COMPARATIVE ANALYSIS OF BIOTIC INDICES FOR EVALUATION OF WATER QUALITY OF ESEN RIVER IN SOUTH-WEST ANATOLIA, TURKEY

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ABSTRACT

Five biotic indices were used for the assessment of water quality of Eşen River in South-west of Turkey. The classification of water quality based on benthic macroinvertebrate and physical and chemical parameters were also done. Taxonomic composition of benthic macroinvertebrate fauna was used for calculation of the following biological indices; Saproby Index (SI), Biological Monitoring Working Party (BMWP), Average Score Per Taxon (ASPT), Family Biotic Index (FBI) and Belgian Biotic Index (BBI). Electrical conductivity, temperature, dissolved O_2 content, pH, BOD_5, Cl^-, NH_4-N, NO_2-N, NO_3-N, PO_4-P were analyzed. According to the data obtained, the water quality of Eşen River varied from poor to high ecological status. The indices SI, BMWP, BBI and ASPT were the more adequate estimate of water quality in accordance with physicochemical characteristics of the examined watercourse.

KEYWORDS: Biotic Indices, Benthic macroinvertebrates, Esen River, Water Quality.

1. INTRODUCTION

Freshwater ecosystems, especially rivers are most threatened ecosystem in the world. Ideally, the quality of running waters should be assessed by the use of physical, chemical and biological parameters in order to provide a complete spectrum of information for appropriate water management [1]. The methods used now to determine the environmental state of a river or a river basin is mostly biological-control methods based on the assessment of the flora and fauna of water bodies. [2]. In the past decades, hundreds of biological monitoring approaches have been developed to assess the water quality, about 60% of which are based on macroinvertebrate analysis [3-5]. Most of the biological approaches are particular to specific geographic regions. Various European countries use various indices with different levels of identification of organisms, and different assumptions of final interpretation of results [6]. For example the Saproby indices [7] in Germany, Biological Monitoring Working Party- BMWP and Average Score Per Taxon-ASPT [5] in England, Biotic Index for Pampean rivers and streams-IBPAMP [8] in Argentina, Belgian Biotic Index-BBI [9] in Belgium, seem to give the most reliable results specific to geographic regions. Unification of river classification and the use of a common biotic index are impossible due to different geographic distribution of macroinvertebrate species, and biotypological differences among the rivers [6]. Yet a biological water quality approach particular to Turkey has not been developed. Biological water quality classification studies started in the 1990's in Turkey. Some researchers used a number of biotic indices such as BMWP, ASPT, FBI and SI for assessment of water quality of rivers [10-19].

According to the European Union water framework directive, all member states are obliged to evaluate environment status according to do criteria imposed by EU directives including river quality by the end of 2015 [20].

The objective of this study is to compare the results of five water quality approaches and to determine the most adequate estimate of water quality in accordance with physicochemical characteristics of the examined watercourse.

2. MATERIALS AND METHODS

Eşen River is the largest river in West Mediterranean river basin of Turkey with the total length of 146 km. The most important pollution sources on Eşen River are over-irrigation, gravel gathering, dams and extensive using of chemicals for farming in the surrounding. Benthic samples were collected from seven stations that represent the river.

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Macroinvertebrate communities along the stream were sampled monthly between June 2003 and June 2005, using a bottom kick net (500 µm mesh). The samples were taken from an area of nearly 100 m^2 in order to include all possible microhabitats at each station. In some areas with the presence of large stones, the collected macroinvertebrates were first picked out and washed into the kick net in order to remove pupae and other attached individuals. In addition, macroinvertebrate samples were separated from the macrophytes and the sediment using sieves (250 µm). Collected organisms were immediately fixed in formaldehyde (4%) in the field and then transferred to 70% ethyl alcohol. The macroinvertebrates were sorted, identified to the lowest possible taxon (species, genus or families) and counted under a stereomicroscope. Simultaneous with macroinvertebrate sampling, water samples were taken and analyzed for the following parameters, BOD_5, Cl^-, NH_4-N, NO_2-N, NO_3-N, PO_4-P. All analyses were done in accordance to national standards. Water temperature (ºC), pH, dissolved oxygen (DO mgL^{-1}) and electrical conductivity (EC μScm^{-1}) were measured in the field by portable equipments. Water quality assessment by physico-chemical parameters was done according to Klee (1991) and Water Pollution Control Regulation (WPCR) (1988) [21, 22].

