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SAPROBIOLOGICAL STATE OF THE RIVER VARDAR–UPPER PART/1987–1990 (REPUBLIC OF MACEDONIA)

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Summary

The investigation was focused on the water quality in a 60–kilometer long area in the upper part of the River Vardar (the Polog Valley geographical unit). Sixty samples of bio–indicators were seasonably collected from five profiles in the period from 1987 until 1990. It was concluded that the water quality decreases from the spring, which is a xenosaprobic zone to the α–mesosaprobic one when leaving the valley, and the β–mesosaprobic zone is mostly present.

The anthropogenic factor has caused large changes in the natural rhythm of water quantity, as well as to the riverbed essence. The same factor has caused severe communal, industrial and agrochemical pollution. These circumstances have caused deterioration of the water quality. In spite of this, the River Vardar in this part of the cross has an enormous power for self–purification, and therefore it still represents a salmonid ecosystem.

Key words: *River Vardar, Republic of Macedonia, pollution, saprobiology, water quality*

INTRODUCTION

After the Second World War, rapid industrialization was commenced in the proximity of the River Vardar floe; the cities expanded and the development of the agriculture required a wide use of chemicals, and this resulted in cases of mass fish death; the same situation was present in the neighboring countries.

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This is the biggest river in the central part of the Balkan Peninsula, with a 28,410 km^2 flow surface Gaševski (1968, 1978). The average inclination in the part taken up for research is 2.2% Georgiev (2000). The spring represents carstic water coming from the Šar–Planina mountain, rich in rainfalls as well as in snow precipitations from November to June (Zikov *et al.,* 1997). This river receives from this mountain five left–hand confluents of alpine character, and two short right–hand carstic confluents coming below the Suva Gora Mountain from the other side.

The part taken for examination is situated in a 50–kilometer long and 10–kilometer large depression. The valley represents a dried up bottom of a former lake, where the above–mentioned alpine–like brooks have deposited myriads of rocks, stones and gravel thus forming a bottom with a high retention capacity (Arsovski, 1997; Rakičević, 1968). The three upper confluents (Jelovljanska, Mazdrača and Bogovinska) are cut at the height of 1400 meters and a channel leads the water out of the flow surface to the neighboring Drim/Bojana system flow, in the Mavrovo Reservoir. From there, enriched from the waters of the Drim/Bojana system, through the electro power aggregates, it goes back in the River Vardar flow, but with a different regime than the previous natural one.

There are numerous works that have studied the consequences arising from the changes of the water ecosystems due to the influence of the pollution in this part of Europe: Aganović & Kapetanović (1973); Bauer (1977); Detsheva (1975); Djisalov (1973); Georgiev *et al.,* (1998); Herford–Michieli (1967, 1969, 1973); Hristić (1990); Janeva (1989, 1991); Janeva & Russev (1989); Janković (1979, 1982); Kosorić (1973); Krstić *et al.,* (1990, 1992, 1994, 1994 a); Krstić & Stojanovski (1993); Krstić & Melovski (1994); Kungulovski *et al.,* (1991); Matoničkin *et al.,* (1975); Meštrović & Munjko (1976); Mitrović–Tutunđić *et al.,* (1982, 1985); Munjko (1979, 1979 a); Nachko (1989); Petrova *et al.,* (1991); Russev & Janeva (1976); Russev *et al.,* (1991); Šorić (1998); Stanković *et al.,* (1984); Stojanovski *et al.,* (1990).

MATERIAL, METHODS AND PROFILES

The determination of the quality of the water in the upper part of the River Vardar was realized by parallel use of the Rothschein (1963) and Zelinka–Marvan (1961) methods. The algae were collected by scraping the surface of the stones. The fauna components were collected in a net by rinsing the stones and water plants. The samples were taken seasonally starting in the summer of 1987 until spring 1990, a total of 60 samples (Figure 1). The profiles were chosen at each 10–15 kilometers starting from the spring, in order to equally follow the water change downstream as well as to monitor

