World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:10, No:7, 2016

Water Quality Determination of River Systems in Antalya Basin by Biomonitoring

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Open Science Index, Environmental and Ecological Engineering Vol:10, No:7, 2016 publications.waset.org/10004916.pdf

***Abstract*—**For evaluation of water quality of the river systems in Antalya Basin, macrozoobenthos samples were taken from 22 determined stations by a hand net and identified at family level. Water quality of Antalya Basin was determined according to Biological Monitoring Working Party (BMWP) system, by using macrozoobenthic invertebrates and physicochemical parameters. As a result of the evaluation, while Aksu Stream was determined as the most polluted stream in Antalya Basin, Isparta Stream was determined as the most polluted tributary of Aksu Stream. Pollution level of the Isparta Stream was determined as quality class V and it is the extremely polluted part of stream. Pollution loads at the sources of the streams were determined in low levels in general. Due to some parts of the streams have passed through deep canyons and take their sources from nonresidential and non-arable regions, majority of the streams that take place in Antalya Basin are at high quality level. Waste water, which comes from agricultural and residential regions, affects the lower basins of the streams. Because of the waste water, lower parts of the stream basins exposed to the pollution under anthropogenic effects. However, in Aksu Stream, which differs by being exposed to domestic and industrial wastes of Isparta City, extreme pollution was determined, particularly in the Isparta Stream part.

***Keywords*—**Antalya Basin, biomonitoring, BMWP, water quality.

I. Introduction

THE usage of biological variables to determine the pollution levels of streams gives more reliable results than the usage of physicochemical variables. Physicochemical variables point out momentary pollution while the usage of biological variables reflects long term pollution statues. Biotic indices have been used in Europe over a hundred years and macrozoobenthic organisms are the most significant organisms that have been used. In Europe, many indices were developed which were based on these organisms [1]. BMWP and Average Score Per Taxa (ASPT) are the most commonly used ones among these indices. BMWP and ASPT have been used for biomonitoring for a long time by most of the countries in the world [2]-[5]. BMWP and ASPT indices were modified by different countries, to adapt them to their conditions [6]. Lately in Europe, most countries tend to develop and modify their own indices [7].

The Water Framework Directive (WFD) is an obligatory agreement among EU countries for the assessment of water quality and according to WFD, macroinvertebrates are used prevalently in water quality assessments. Consequently, ecological status of running-waters should be evaluated by the use of macroinvertebrates in terms of the introduction of the WFD [8], [9]. In Turkey, biotic indices have been used since 1992 [10]-[13], [9], [14]-[21]. General Directorate of Water Management that belongs to Ministry of Forestry and Water Affairs has been carrying on studies based on basins, since 2013. In these studies, the indices based on macrophytes, fishes, diatoms, macrozoobenthic organisms have been used [22], [23]. In these studies, many indices have been tested on macrozoobenthic organisms, but the usage rate of BMWP and ASPT are higher than other indices. In Antalya Basin, these indices were applied on certain streams and results were evaluated. In this study, water quality of certain streams of Anyalya and West Mediterranean Basins, were determined and the results of BMWP and ASPT were examined. Because of the absence of an index particular to Turkey, the indices, developed for other countries were used in Turkey and the performances were tested. Therefore, the application of these indices must be increased.

II. Material and Methods

For evaluation of water quality of the river systems in Antalya Basin, both physicochemical and macrozoobenthos samples were collected from 22 determined stations in June, 2015. The stations were located in Antalya Basin as; 4 on Aksu Stream, 2 on Dim Stream, 3 on Alara Stream, 3 on Karpuz Stream, 2 on Manavgat Stream, 2 on Göksu Stream, 3 on Köprüçay Stream, 1 on Ulupınar Stream and 2 on Demre Stream. When Ulupınar and Demre Streams are included in West Mediterranean Basin, the other stations are in Antalya Basin. When evaluated by altitude, stations vary between 765 m (Station X) and 2 m (Stations XVII and XX). Distribution and study fields of the stations were indicated at Fig. 1.