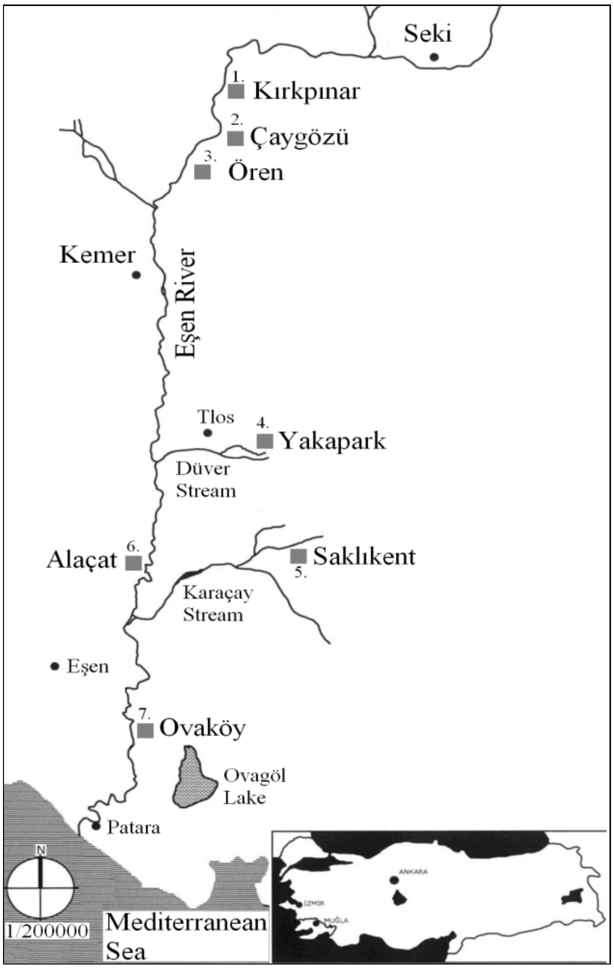

FIGURE 1 - Study area and the sampling points (■ Sampling points, ● Settlement Areas).

2.1 Biotic indices

This study is restricted to indices focused on the determination of water quality. The following five indices were tested: Average Score Per Taxon (ASPT) [6], the Saproby Index (SI) [7], Belgian Biotic Index (BBI) [5], Biological Monitoring Working Party (BMWP) [4], Family Biotic Index [23]. Correlation analysis was based on Pearson's and multiple regression analysis from SPSS version 11.5.

3. RESULTS AND DISCUSSION

The results of physical and chemical parameters variables measured at the seven stations are presented in Table 1. The lowest EC value was measured in the first station while the highest value was found in the seventh station and ranges between 145 μScm^{-1} and 622 $\mu S\ cm^{-1}$. The water temperature varied from 9, 9 ºC to 25, 8 ºC. The highest DO was found at the third station and varied between 4, 7 mg L^{-1} and 13, 8 mg L^{-1}. The highest biological oxygen demand was measured in sampling point six (5, 04 mg L^{-1}). The average of pH values were similar among the sampling points and ranged between 7, 05 and 8, 64. The highest ammonium nitrogen (NH_4-N) was measured in sampling point seven as 4, 35 mg L^{-1}, but the highest average was measured in sampling point six as 1, 73 mg L^{-1}. The average nitrite nitrogen (NO_2-N) was high in sampling points three, six and seven but the highest level was measured in sampling point three and six as 0, 0329 mg L^{-1}. The highest average nitrate nitrogen (NO_3-N) was found in sampling point six as 5, 97 mg L^{-1}, but the highest nitrate nitrogen value was measured in sampling point seven. The highest level of phosphorus (PO_4-P) was measured in sampling point three as 2, 32 mg L^{-1} (Table 1).

