

# Ecological Quality Assessment of Salmonid Rivers in Bulgaria Using Ichthyologic Parameters

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**Abstract:** The salmonid rivers in Bulgaria are characterized with naturally poor species composition of the ichthyocenoses what makes the existing fish indices based on the species richness as an indicator inapplicable for ecological quality assessment.

An algorithm is proposed for assessment the ecological status of all trout rivers within the both Eco-region 12 and Eco-region 7 according WFD. Ten ichthyologic parameters were used: total number and biomass of ichthyofauna, total number, biomass and number of size-age groups of the trouts of genus *Salmo*, percentage in number and number of the size-age groups of Bullhead (for Danube tributaries), percentage in number of cyprinid species, percentage in number of the introduced species, health status of fish community. The values of the used parameters were organized in four ranges with respective rates 0, 1, 3, and 5. The integrated Trout River Index (TRI) was calculated as the score of the rates. The ecological quality assessment was made through comparison of the values obtained with the referent values of TI taking in account the river type.

The proposed algorithm was tested for ecological quality assessment of salmonid river stretches within the watersheds of both the Danube River and Aegean Sea.

**Key words:** WFD, Ecological status, Fish index, Eco-regions, River type

## Introduction

First KARR (1981) proposed and developed the approach for assessment of rivers' ecological quality using the fish assemblages in accordance with the theory of biotic integrity. Subsequently, that approach was widely applied in development different fish based indices for assessment the ecological status of surface water bodies. Recently European Fish Index (EFI) and its improved version EFI+ were elaborated based on the principles of biotic integrity but including also a number of abiotic variables (FAME CONSORTIUM 2004). As far as both these methods were proved not applicable for Bulgarian rivers, in the next years a fish based index BRI suitable for the ecological classification of Bulgarian rivers was developed (MIHOV 2010) following most closely the classical approach of KARR (1981).

The salmonid rivers in Bulgaria are characterized with naturally poor species composition of the fish communities usually including 1 to 3 species, the trouts *Salmo* sp. being predominating and often the only species there. This is the main reason that the application of fish based indices (such as: EFI, EFI+, BRI) which use the species richness as a criterion for assessment of the rivers' ecological status is quite limited or even in some cases impossible for the trout streams (FAME CONSORTIUM 2004, MIHOV 2010).

The aim of this study was to develop methodology for ecological quality assessment of salmonid rivers in Bulgaria as required by the EU Water Framework Directive 2000/60/EC using the parameters of the ichthyofauna.

## Material and Methods

For the analyses were used fish samples gathered under different projects from 2005 to 2007, in 2009 and in 2011. Totally 34 samples were collected during low water periods (summer-autumn) at 23 sites on mountain and alpine rivers and streams identified as 'salmonid/trout waters' as defined in the Regulation No 4/2000 within the basins of rivers referred to both Eco-region 12 (Iskar, Ogosta, Vit) and Eco-region 7 (Maritza, Struma, Mesta and Arda) according WFD (Table 1). One of the studied sites were sampled 5 times for all the period of investigations, 10 sites – twice and 7 sites – once.

Fish were sampled with electricity using backpack devices working with unidirectional impulse current SEN (fa. Bednář – Czech Republic). Sampling was performed in accordance with the Standard EN 12011:2003 (Water quality – Sampling of fish with electricity).

Along the fish sampling basic physico-chemical parameters were measured, i.e. water temperature, dissolved oxygen concentration and saturation, pH and conductivity. Moreover some relevant morphological parameters were registered visually, such as: current velocity (in three levels), water level, bottom morphology and depths, prevailing bottom substrate, riverbank morphology and alterations (embankment, strengthening) shading of the river (in %), presence of migration barriers downstream and upstream the sampling point.

In the field, species identification of fishes caught was made through morphological and anatomic features, the number of specimens of each species was counted determined and both their individual length (the nearest 1 mm) and total weight the (nearest 1 g) were measured. After the processing all fishes were released in the river at the place of capture.

The fish density at the sampling sites was calculated as individuals/ha and the biomass – as kg/ha.

The algorithm for the ecological quality assessment of salmonid rivers was developed taking in consideration first at all representative parameters of the trout populations and of the populations of indicator species, the significance of presented other species – native and/or introduced in the fish community structure, health status of the community.

The values of the chosen parameters obtained

from the field studies were organized in four ranges with respective rates 0, 1, 3, and 5 as following the approach of BATTES (1999). The integrated index was calculated as the score of the rates. The ecological quality assessment was made through comparison of the values obtained with the referent values of EQR for each of the both ecoregions 12 and 7 and respectively for the river type.