Water samples taken from the 22 stations in Antalya Basin were brought back to the laboratory and analyzed within 24 hours. Dissolved oxygen (DO), pH, water temperature and conductivity were measured in the field. Biological oxygen demand (BOD_5), Cl^-, NH_4^+–N, NO_2^-–N, NO_3^-–N, PO_4^-–P were measured in the laboratory [24]. Assessments of water quality by physicochemical parameters were performed according to Klee's [25] method.

Macroinvertebrate sampling was done by using a standard hand net (50 × 30 size with 500-µm mesh), in an area of 100 m. All of the microhabitats existing in 100 m were scanned. The samples were separated by sieving (250 µm) and fixed in formaldehyde (4%). In the laboratory, the samples were

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classified at family level and preserved in 70% alcohol in the laboratory. Identification and counting processes of the samples were accomplished under a stereomicroscope. In this study, BMWP and ASPT were used to calculate the biotic indices for the macrozoobenthic community.

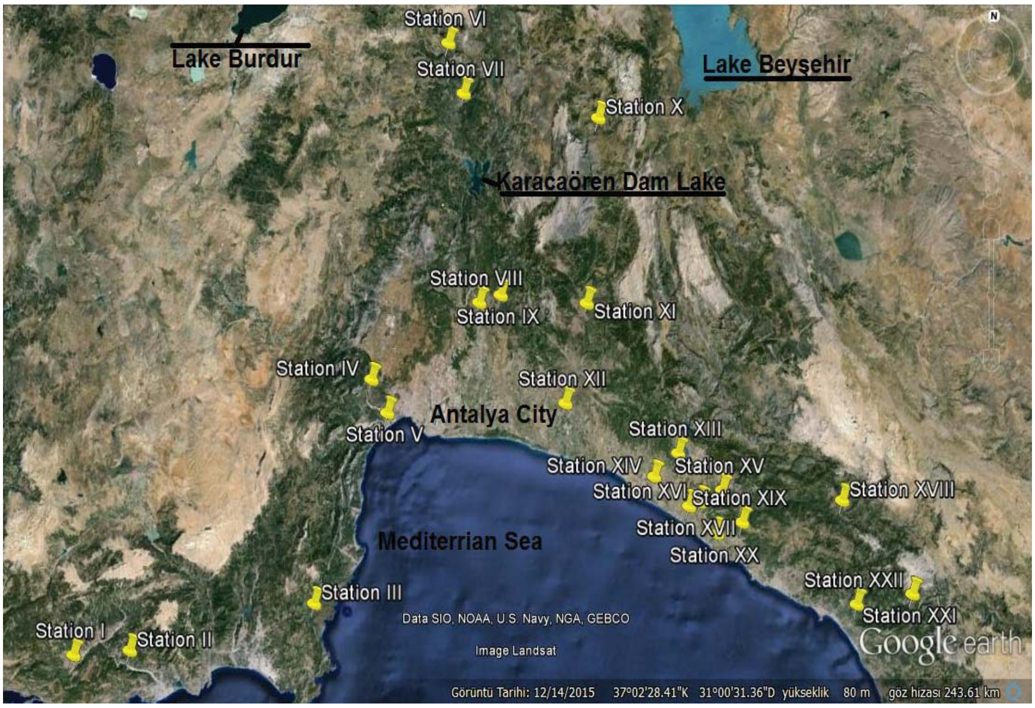

Fig. 1 Study area and stations

TABLE I
PHYSICOCHEMICAL VARIABLES FOR STATIONS IN ANTALYA BASIN

Stations	Temp. (Co)	O2 (mg/l)	pH	E.C (µS/cm)	BOI (mg/l)	NH4+-N (mg/l)	NO2—N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	Cl- (mg/l)	Altitude
1	21,1	8,9	8,9	228,1	2,56	BDL	BDL	0,45	BDL	13,5	205
2	20,54	9,3	7,82	382,7	3,05	BDL	BDL	0,79	BDL	6,46	77
3	18,2	9,8	8,11	342	3,2	BDL	BDL	0,12	BDL	5,57	173
4	22,6	8,6	8,3	672	8,22	BDL	0,011	0,466	0,017	34,6	13
5	24,7	7,65	8,1	439	6,2	1,36	2,44	BDL	0,03	26,4	4
6	25,2	6,01	8,55	1166	22	3,597	0,926	3,99	1,4	112	655
7	19,7	9,28	8,67	375	3,07	0,02	BDL	0,083	BDL	8,24	331
8	20,1	9,3	8,23	362	4,2	0,07	BDL	0,423	BDL	7,42	29
9	18,6	9,98	8,33	365	3,86	0,013	BDL	0,163	BDL	16,2	68
10	18,6	9,5	8,45	298	2,05	0,021	BDL	0,132	BDL	7,8	764
11	15,3	9,8	8,34	346	3,86	0,023	BDL	0,343	BDL	9,2	123
12	18,6	9,5	8,33	369	7,2	0,017	0,022	0,182	0,17	17,24	9
13	18	10,32	8,41	276	4,2	0,019	BDL	0,248	BDL	8,2	11
14	19,2	9,2	8,35	303	3,8	0,019	BDL	0,015	0,016	18,4	1
15	18,2	8,3	8,14	366	1,44	0,03	BDL	0,05	BDL	4,24	75
16	21,1	7,3	8,12	426	3,2	0,08	BDL	0,32	BDL	42,2	9
17	22,2	9,54	8,24	686	4,5	0,019	BDL	0,412	0,035	14,3	2
18	16,5	9,11	8,27	264	2,2	ALA	BDL	0,29	BDL	2,21	264
19	18,8	9,98	8,42	366	2,89	0,012	BDL	BDL	BDL	6,8	30
20	18,3	9,96	8,2	316	6,12	0,0326	BDL	0,312	0,022	12,6	3
21	15,2	7,6	8,05	305	2,3	0,28	BDL	0,11	<0,05	3,3	218
22	17	6,9	8,02	314	0,3	0,11	BDL	0,17	<0,05	3,4	18

***BDL:** Below Detection Limit

TABLE II
DISTRIBUTION AND DOMINANCY (%) OF THE IDENTIFIED FAMILIES AT THE STATIONS

	Stations																					
Taxa List	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Turbellaria																						
Planaridae				0,44	0,17		0,76	7,77		5,39		13,2		0,47					7,33			