In this study, 22061 individuals were collected. A total of 111 benthic macroinvertebrate taxa consisting of 48 genera and 63 species, which belong to classes Turbellaria, Gastropoda, Bivalvia, Hirudinea, Malacostraca and Insecta were identified. Of these, 86%, 84 (96 taxa) belong to Insecta (Fig. 2). It was determined that, *Gammarus* sp. was dominant on 1, 2, 4 and 5, while *Chironomus* sp. was dominant on 3, 6 and 7 sampling points.

The advantage of monitoring by the use of bioindicators is that biological communities reflect overall ecological quality. Moreover monitoring integrates the effects of different stressors providing a broad measure of their impact and an ecological measurement of fluctuating environmental conditions [1, 9, 24-27]. Biological water quality can be assessed by various kinds of organisms such as macrophytes, phytoplankton, diatoms, macroinvertebrates and fishes for regular observations. The use of benthic macroinvertebrates as biological indicators has been widely applied in river quality assessment, because these organisms are relatively sedentary and thus are unable to avoid deteriorating water/sediment quality. These organisms, having relatively long life-spans, reveal marked responses to stress depending on their species-specific sensitivity/tolerance levels and

TABLE 1 – Maximum, minimum and mean levels of physicochemicals according to the sampling points

		1	2	3	4	5	6	7
	Min*.	145.0	224.0	268.0	146.0	344.0	345.0	289.0
EC μScm^{-1}	Mean	277.2	321.4	340.6	234.6	427.1	487.0	416.1
	Max.	400.0	425.0	458.0	387.0	590.0	590.0	622.0
	Min.	10.8	12.4	10.0	9.9	13.1	13.4	13.7
ºC	Mean	11.6	12.9	14.8	10.5	14.3	19.3	19.8
	Max.	11.9	14.6	19.0	12.4	18.5	25.8	24.7
	Min.	6.8	6.2	6.6	6.4	4.7	6.3	6.1
DO mgL^{-1}	Mean	9.0	8.5	9.2	8.8	6.1	8.4	8.3
	Max.	10.5	10.5	13.8	10.3	7.7	11.3	10.6
	Min.	7.2	7.1	7.5	7.2	7.1	7.3	7.5
pH	Mean	7.7	7.5	7.9	7.7	7.5	7.7	7.9
	Max.	8.6	8.3	8.6	8.6	8.3	8.3	8.6
	Min.	0.8	0.7	0.3	0.6	0.5	0.8	0.5
BOD_5 mgL-1	Mean	2.4	2.5	2.7	2.5	1.4	2.6	2.4
	Max.	3.9	4.3	4.3	4.5	2.5	5.0	4.8
	Min.	0.2	0.2	0.2	0.2	0.3	0.2	1.5
Cl^- mgL^{-1}	Mean	1.7	1.7	1.5	1.5	2.1	2.5	2.7
	Max.	4.0	2.5	2.0	2.5	4.0	6.0	4.0
	Min.	BDL	BDL	BDL	BDL	BDL	0.2	BDL
NH_4-N mgL^{-1}	Mean	0.6	0.7	0.8	0.8	0.5	1.7	1.4
	Max.	2.5	1.5	2.5	2.2	2.5	3.6	4.4
	Min.	BDL	BDL	BDL	BDL	BDL	BDL	BDL
NO_2-N mgL^{-1}	Mean	0.006	BDL	0.006	BDL	BDL	0.003	0.002
	Max.	0.01	BDL	0.033	BDL	BDL	0.033	0.02
	Min.	BDL	BDL	BDL	BDL	BDL	0.6	N.A
NO_3-N mgL^{-1}	Mean	2.2	2.7	2.9	2.7	1.9	6.0	4.9
	Max.	8.8	8.0	8.8	7.5	8.8	12.5	15.0
	Min.	BDL	BDL	BDL	BDL	BDL	BDL	BDL
PO_4-P mgL^{-1}	Mean	0.2	0.001	0.2	0.03	0.04	0.05	0.005
	Max.	0.3	0.014	2.3	0.4	0.7	0.8	0.04