## Results and Discussion

### Algorithm for ecological quality assessment

The ecological quality assessment of the salmonid rivers shall be carried out in seven steps:

#### Step 1. Identification of the salmonid rivers

Two main categories of rivers are identified according Bulgarian legislation (REGULATION NO 4/2000) distinguished by the abiotic their environmental parameters (i.e.: morphology, water temperature, concentration and saturation of dissolved oxygen, etc.). These are the salmonid/trout and the cyprinid waters. The typical salmonid waters are characterized first at all with a temperatures  $\leq 18$  °C and concentrations of dissolved oxygen  $\geq 7$  mg/L. In Bulgaria the salmonid rivers are distributed mainly within the mountain and alpine areas higher the altitudes of about 800-900 m a.s.l. Within the different river basins this boundary varies from 600-700 up to 1000 m. Although in some particular cases stable trout populations are recorded at less then 300 m a.s.l., such as in the rivers Zlatna Panega (Iskar River basin), Damla Dere (Tundzha River basin), Aidere (Veleka River basin), Sadovska (Kamchia river basin) and some others (CHESHMEDJIEV *et al.* 2010; CHESHMEDJIEV *et al.* 2011), the question of assignment of these rivers to the salmonid waters *s. str.* needs further investigations.

#### Step 2. River typology defining

All river basins in Bulgaria are distributed within two eco-regions:

**Eco-region 12 (Pontic Province)** covering the Danube basin and all the rivers flowing directly into the Black Sea;

**Eco-region 7 (East Balkans)** covering the river basins of the Aegean Sea watershed: Struma, Mesta, Maritza, Tundzha and Arda.

According the adopted river typology (CHESHMEDJIEV *et al.* 2010) the typical salmonid streams refer mainly to the river types R1 (alpine

**Table 4.** List of the sampling sites at the studied salmonid rivers.

River basin	Eco-region	River/Site	River type	Geographical coordinates		Altitude, m a.s.l.
				N	E	
Mesta	7	Bela Mesta	R3	42°02'29,15"	23°42'37,47"	970
	7	Cherna Mesta	R3	42°03'23,0"	23°43'49,4"	1003
	7	Demyanitsa	R3	41°48'23,3"	23°28'21,5"	1207
	7	Mesta downstream Yakoruda	R3	41°57'53,63"	23°36'21,29"	813
	7	Banderishka	R1	41°45'21,6"	23°24'59,7"	1980
	7	Retizhe	R3	41°45'26,11"	23°40'16,74"	672
	7	Kamenitsa	R3	41°42'53,1"	23°41'44,0"	643
	7	Dospat /up <sup>1</sup>	R3	41°49'00,4"	23°54'04,5"	1271
	7	Dospat /down <sup>2</sup>	R3	41°33'30,7"	24°07'21,5"	1045
Struma	7	Struma	R3	42°30'41,6"	23°08'054,9"	851
	7	Treklyanska	R3	42°29'06,9"	22°45'06,1"	585
	7	Iliyana	R3	46°06'35,2"	23°19'28,7"	1022
	7	Dupnishka Bistritsa	R1	42°12'31,9"	23°10'38,5"	1105
Maritsa	7	Stryama	R3	42°41'23,0"	24°26'0,82"	737
	7	Ibar	R3	42°16'43,9"	23°41'12,92"	889
Tundzha	7	Damla Dere	R5	42°42'31,6"	24°35'25,2"	496
Arda	7	Arda	R3	41°27'38,18"	24°38'01,75"	1017
Vit	12	Beli Vit	R2	42°49'35,8"	24°25'15,2"	669
	12	Toplya	R2	42°57'08,8"	24°29'17,5"	454
Ogosta	12	Botunya	R2	43°09'22,7"	23°14'15,7"	688
Iskar	12	Iskar	R2	42°15'17,0"	23°26'59,57"	1200
	12	Malyovishka	R1	42°11'19,76"	23°22'29,73"	1960
Osam	12	Cherni Osam	R2	42°48'11,0"	24°46'29,0"	600
Kamchia	12	Sadovska	R4	42°49'55,1"	26°40'46,9"	297
Veleka	12	Aidere	R4	42°02'02,2"	27°30'35,7"	226

<sup>1</sup> Dospat River upstream the Dospat Reservoir.

<sup>2</sup> Dospat River downstream the Dospat Reservoir.

rivers) R2 (mountain rivers in Eco-region 12) and R3 (mountain rivers in Eco-region 7). Moreover, single sections in the river types R4 (semi-mountain rivers in Eco-region 12) and R5 (semi-mountain rivers in Eco-region 7) could be also conditionally defined as trout streams.