Oligochaeta						65	0,27	7,43		0,11	0,62		3,63	6,66			3,62			1,16		
Hirudinae					0,17																	
Gastropoda																						
Melanopsidae								8,1						4,76								
Neritidae								0,33						4,76						2,9		
Lymnaeidae			28,5	0,2				0,33						6,66						1,74	0,54	1,04
Physidae			21,4	1,78	22,2		0,32	0,33					47,2	3,33			7,6		1,31	1,74		
Planorbidae								1,35					1,81	4,76			0,36					0,52
Hydrobiidae																	1,44		0,65			
Ancylidae										0,44			4,45									
Sphaeriidae			1,41											3,33								
Acarina																		0,51			8,64	
Hydracarina										0,44	0,62	0,86							0,54			
Crustacea																						
Paleomonidae				8,02													11,5			11		
Gammaridae					0,7		63,6	11,1	3,41	0,67	6,87	10	1,81	20,9				0,1	4,38			
Asellidae													0,9	2,85								
Ephemeroptera																						
Baetidae	65,5	62,3	0,7	31,5	11,6		0,71	37,1	23	19,1	11,2	15,8	13,6	2,85	20,7	51,5	34,7	12,6	8,65	34,8	29,5	23
Heptageniidae	0,87	1,22							5,98	18,5	7,5				6,87	2,03		13,7	3,83		0,82	0,52
Leptophlebiidae										1,68												0,52
Potamonthidae										5,05	1,87								14,7	1,45		
Ephemeridae										0,11									0,21			
Ephemerellidae	2,78	4,7			0,61		23,5	9,12	0,85		1,87			15,2				1,53	7,55			
Caenidae	9,67	4,9	3,08	31,5	54			4,05	3,41	1,23				0,47	11	5,08	17,3	8,78	0,65		0,27	6,28
Isomychiidae																		0,1				
Plecoptera																						
Taeniopterygidae															1,16	1,01		1,22				
Capnidae															3,48	4,4						
Leuctridae	4,54	6,13	0,84						5,12	19,2	3,12	1,14			6,38	6,1		1,83	1,75			
Perlodidae										0,22					8,32	7,45		6,74				
Perlidae										2,24	3,12							13,8				
Chloroperlidae										0,11												
Nemouridae															0,32	1,01		3,26	0,1		1,09	
Trichoptera																						
Hydropsychidae	1,53	6,13	9,46				0,05	7	1,7	1,46	5	16,6			18	23		5,1	0,98		1,09	2,6
Hydroptilidae	1,39		0,22	5,18	3,18					2,24	0,62	6,6			7,35		0,36					0,52
Rhyacophilidae			1,17															3,37				
Brachycentridae										0,78												
Sericostomatidae										0,67								6,94	0,1			
Glossosomatidae			0,11				0,32															
Philopotamadidae															1,16							
Diptera																						
Chironomidae	4,02	13,2	21,1	8,76	5,48	33	9,78	5,74	39,3	6,96	50	12,6	18,1	13,3			12,3	5,2	37,7	2,9	25,1	58,1
Tabanidae	0,36	0,2		0,44	2,26				0,85	0,22	0,62	0,28	1,81				0,72		0,1			1,04
Blephariceridae										0,44	2,5											
Culicidae																						
Empididae		0,2																			0,82	
Athericidae			0,7							0,56								0,61	1,86			
Limoniidae										0,44								0,1				
Simuliidae	4,1		6,35	5,34	2,47	1,79		1,35	2,56	1,01		0,86	5,45					3,88	6,68		29,1	4,18
Ceratopogonidae							0,49															
Stratiomyidae																	0,72	0,1				
Tipulidae	0,87									0,11		0,28										