*minimum level as Min, average level as Mean and maximum level as Max were given. BDL: Below detection limits

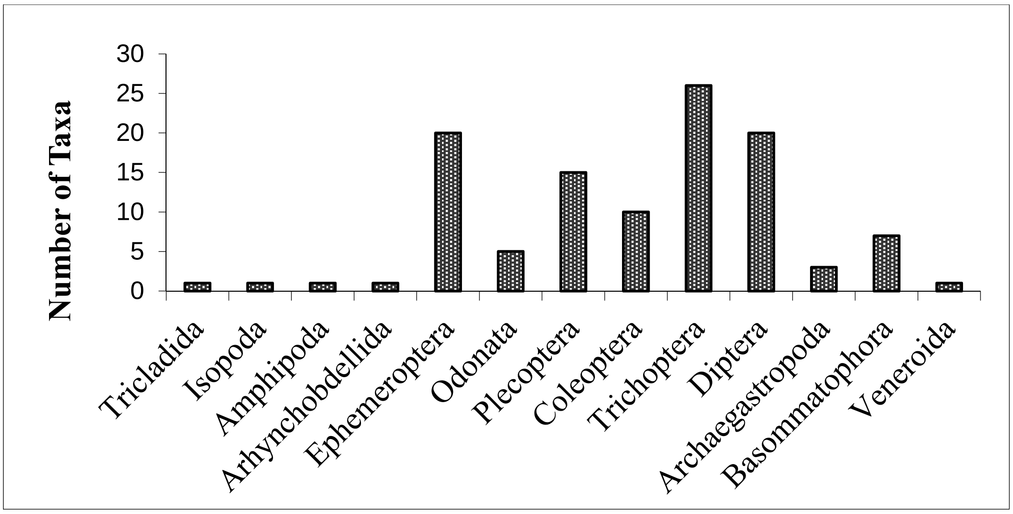

FIGURE 2 - Distribution of Taxa on Order Base.

TABLE 2 - Assessment of water quality according to applied indices.

	1	2	3	4	5	6	7
WPCR	VG	VG	VG	VG	VG	G	VG
Klee (1991)	G	G	G	G	VG	M	G
Sİ.	G	G	M	G	VG	M	P
FBI	G	G	G	G	G	M	M
BMWP	G	G	G	G	G	P	P
ASPT	VG	VG	VG	VG	VG	M	G
BBI	G	G	G	G	G	M	M

Letters refer to water quality: Very Good: VG, Good: G, Moderate: M, Poor, and Very Poor: VP.

play a vital role in cycling nutrients and materials between the underlying sediment and the overlying water column [3-7, 28, 29]. According to our study water quality varied from poor (according to BMWP and SI 7th and according to BMWP 6th) to very good. However there was a disagreement between the in-dices applied. The physical chemical parameters based indices showed higher results than the biological based indices. According to BMWP the 6th station was found "poor" water quality class while it was found "moderate" water quality class according to other biotic indices. The 7th station was found "poor" according to SI and BMWP indices and "moderate" according to FBI and BBI. However the 7th was found "good" water quality class according to ASPT (Table 2).

Table 3 summarizes the correlations of both biological and physicochemical indices. It was found that two physicochemical indices have significant correlation value (r value 0,582, $p<0.01$). Among physicochemical indices and biotic indices, the significant correlation was found between Klee (1991) and SI (r value 0,224, $p<0.05$). Among biotic indices the highest significant correlation was found between BMWP and BBI (r value 0, 827, $p<0.01$) followed by BMWP and ASPT (r value 0, 708, $p<0.01$). The significant negative correlation was found between SI and BBI, BMWP, ASPT respectively. A negative correlation was found between physicochemical indices (WPCR and Klee) and BMWP, ASPT, BBI. However an increase in the results in BBI index and BMWP, ASPT scores systems shows good ecological quality while an increase in SI, FBI, and physicochemical based indices shows bad ecological quality.