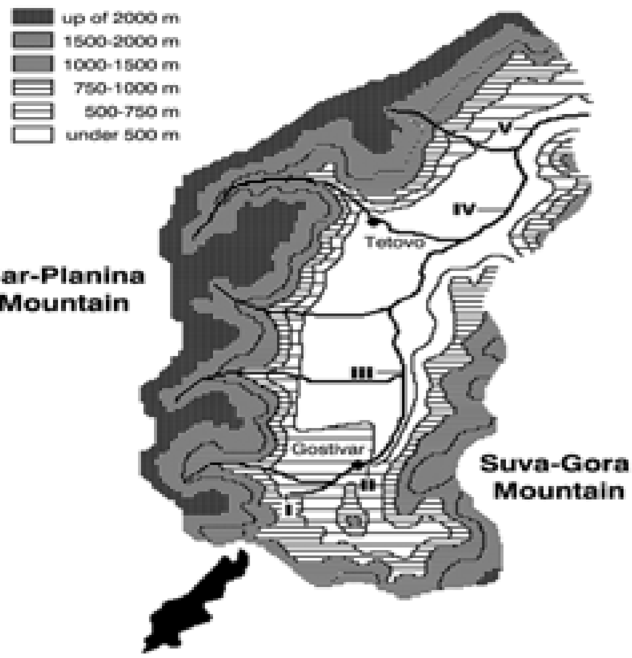

Figure 1. The flow of studied cross and position of the studied profiles
Slika 1. Slijev istraživanoga toka i položaj istraživanih postaja

the influence of the polluted waters coming directly from the town of Gostivar and indirectly from the town of Tetovo. The adult fish exemplars were used as data by checking the catch of the anglers. Juvenile specimens were accidentally caught as well. The determination of the indicator value was done according the Makrushinim list (1974). The identification manuals: Fott (1971); Lazar (1960), Zhadin (1948); Bertrand (1954); Edington & Hidrew (1981); Hynes (1977); Macan, (1970); Vuković & Ivanović (1971); Kottelat (1997) were also used.

RESULTS

Air and water temperature

The data on the air and water temperature is shown in Figure 2. The difference in the measured water temperature can be explained with the change of the water quantity caused by the periodical activity of the power plant installations. There were cases when the water level where the samples were collected would increase for about 0.5 meters in just several minutes; therefore, the water temperature in the next profile was quite different.