Differentiation of the rivers between the two eco-regions is necessary step in the ecological quality assessment algorithm because of specificity of the fish species composition there. Thus, one of the key indicator species in the mountain rivers of the Danube basin is the Bullhead which is absent in the river type R3.

### Step 3. Selection of indicator fish species

#### **Salmo sp.**

Three species of trout of the genus *Salmo* are reported for Bulgarian rivers: *Salmo trutta fario* (VASSILEV, PEHLIVANOV 2005), *Salmo labrax* (KOTTELAT, FREYHOF 2007) and *Salmo macedonicus* (ECONOMIDIS *et al.* 2009). The Brown trout *S. trutta fario* can be considered the most common species as a result of the long-term widespread artificial stocking even with fishes of genetic lines introduced in Bulgaria from Central and Western Europe. The Black Sea salmon *S. labrax* occurs in Black Sea tributaries (KOTTELAT, FREYHOF 2007) and Acedonian river trout *S. macedonicus* was reported recently for Mesta River (ECONOMIDIS *et al.* 2009). Irrespective of their species affiliation all the representatives of the genus *Salmo* brought similar requirements to the ecological quality of the habitats and therefore they are included into the algorithm as *Salmo sp.*

The trouts *Salmo sp.* are indicator species sensitive to both the water pollution and decreasing of the dissolved oxygen as well as to the silt accumulation on the bottom as an effect of the morphological changes. Being potamodromous fishes they are indicators for the river longitudinal connectivity.

#### **Cottus sp.**

In Bulgarian waters Bullhead is characterized with restricted distribution only in the upper streams of Bulgarian Danube tributaries (Ogosta, Iskar, Vit, Osam and Yantra) being absent in Black Sea rivers and in all Aegean Sea basin as well. Two species of Bullhead are reported: *Cottus gobio* and *Cottus haemusi* (KOTTELAT, FREYHOF 2007). As far as they both brought the same requirements to the ecological quality of the habitats they are included into the algorithm as *Cottus sp.*

Bullhead is an indicator species sensitive to the water pollution, to the decreasing of the dissolved oxygen and to the hydromorphological changes of the rivers.

#### **Cyprinid species**

Some cyprinid fishes, such as Barbells (*Barbus petenyi*, *B. cyclolepis*, *B. strumicae*) or/and Minnows (*Phoxinus phoxinus*, *Ph. strymonicus*) are often associated species in the salmonid rivers being in dynamic equilibrium with the trout populations through the competitive and predator-prey interrelations. As far as the cyprinid species are more tolerant, (the Minnows can be considered even a pioneer species)

their abundance as a rule increases and the areal occupied extends as the trout population reduces and vice versa.

#### **Introduced alien species**

The main significant introduced species in the Bulgarian salmonid rivers is the Rainbow trout *Oncorhynchus mykiss* which is competitor for food and occasionally – predator for the native trout.

#### **Step 4. Indicative parameters and metrics**

Ten ichthyologic parameters were considered representative for the needs of ecological quality assessment of salmonid rivers, including: total numbers (ind./ha) and biomass (kg/ha) of the ichthyofauna; total numbers (ind./ha), biomass (kg/ha) and number of the size-age groups of the *Salmo sp.* trouts; percentage in numbers and number of the size-age groups of the Bullhead (for Danube tributaries only); percentage in numbers of the cyprinid species; percentage in numbers of the introduced species; health status of the fish community expressed as a percentage of the specimens with external diagnostic features: ulcers, erythema, exophthalmos, malformations, etc.

#### **Step 5. Defining the referent conditions**

The referent parameters of fish community necessary for the comparative analysis are defined using data obtained from the sites unaffected by human pressure. The main human impact in the salmonid rivers currently is related to the hydromorphological and hydrological alterations: longitudinal connectivity interruption, strengthening of the riverbanks, impoundment and water abstraction. The unaffected sites are identified using preliminary information from the River Basin Directorates verified in the field surveys. Furthermore, relevant data from the literature (VOSTRADOVSKI 1977; JANKOV 1987) were used to define the referent population densities of the trout in rivers.

#### **Step 6. Data organization**

The values of the used parameters were organized in four ranges with respective rates 0, 1, 3, and 5 (Table 2). The integrated index, called Trout River Index (TRI), was calculated as the score of the rates.

#### **Step 7. Ecological quality assessment**

The ecological quality assessment is done through comparison of the values obtained with the referent values of the integrated Trout River Index the river typology being taken in account (Table 3 A, B).