The highest ecological water quality was determined in the 5th station according to SI in winter season. The most effective physicochemical parameter on SI was temperature (Table 4). All biotic indices were in accordance between each other except FBI.

According to correlation of between physical-chemical parameter and indices, significant correlation value was determined between NH_4-N with both physicochemical indices (Klee (1991) and WPCR), followed by NO_3-N. Among biotic indices the significant correlation was found between NO_2-N and SI (r value 0,229, $p<0.05$), between BOD_5 and SI (r value 0,188, $p<0.05$). The significant correlation was found between temperature and SI because saproby value increases with temperature [7]. Benthic macroinvertebrate species are differentially sensitive to many biotic and abiotic factors in their environment [30, 31]. In many studies diversity indices are also used for assessing water quality but the biotic index and score systems are better for assessing organic pollution and eutrafication but poor for assessing toxic and physical pollution [3].

From the biotic indices and scores systems applied at Eşen river, SI BMWP, BBI and ASPT were adequate in assessing water quality while FBI was inadequate.

Kantzaris et al. [29] applied nine biotic indices and scores at two rivers in Greece and BMWP, ASPT and LQI were determined inadequate in assessing water quality while BBI and IBE were suitable. Zeybek et al. [32] applied five versions of BMWP and three versions of ASPT indices in Değirmendere Stream and obtained different score values because, in their view, applied ver sions were based on the geological and ecological futures of their source countries.

TABLE 3 - Correlation assessment between biotic indices and physicochemical indices.

	WPCR	KLEE	SI	FBI	BMWP	ASPT	BBI
WPCR	1	,582**	,128	,152	-,340**	-,222*	-,273**
KLEE		1	,224*	,157	-,186*	-,112	-,173
SI			1	,349**	-,558**	-,535**	-,571**
FBI				1	-,228*	-,317**	-,241**
BMWP					1	,708**	,827**
ASPT						1	,681**
BBI							1

** and * Correlation is significant at the 0.01 and 0.05 levels (2-tailed).

TABLE 4 - Assessment of Pearson correlation between physicochemical parameters and biotic indices

	WPCR	KLEE	SI	FBI	BMWP	ASPT	BBI
BOD_5	,144	,265**	,188*	,095	,020	-,036	-,088
Temperature	,355**	,307**	,609**	,127	-,574**	-,478**	-,587**
pH	,188*	,177	,190*	-,006	-,028	-,075	-,023
TH	,134	-,017	,134	-,022	-,339**	-,170	-,332**
NH_4-N	,747**	,827**	,182*	,147	-,329**	-,173	-,226*
NO_3-N	,735**	,816**	,175	,098	-,290**	-,157	-,200*
NO_2-N	-,032	,055	,229*	,117	-,154	-,232*	-,183*
PO_4-N	-,080	,106	-,015	,138	,045	,024	,076