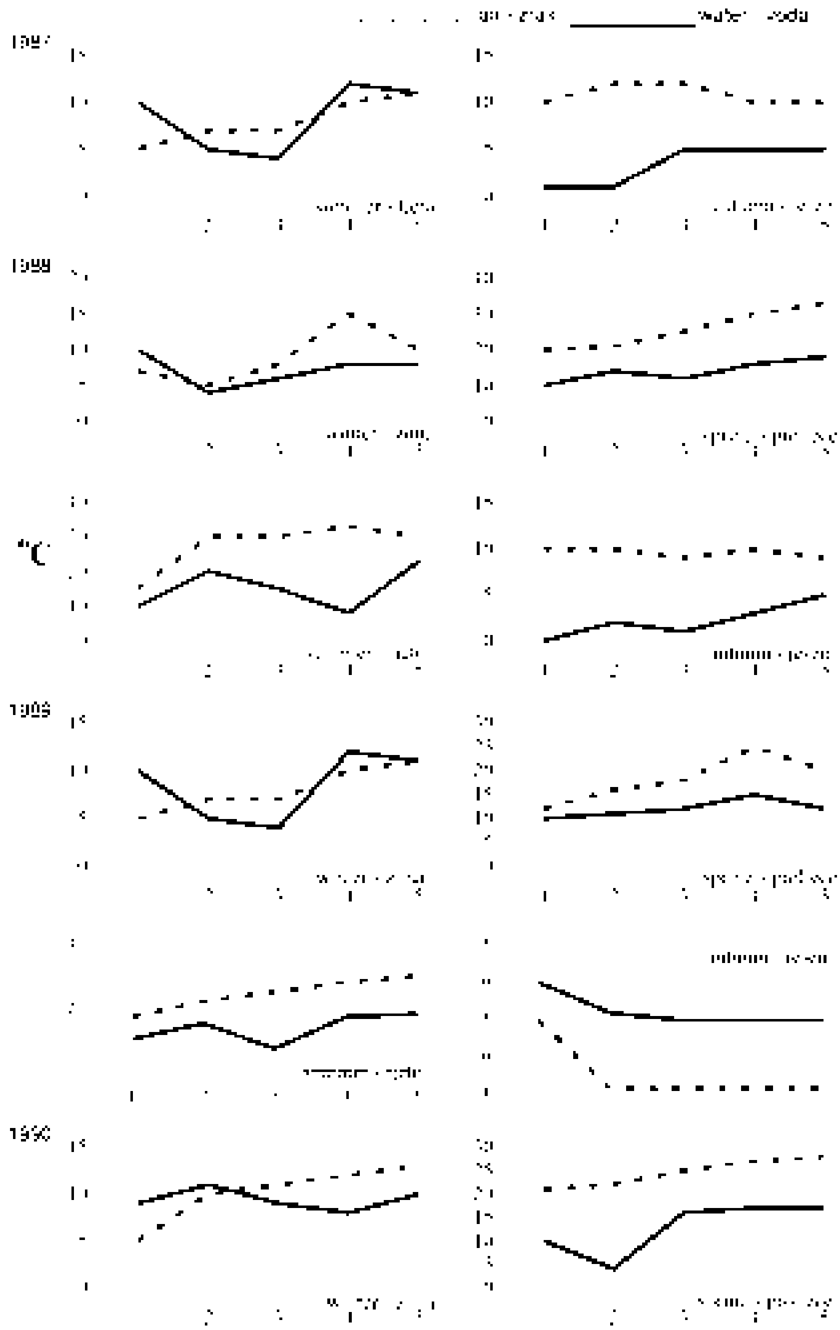

Figure 2. Air and water temperature when collecting the samples
Slika 2. Temperatura zraka i vode prigodom sakupljanja uzoraka

Number and frequency of the bio–indicators

Fifty–five indicators were available for the biological valorization of the water in the River Vardar (Table 1).

Table 1. List of the determined bio–indicators in the investigated area
Tablica 1. Lista utvrđenih bioindikatora na istraživanome području

Phylum: **CYANOPHYTA**	Phylum: **MOLLUSCA**
Ordo: *HORMOGONALES*	Class: GASTROPODA
Oscillatoria limosa (Roth) Agardh.	Family: **Ancyllidae**
O. tenuis Agardh.	*Ancylus fluviatilis* Müll.
Phylum: **CHLOROPHYTA**	Family: **Lymneidae**
Class: SIPHONOCLADINAE	*Radix peregra* Müll.
Ordo: *CLADOPHORALES*	Phylum: **ARTHROPODA**
Family: **Cladophoraceae**	Class: CRUSTACEA
Cladophora glomerata (L.) Kütz. ampl. Brand.	Ordo: *AMPHIPODA*
Class: ULOTRICHINAE	Family: **Gammaridae**
Ordo: *ULOTRICHALES*	Rivulogamarus fossarum Koch.
Family: **Chaetophoraeae**	Class: INSECTA
Stigeoclonium tenue Kütz.	Ordo: *EPHEMEROPTERA*
Phylum: **CHRYSOPHYTA**	Family: **Baetidae**
Class: DIATOMEAE	*Baëtis rhodani* Pict.
Ordo: *CENTRALES*	Family: **Heptageniidae**
Melosira granulata (Ehrbg.) Ralfs.	*Heptagenia coerulans* Rast.
M. varians Agard.	*Ecdyonurus venosus* Fabr.
Ordo: *PENNALES*	Epeorus assimilis Etn.
Asterionella formosa Hausg.	Family: **Ephemerellidae**
Cymatopleura solea (Bréb.) W. Smith.	*Ephemerella krieghoffi* Ulm.
Cymbella ventricosa Kütz.	*E. belgica* Lest.
C. gracillis (Rabh.) Cleve	Family: **Caenidae**
Diatoma elongatum Agardh	Caenis macrura Steph.
D. vulgare Bory.	Ordo: *PLECOPTERA*
Eunotia lunaris (Ehrbg.) Grun.	Family: **Chloroperlidae**
Fragillaria capucina Desmaz.	*Chloroperla torrentium* Pict.
F. crotonensis Kitton.	Family: **Nemouridae**
Navicula cryptocephala Kütz.	*Protonemura intricata* Ris.
N. rhyncocephala Kütz.	Family: **Perlidae**
N. gracilis Ehrbg	Perla marginata Schönemd.
N. pygmaea Kütz.	Ordo: *TRICHOPTERA*
Nitzschia acicularis W. Smith	Family: **Rhyacophilidae**
N. angustata (W. Smith) Grun.	*Rhyacophila vulgaris* Pict.
N. palea (Kütz) Smith	Family: **Glossosomatidae**
Surirella ovata Kütz.	*Agapetus fuscipes* Curt.
Synedra acus Kütz.	*Hydropsiche* sp. div.