Dixidae	0,14																					
Hemiptera																						
Notonectidae												0,57					6,15					
Corixidae												1,72								29		
Velidae												1,72										
Gerridae														1,9			0,72			4,36	1,09	
Odonata																						
Gomphidae		0,2						0,33	0,85	1,12	0,62	0,86					0,72		0,1			
Aeshnidae				0,14				0,33		1,11						0,67		0,2			0,54	1,04
Euphaeidae	0,07									1,68					0,29	1,01						
Calopterygidae								0,33		0,67	2,5	3,44		6,19			0,72	0,2				
Coenagrionidae				0,44	0,7			0,33			0,62									0,87		
Platisenemidae				1,18				0,33		0,91		5,45					0,72			2,9		
Lestidae								0,33						1,42					0,1	0,87		
Libellulidae		0,6			0,35					0,11		0,28								0,58		
Coleoptera																						
Hydraenidae										0,44												
Dytiscidae															0,09					3,48		
Noteridae										0,22												
Gyrinidae										0,11		0,28				0,33						
Elmidae								1,35	12,8	4,04	0,62	7,18			14,3	11,5		9,8	2,51		0,27	0,52

III. RESULTS

A. Physicochemical Variables

The minimum, maximum, and average values of measured physical and chemical variables and water quality classes of the stations during the study period are represented in Table II. Maximum value of pH was determined at 1st station, minimum was at 2nd station. The highest temperature was detected at 5th station and the lowest was at 11th station. When the lowest value of dissolved oxygen was found at 6th station, the highest values of the other parameters were determined at this same station (Table I). Therefore, the most polluted station was determined as 6th station when the most polluted stream was determined as Isparta Stream. According to the physicochemical parameters, levels of water quality were showed alteration between quality class I and V.

B. Biological Results

In this study, a total of 15.336 individuals comprising macrozoobenthic taxa were identified. The most individuals were collected at 6th station, while the fewest individuals were collected at 4th station. But, the most families were identified at 1st station, while the fewest families were identified 6th station. The individuals collected from the stations belonged to Turbellaria (1 taxon) Gastropoda (7 taxa), Bivalvia (1 taxon), Oligochaeta (1 taxon) (Oligochaeta identified grup level), Hirudinea (1 taxon), and Insecta (52 taxa). Table II shows the dominancy (%) of the identified families at the stations.

C. Biological (BMWP and ASPT) and Physicochemical Water Quality Results

According to BMWP scores, it was determined that the 8th, 10th, 18th and 19th stations are quality class I; 11th, 12th, 15th and 16th stations are quality class II; the first five stations, 9th, 14th, 17th, 20th and 22nd stations are quality class III; 7th and 13th stations are determined as quality class IV when the 6th station is determined as quality class V. According to ASPT scores, it was determined that the 1st, 2nd, 9th, 11th, 15th, 16th, 18th and 19th stations are quality class I, 3rd, 4th, 5th, 8th, 12th, 20th and 21st stations are quality class II, 7th, 14th, 17th and 20th stations are quality class III, 6th and 13th stations are quality class IV.