**Table 2.** Organization and rates the indicative parameters and metrics.

	Parameters and metrics	Rates			
		5	3	1	0
		Values			
1	Total numbers of the ichthyofauna, ind./ha	> 2000	150-2000	< 150	
2	Total biomass of the ichthyofauna, kg/ha	> 80	15-80	< 15	
3	Total numbers of the trout <i>Salmo</i> sp., ind./ha	> 1200	100-1200	1-100	0 <sup>1</sup>
4	Total biomass of the trout <i>Salmo</i> sp., kg/ha	> 60	6-60	< 6	
5	Size-and-age composition of the population of the trout <i>Salmo</i> sp. (number of size groups)	> 3	2-3	1	
6	Relative contribution (in %) of the Bullhead <i>Cottus</i> sp. in the total numbers (for Danube tributaries)	> 30%	1-30%	< 1%	0
7	Size-and-age composition of the population of the Bullhead <i>Cottus</i> sp. (number of size groups)	≥ 3	≤ 2		
8	Relative contribution (in %) of the cyprinid species in the total numbers	< 25%	25-50%	> 50%	
9	Relative contribution (in %) of the introduced species in the total numbers	< 5%	5-10%	> 10%	
10	Health status: Percentage of the individuals with diseases, anomalies, malformations etc.	0%	0-1%	> 1%	

<sup>1</sup> Zero values mean complete absence of the species

**Table 3.** Ecological quality assessment patterns.

**A.** Trout River Index (TRI) valid for the rivers of type R2 in Eco-region 12 (Pontic province).

Values of TI	37 – 46	27 – 36	17 – 25	7 – 16	7 >
Ecological status	HIGH	GOOD	MODERATE	BAD	POOR

**B.** Trout River Index (TRI) valid for the rivers of type R3 in the Eco-region 7 (East Balkans).

Values of TI	32 – 40	24 – 31	14 – 23	5 – 13	5 >
Ecological status	HIGH	GOOD	MODERATE	BAD	POOR

### Testing the proposed algorithm and the Trout Index created

The developed algorithm for calculation the Trout River Index based on ichthyologic parameters was tested for ecological quality assessment of 21 typical salmonid rivers of types R1, R2 and R3 and in separate semi-mountain rivers (of types R4 and R5) populated with trout in different river basins within the both Eco-region 12 and Eco-region 7. The assessment was done on 31 fish samples collected in different years along the period from 2005 to 2011. The results obtained (Table 4) suggest the ‘Good’ and ‘High’ ecological status of the most part of surveyed sites what is an expected result in a low human pressure.

An expected result is also the worsened ecological quality of Dospat River downstream Dospat Reservoir (site Dospat/down) where it is strongly affected by various human pressures. ‘Moderate’ ecological status of Beli Vit River seems to be the response of the increased human pressure caused by the development of holiday villages and recreational activities in the region during the last years.

The performed tests demonstrated that the proposed Trout River Index is applicable in the salmonid zones of Bulgarian river types R2 and R3. It is not relevant for the alpine rivers of type R1 in Bulgaria because of the quite low fish population density which does not allow to obtain representative data for analyses. The application of the proposed Trout

River Index in the azonal salmonid stretches at low altitude (semi-mountain river types R4 and R5) needs more prolonged studies with a view to accumulate more representative data about both the fish community parameters and the environmental features.

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**Table 4.** Ecological status of the studied sites/points. (The values of TRI are given in parentheses).

River basin	River/Site	Years	2005	2006	2007	2009	2011
		River type					
Mesta	Bela Mesta	R3	GOOD (28)				
	Cherna Mesta	R3	GOOD (26)	GOOD (30)	GOOD (30)	HIGH (38)	GOOD (30)
	Demyanitsa	R3	GOOD (27)	GOOD (26)			
	Mesta downstream Yakoruda	R3		GOOD (28)	GOOD (29)		
	Banderishka	R1				Not applicable	
	Retizhe	R3			HIGH (36)		
	Dospat /up	R3	HIGH (33)			HIGH (34)	HIGH (39)
	Dospat /down	R3			MODERATE (23)	MODERATE (25)	
Struma	Sruma	R3				Not applicable	
	Treklyanska	R3				HIGH (40)	HIGH (40)
	Iliyana	R3					HIGH (40)
Maritsa	Stryama	R3					HIGH (32)
	Ibar	R3					HIGH (32)
Tundzha	Damla Dere	R5					HIGH (32)
Arda	Arda	R3					GOOD (31)
Vit	Beli Vit	R2					MODERATE (23)
	Toplya	R2				HIGH (36)	
Ogosta	Botunya	R2				HIGH (42)	
Iskar	Iskar	R2				HIGH (42)	
	Malyovishka	R1				Not applicable	
Osam	Cherni Osam	R2				GOOD (35)	
Kamchia	Sadovska	R4					Not applicable
Veleka	Aidere	R4					GOOD (28)

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