S. ulna (Nitzsch.) Ehrb.

Phylum: **BRYOPHYTA**

Class: MUSCI

Fontinalis antipyretica L.

Phylum: **PROTOZOA**

Class: CILIATA

Ordo: *HOLOTRICHA*

Family: **Paramaecidae**

Paramecium caudatum Ehrbg.

Phylum: **VERMES**

Class: PLATHELMINTES

Ordo: *TRICLADIDA*

Family: **Planaridae**

Polycelis felina (Daly.)

Class: CHAETOPODA

Ordo: *OLIGOCHAETA*

Family: **Naididae**

Limnodrilus hoffmeisteri Clap.

Tubifex tubifex (Müll.).

Class: HIRUDINEA

Family: **Erpobdellidae**

Erpobdella octoculata (L.)

Family: **Sericostomatidae**

Sericostoma pedemontanum McLacm.

Family: **Goeridae**

Silo palipes Fbr.

Ordo: *DIPTERA*

Family: **Simuliidae**

Simulium sp. div

Phylum: **VERTEBRATA**

Class: PISCES

CYPRINIFORMES

Family: **Cyprinidae**

Alburnoides bipunctatus (*Bloch.)*

Barbus macedonicus Kar.

Leuciscus cephalus (L.)

Family: **Cobitidae**

Barbatula barbatula (L.)

CLUPEIFORMES

Family: **Salmonidae**

Salmo trutta (L.)

Sixteen species have been distinguished only once, and therefore they were not included in the analyses. There was no data for the indicator values of the other components in the River Vardar ecosystem.

Saprobiologic index according Rothschein

The values of the saprobiologic index according Rhothschein are shown numerically in Table 2 and graphically for the entire period in Figure 3. We can see from the attachments, especially from the graphical ones, that the quality of the water is best in the first profile, by the spring, while as we go downstream the quality deteriorates. Without analyzing the seasonal oscillations which are influenced by many factors (the snow melting, the autumn precipitations) we can generally conclude that the water quality in the first profile is somewhere between xenosaprobic and oligosaprobic, in the third profile in the downward area of the oligosaprobic water, in the second and fourth profile in the upper part of β–mesosaprobic zone, and in the fifth profile, a medium β–mesosaprobic water. This situation is considered to be a consequence of the entrance of the polluted communal and industrial waters from the towns of Gostivar (directly) and Tetovo (indirectly through the Pena confluent), and in the fifth profile the polluted waters are coming from the Chromium complex. The water improvement in the third profile is considered

Table 2. Numerical values of the saprobiological index according Rothschein
Tablica 2. Brojčane vrijednosti saprobiološkog indeksa po Rothscheinu

		winter zima	spring proljeće	summer ljeto	autumn jesen	average prosjek
1987	S_R I	/	/	80.73	66.20	***73.46***
	S_R II	/	/	52.71	53.85	***53.28***
	S_R III	/	/	71.64	48.06	***44.85***
	S_R IV	/	/	50.44	49.51	***49.98***
	S_R V	/	/	32.98	36.65	***34.81***
1988	S_R I	80.50	73.40	65.82	69.04	***72.19***
	S_R II	35.94	36.20	49.65	67.92	***47.42***
	S_R III	66.30	70.12	49.50	53.79	***59.92***
	S_R IV	50.09	49.27	51.29	51.87	***50.63***
	S_R V	50.58	48.59	49.78	44.56	***48.37***
1989	S_R I	71.55	60.37	70.29	69.60	***67.95***
	S_R II	52.44	50.57	36.94	49.60	***47.39***
	S_R III	52.56	50.58	37.66	64.08	***51.22***
	S_R IV	49.60	51.82	38.68	52.02	***48.03***
	S_R V	47.83	32.56	35.95	44.60	***40.23***
1990	S_R I	68.64	81.72	/	/	***75.18***
	S_R II	38.02	60.74	/	/	***49.38***
	S_R III	48.74	72.69	/	/	***60.71***
	S_R IV	34.46	52.47	/	/	***43.46***
	S_R V	46.46	43.16	/	/	***40.31***

average values for all the studied to the period prosječne vrijednosti kroz period istraživanja	
S_R I	**71.28**
S_R II	**49.37**
S_R III	**53.92**
S_R IV	**48.02**
S_R V	**40.93**

SR = Saprobiological index — Saprobiološki indeks

to be consequence of some strong clean carstic confluents and springs, from the limestone Suva Gora mountain as well Šar–Planina mountain; on the other hand, another important factor is the significant self purification power of the River Vardar.

