power stations, creates unfavorable habitat conditions for the existence of benthic macroinvertebrates. Organic matter is washed away by the water current and transported down the river. The content of organic matter in the substrate directly affects the concentration of macrofauna [Zdoliński et al. 2009]. The presence of a dam causes disturbance in the migration of aquatic organisms [Kasza 2009].

A total of 24 diatom species were identified in the study river (Table 2). Most of them are cosmopolitan species found in various types of habitats. *Diatoma vulgare* Bory and *Encyonema minutum* (Hilse) (Fig. 3) dominated in terms of

**Table 1.** List of macroinvertebrate families and their average density in the study sites (\*indicator taxa have been marked with an asterisk)

Class/Order	Family	Average density (ind./ m <sup>2</sup> )		
		1	2	3
Amphipoda	<i>Crangonyctidae</i> Bousfield	493.75	37.5	106.25
Decapoda	<i>Cambaridae</i> Hobbs	12.5	-	-
Diptera	<i>Tipulidae</i> Latreille*	-	-	6.25
Gastropoda	<i>Lymneidae</i> Rafinesque*	6.25	12.5	43.75
Isopoda	<i>Asselidae</i> Latreille*	281.5	100	93.75
Oligochaeta*	-	31.25	-	-
Trichoptera	<i>Limnephilidae</i> Kolenati*	50	6.25	43.75
	<i>Hydropsychidae</i> Curtis*	41.62	31.25	6.25
	<i>Rhyacophilidae</i> Stephens*	-	-	6.25

**Table 2.** List of phytobenthic diatoms species in the Soła river (\*species indicator for carbonate river have been marked with an asterisk)

Species	Abundance (number of thecae)		
	1	2	3
<i>Cocconeis placentula</i> Ehrenberg	-	11	-
<i>Diatoma ehrenbergii</i> Kützing*	-	-	1
<i>Diatoma mesodon</i> (Ehrenberg) Kützing*	4	8	2
<i>Diatoma moniliformis</i> (Kützing) Williams*	19	-	9
<i>Diatoma problematica</i> Lange-Bertalot	16	59	25
<i>Diatoma vulgare</i> Bory	63	115	113
<i>Didymosphenia geminata</i> (Lyngbye) Schmidt*	-	25	4
<i>Encyonema prostratum</i> (Berkeley) Kützing	1	19	-
<i>Encyonema minutum</i> (Hilse) Mann*	174	-	119
<i>Encyonema ventricosum</i> (Agardh) Grunow	47	31	-
<i>Encyonema vulgare</i> Krammer	25	25	16
<i>Fragilaria recapitellata</i> Lange-Bertalot i Metzeltin*	6	25	32
<i>Fragilaria vaucheriae</i> (Kützing) Petersen	-	-	15
<i>Gomphonema minutum</i> (Agardh) Agardh	1	7	5
<i>Gyrosigma acuminatum</i> (Kützing) Rabenhorst	-	2	-
<i>Melosira varians</i> Agardh	4	7	25
<i>Navicula lanceolata</i> Mann, Droop	11	50	15
<i>Nitzschia gracilis</i> Hantzsch	4	3	-
<i>Nitzschia intermedia</i> Hantzsch	-	3	1
<i>Pinnularia brauniana</i> (Grunow) Mills	5	-	-
<i>Roicosphenia abbreviata</i> (Agardh) Lange-Bertalot	4	3	-
<i>Suriella brebissoni</i> Krammer, Lange-Bertalot*	13	7	17
<i>Suriella spiralis</i> Kützing	3	-	-
<i>Ulnaria ulna</i> (Nitzsch) Compère	-	-	1
<b>Total</b>	<b>400</b>	<b>400</b>	<b>400</b>

**Table 3.** Physicochemical parameters of water at the studied sites of Soła river

Parameters	Study sites		
	1	2	3
Conductivity ( $\mu\text{S}/\text{cm}$ )	168	170	175
Temperature ( $^{\circ}\text{C}$ )	4	3	4
pH	7.42	7.49	7.57
Dissolved oxygen ( $\text{mgO}_2/\text{dm}^3$ )	13.55	11.49	11.33
$\text{NO}_2$ ( $\text{mgNO}_2/\text{dm}^3$ )	0.026	0.029	0.008
$\text{NO}_3$ ( $\text{mgNO}_3/\text{dm}^3$ )	3.390	2.571	4.422
$\text{NH}_4$ ( $\text{mgNH}_4^+/\text{dm}^3$ )	0.022	0.028	0.010
Alkalinity ( $\text{mgCaCO}_3/\text{dm}^3$ )	64	62	66
$\text{BOD}_5$ ( $\text{mgO}_2/\text{dm}^3$ )	2.39	0.65	0.49

abundance. *D. vulgare* prefers eutrophic waters while the *E. minutum* more often occurs under mesotrophic conditions [Bąk et al. 2012]. It confirms the earlier observations of other authors about the trophic state of the examined part of the Soła [Jaguś 2011; Jachniak, Jaguś 2013]. It is also worth emphasizing the occurrence of the

*Didymosphenia geminata* (Lyngbe) M. Schmidt species (Fig. 2), because its spread in Europe and in other continents has recently been documented [Whitton et al. 2009].