** and * Correlation is significant at the 0.01 and 0.05 levels (2-tailed).

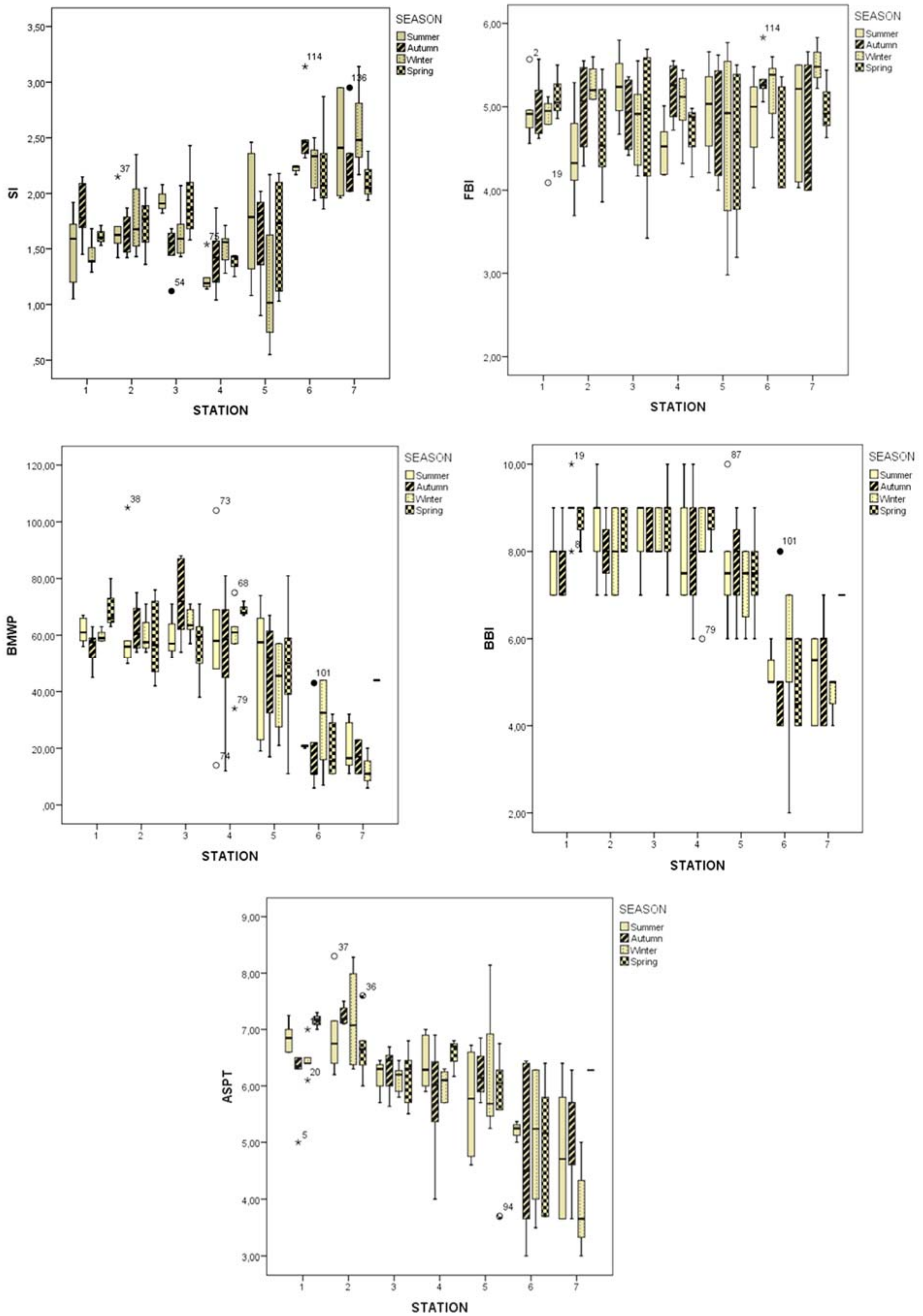

FIGURE 3 - The distribution of the results of the biological water quality according to seasons and stations.

4. CONCLUSION

The results of this study verify the use of macroinvertebrates as bioindicators for the assessment of water quality in southwest of Turkey. In conclusion, the indices SI, BMWP, BBI and ASPT seem to be more suitable than FBI. The biotic indices and scores were also found consistent with the physicochemical parameters but FBI was the least sensitive to pollution. The biotic indices used in our research were designed in order to sample many sites, in many countries with minimal effort [29]. However there is a need for the establishment of a Turkish Biotic Index which takes into account regional macroinvertebrates, their abundance, biology and ecology. This proposed Index can more or less differ from those used in the development of the other biotic indices.

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