Saprobiologic index on Zelinka–Marvan

While the Rothschein method for determination of the water quality in the upper part of the river Vardar has given results for the common values of all the bio–indicators of a concrete profile, the Zelinka–Marvan method of determination of the level of saprobity offers the possibility for a precise

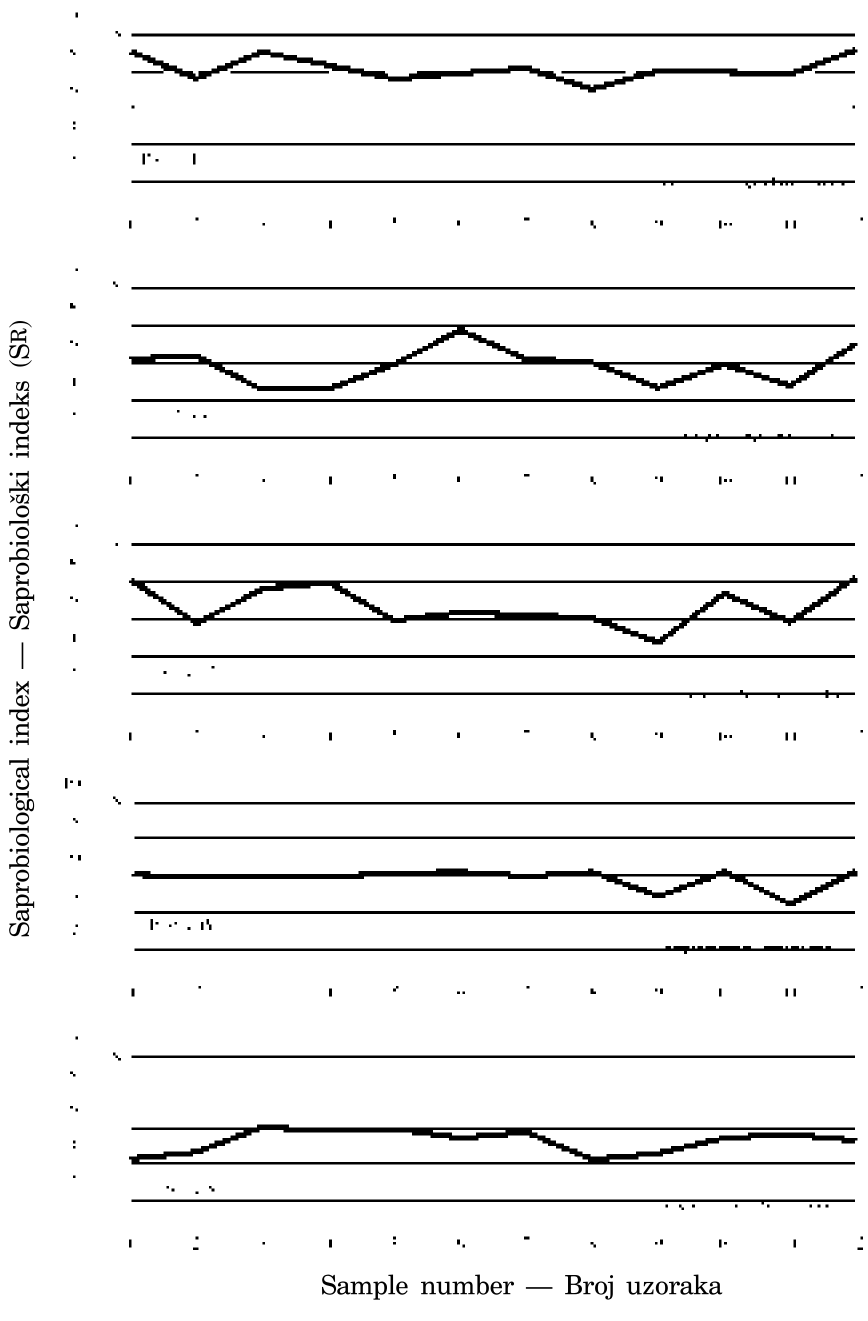

Figure 3. Change of the saprobiological index according Rothschein (SR), according profiles