### Ecological potential of the Soła river

The biological assessment pertaining to the ecological potential of the Soła river, conducted on the basis of the applied indices, showed slightly different results (Fig. 4). The values of the MMI\_PL index fluctuated between 0.53 and 0.62. The IO index ranged from 0.43 to 0.51, with the lowest values in the second of the investigated sites. On the basis of the limits of biological indicators set out in Annex 5 of Regulation...[2016] the examined sites were classified to ecological potential class. The MMI\_PL index qualified the water in all examined stands to third class, whereas the index IO index indicated third class at the second stand and second class at first and third stand (Fig. 2). These results partly overlap with the measurements of these biological indicators carried



**Fig. 2.** Selected macroinvertebrate taxa occurring in the benthic zone of the Sola river: a. *Hydropsychidae*; b. *Limnephilidae*; c-d. *Tipulidae*; e. *Lymneidae*; f. *Oligochaeta*



**Fig. 3.** Selected diatom species identified in the examined section of the Sola river: a. *Diatoma vulgaris* (x1000); b. *Melosira varians*, (x1000); c. *Didymosphenia geminata* (x400); d. *Navicula lanceolata* (x1000); e. *Encyonema prostratum* (x1000); f. *Gyrosigma acuminatum* (x400).

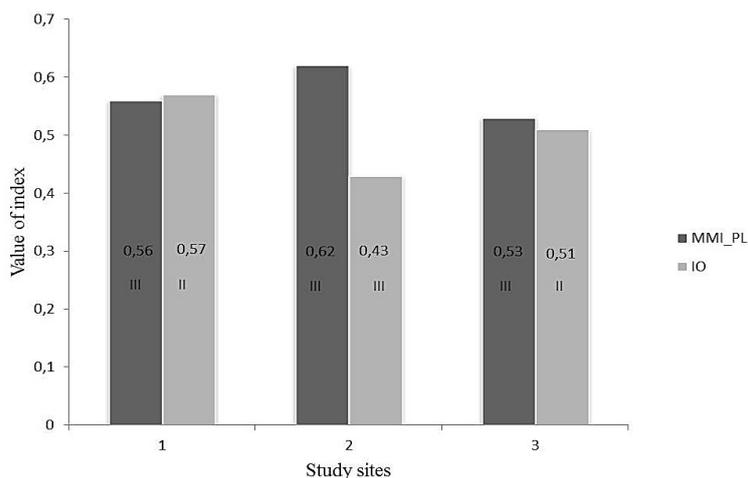


Fig. 4. Values of indices applied to assessment of ecological potential of the Soła river (II, III – class of ecological potential according of Regulation.....2016)

out by Voivodship Inspectorate for Environmental Protection in the framework of surface water monitoring [http://www.katowice.pios.gov.pl].

The obtained values of conductivity, dissolved oxygen, ammonia, alkalinity and BOD<sub>5</sub> indicated first class of ecological potential of all investigated sections of the Soła river, while the pH and nitrites classify them into second class. Among all the analysed physicochemical parameters, only the content of nitrates has not reached the values required for first and second class of water quality. The Regulation... [2016] did not determine the limits values of this parameter for the classes below second.

Maximum ecological potential is attributed to rivers in which the hydromorphological changes are limited only to the changes in the flow volume (SNQ – medium low flow) and are associated with a disruption of the continuity river through the dam. If appropriate protective measures were taken, e.g. in the form of a fish pass, then this section of the river would reach the first class of ecological potential in terms of hydromorphological elements. In other cases, the second class is assigned [Regulation.....2016]. On the basis of these guidelines, the hydromorphological elements at all studies sites of the Sola river were classified in the second class of ecological potential.

The final classification of the ecological potential showed that the examined section of the Soła river represents the third class of ecological potential (Table 4), which means a moderate disruption in the functioning of the water ecosystem as well as a violation of the hydrological regime and morphological conditions of the riverbed [Water Framework Directive 2000].

### CONCLUSIONS

The assessment of the ecological potential of the Soła river carried out in this work shows a partial state of functioning of the aquatic ecosystem. In the future, classification of other biological indicators, i.e. phytoplankton together with chlorophyll a and macrophytes should be carried out. Monitoring of river cascade sections should include the transition fragments between reservoirs, because of their completely different hydromorphological conditions, which have an impact on the obtained values of biological indicators.

The presence of an invasive *Orconectes limosus* species is a major threat to the studied water ecosystem. The population status of this species should be monitored, as its spread may contribute to the displacement of other native species of aquatic fauna.

Table 4. Final classification of the ecological potential of the Soła river

Study sites	Biological elements		Physicochemical elements	Hydromorphological elements	Final classification
	IO	MMI_PL			
1	II class	III class	below II class	II class	III class
2	III class	III class	below II class	II class	
3	II class	III class	below II class	II class	

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