Slika 3. Izmjena saprobiološkog indeksa po Rothscheinu (SR) po profilima

Table 3. Numerical values of the saprobiological index according Zelinka–Marvan
Tablica 3. Brojčane vrijednosti saprobiološkog indeksa po Zelinka–Marvanu

	Profiles — lokacija									
	I	II	III	IV	V	I	II	III	IV	V
1987	summer — ljeto					autumn — jesen				
S_x	3.52	1.53	2.30	1.90	1.22	1.60	1.32	0.92	0.29	0.33
S_o	3.04	2.97	2.39	2.38	1.63	4.02	3.23	2.33	2.68	1.29
S_β	1.60	2.95	1.76	2.78	2.44	3.29	3.41	3.46	3.94	3.14
S_α	1.46	2.27	1.95	2.60	3.61	0.98	1.64	3.21	2.92	4.88
S_p	0.41	0.27	1.59	0.29	1.34	0.11	0.27	0.23	0.17	0.35
1988	winter — zima					spring — proljeće				
S_x	2.96	0.89	0.84	0.37	0.14	3.49	0.41	2.23	0.48	0.28
S_o	3.14	3.21	2.70	2.39	2.39	3.25	2.74	2.56	3.09	1.92
S_β	2.30	3.68	4.74	3.63	3.73	2.35	3.98	2.63	4.05	2.72
S_α	1.30	2.53	1.55	3.03	3.43	0.87	2.47	2.35	2.24	3.36
S_p	0.29	0.21	0.21	0.57	0.90	0.06	0.39	0.23	0.14	1.72
	summer — ljeto					autumn — jesen				
S_x	2.60	0.70	1.27	0.44	0.14	2.14	0.75	1.20	0.12	0.08
S_o	4.40	2.00	3.14	2.09	1.67	3.85	2.47	3.90	3.33	1.28
S_β	2.46	3.13	3.30	3.51	3.22	2.31	4.03	3.86	4.25	4.23
S_α	0.47	3.57	1.96	3.70	4.19	1.56	2.46	1.04	2.30	3.80
S_p	0.07	0.60	0.33	0.26	0.78	0.13	0.30	0.00	0.00	0.60
1989	winter — zima					spring — proljeće				
S_x	3.27	1.94	1.73	0.40	0.65	3.58	1.67	2.36	0.45	0.32
S_o	2.96	2.28	3.76	2.58	2.81	4.23	2.26	3.24	2.74	2.23
S_β	1.94	2.28	3.37	4.10	4.00	1.92	2.59	2.31	3.43	4.04
S_α	1.56	2.94	1.12	3.54	2.54	0.08	2.76	1.67	3.03	2.87
S_p	0.27	0.56	0.00	0.38	0.00	0.00	0.71	0.43	0.29	0.54
	summer — ljeto					autumn — jesen				
S_x	1.46	0.63	0.69	0.60	0.08	1.97	1.69	1.87	0.65	0.11
S_o	3.27	2.47	2.04	2.99	2.46	3.65	3.31	3.04	3.00	1.49
S_β	3.10	3.95	5.00	3.73	4.66	2.20	2.60	3.58	3.64	4.21
S_α	1.89	2.63	2.27	2.40	2.56	1.24	2.00	1.50	2.17	4.19
S_p	0.28	0.32	0.00	0.28	0.24	0.92	0.23	0.00	0.51	0.00
1990	winter — zima					spring — proljeće				
S_x	2.48	1.77	2.45	0.08	0.14	4.14	2.30	2.58	1.00	0.17
S_o	3.89	2.07	1.95	2.01	1.90	2.91	2.50	3.26	3.01	1.51
S_β	3.12	2.63	2.45	3.90	3.97	2.38	2.32	2.89	3.64	3.62
S_α	0.57	3.34	2.37	3.90	3.57	0.67	2.58	1.15	2.02	3.92
S_p	0.05	0.16	0.75	0.10	0.21	0.00	0.29	0.10	0.21	0.45

$S_{x,o,\beta,\alpha,p}$ = Saprobic deqrees — stupnjevi saprobnosti

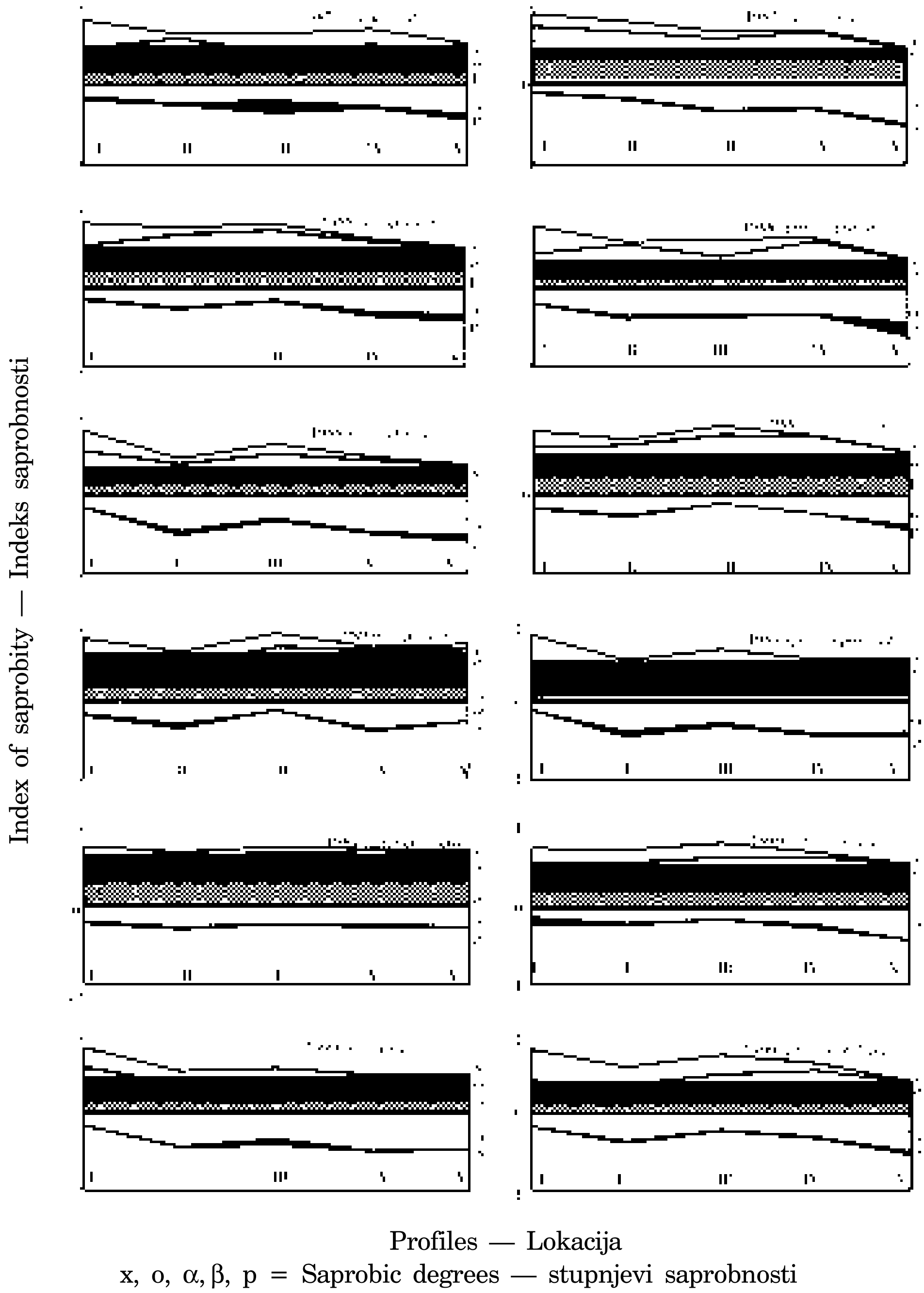

Figure 4. Seasonal change of the saprobiological index according Zelinka–Marvan
Slika 4. Sezonska promjena saprobiološkog indeksa po Zelinka–Marvanu

determination of the relative participation of each zone in the water quality. The results are numerically shown in Table 3 and graphically in Figure 4.

As it can be seen from the attachments, a constant down–ward trend of the water quality has been noted, starting from the spring all the way to the exit from the Polog valley. The results obtained for the quality of the water by using these two methods are generally complementary.

It is possible to state the highest relative participation of the water with the quality from the β–mesosaprobic zone during the entire investigation period. The index of saprobity related to the xenosaprobity is biggest in the first profile and changed from 4.14 in the spring of 1990 to the insignificant 0.08 in the spring of 1988 and the summer of 1989. Furthermore, the relative participation of the organisms — bio–indicators for oligosaprobe water also marks a downfall, although this decline is by far smaller.

On the other hand, the relative participation of the β–mesosaprobic and α–mesosaprobic water category index going from the first to the fifth profile marks a constant increase. In fact, just these two zones mark the water quality in the upper part of the river Vardar.

The participation of the polysaprobe water in the ecosystem of the upper part of the River Vardar is insignificant if compared to the participation of the other water categories.

DISCUSSION

The results from the investigation of the water quality of the river Vardar in the Polog Valley have shown that the ecosystem as a conditional natural biotope is under a strong anthropogenic influence. The attribute »conditional natural biotope« is used because of the fact that the natural rhythm of the water quantity, for which the biota compounds of the River Vardar ecosystem were adapted for, has been changed by the anthropogenic factor to such a degree that it is very difficult to say how has the River Vardar managed to keep the original character in the examined part. In the summer period, some 0.5 kilometers down the spring, the River Vardar does not even exist as a geographic entity »river«; the reason for this is that the riverbed is dry for about 2 km forming a channel which is 100 % changed into the natural form of the bed. Then, the River Vardar in fact exists and starts from the outlet of the water at the power plant. The aggregates of the power plant do not work constantly; the capacity also oscillates occasionally (daily or weekly); therefore if we go downstream, up to Gostivar, the water level changes quite a lot. Downwards from Gostivar the influence of the anthropogenic factor on the water quantity is smaller, except in the summer period when between the second and third profile there is a huge loss of water because of the irrigation. Thus, the waters from the Mavrovo reservoir periodically flow into the riverbed of Vardar; it is cold and clean water that essentially improves the water quality of River Vardar, a typical lowland salmonid ecosystem. Nevertheless, it is a fact that the pollution of the River Vardar ecosystem caused by the waters from Gostivar, influences by large the quality of the water; it is deteriorated in the second, and occasionally in the third profile, depending mainly on the season. The situation somehow is meliorated in the fourth profile, which is far from Gostivar; it is obvious that the reasons for this improvement are the fast stream and the self–purifying power of the River Vardar, and thus it goes back to the its previous condition. It is impossible to conclude how much the polluted waters from Tetovo influence the quality of the water in the River Vardar, because these waters come into the River Vardar indirectly, through the confluent Pena, a stream 10 kilometers distant from Tetovo and the entrance of the Pena River in the River Vardar. The Pena River confluent enters Tetovo as typical salmonide clean stream with alpine characteristics, goes through Tetovo to the entrance of the River Vardar where it represents a dead watercourse.

The situation is worst in the fifth profile. This is due to the influence of the polluted water coming from the Chromium metallurgy complex in the village Jegunovce. We do not exclude the influence of the Tetovo polluted water through Pena River to be present up to this point.

ACKNOWLEDGEMENT

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Sažetak

SAPROBIOLOŠKO STANJE RIJEKE VARDAR — GORNJI TOK / 1987–1990. (REPUBLIKA MAKEDONIJA)

S. Georgiev

Kakvoća vode rijeke Vardara u njegovu gornjem toku (geografska cjelovitost udolina Polog) istraživana je na području dugom 60 km, na pet profila u razdoblju 1987–1990, primjenom bioindikatora. Rezultati su pokazali pogoršanje kakvoće vode od izvora, kao ksenosaprobne zone, do α–mezosaprobne kod izlaska iz udoline, najčešće prisutna β–mezosaprobna zona. Antropogeni čimbenik snažno je utjecao na izmjenu prirodnog ritma količine vode u koritu rijeke, te na jako onečišćenje komunalnim, industrijskim i agrarno–kemijskim otpacima. Rijeka Vardar na ovome dijelu toka ipak ima veliku moć samoproćišćenja, pa još uvijek tvori salmonidni ekosustav.

Ključne riječi: *Vardar, Republika Makedonija, onečišćenje, saprobiologija, kakvoća vode*

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