According to WFD, when the physicochemical parameters were evaluated by taking into consideration of saprobic classification, according to BOD values, because of being included to quality class II; 2nd, 3rd, 7th, 8th, 9th, 11th, 13th, 14th, 17th, 18th and 19th stations were determined as betamesosaprobic. In the view of BOD and Cl values, the 20th station was found in the II-III water quality class; 1th and 10th stations were found I-II water quality class; 4th station was found III water quality class. The 5th station was found IV water quality class in terms of nitrite nitrogen and the 6th station was found IV water quality class in terms of BOD, Ammonium and nitrite nitrogen and Cl values. The quality classes were determined according to these parameters due to their high values.

As the result of the comparison, the values obtained from ASPT were seemed more compatible than the values obtained from physicochemical parameters. Even though the values pointed out different pollution classes, they all stated increasing of the pollution transparently (Table III).

In Demre Stream, in terms of water quality, according to all evaluation systems and indices, any alterations were determined between downstream and upstream. And in Boğa Stream, increasing pollution was determined at the station that takes place on downstream. Kovada and Isparta Streams, which are the sources of Aksu Stream, were identified as heavily polluted. Isparta stream has been polluted by the waste water coming from the city of Isparta. Kovada Stream has been affected from urban areas and Kovada Lake. The streams of Isparta and Kovada feed Karacaören I and Karacaören II dam lakes. At the 8th station, which takes place after Karacaören II dam lake, decreasing pollution was recorded.

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The 9th station has been representing another tributary belonging to Aksu Stream. In Manavgat and Dim Streams, according both physicochemicals and biotic indices, any alterations were determined between stations from downstream and upstream. As to Köprüçay, Karpuz and Alara Streams, increasing pollution was determined according to both of the water quality assessment systems (Table III).

TABLE III
WATER QUALITY CLASSES OF STATIONS, ACCORDING TO BMWP, ASPT AND PHYSICOCHEMICAL PARAMETERS

Stations	BMWP Quality Classes	ASPT Quality Classes	WFD Quality Classes	Klee [25] Quality Classes
1. Demre Stream	III	I	Oligo-Betamesosprob	Oligosaprob
2. Demre Stream	III	I	Betamesosprob	Oligosaprob
3. Ulupınar Stream	III	II	Betamesosprob	Oligosaprob
4. Boğa Stream	III	II	Alphamesosaprob	Oligo-Betamesosprob
5. Boğa Stream	III	II	Polisaprob	Alpha-betamesosprob
6. Isparta Stream	V	IV	Polisaprob	Alphamesosaprob
7. Kovada Stream	IV	III	Betamesosprob	Oligosaprob
8. Aksu Stream	I	II	Betamesosprob	Oligosaprob
9. Aksu Stream	III	I	Betamesosprob	Oligosaprob
10. Köprüçay Stream (Upstream)	I	I	Oligo-Betamesosprob	Oligosaprob
11. Köprüçay Stream (Midstream)	II	I	Betamesosprob	Oligosaprob
12. Köprüçay Stream (Downstream)	II	II	Alpha-betamesosprob	Oligo-Betamesosprob
13. Manavgat River (Upstream)	IV	IV	Betamesosprob	Oligosaprob
14. Manavgat River (Downstream)	III	III	Betamesosprob	Oligo-Betamesosprob
15. Karpuz Stream (Upsteream)	II	I	Oligosaprob	Oligosaprob
16. Karpuz Stream (Midstream)	II	I	Alphamezosaprob	Oligo-Betamesosprob
17. Karpuz Stream (Downstream)	III	III	Oligo-Betamesosprob	Oligosaprob
18. Alara Stream (Upstream)	I	I	Oligosaprob	Oligosaprob
19. Alara Stream (Midstream)	I	I	Oligosaprob	Oligosaprob
20. Alara Stream (Downstream)	III	III	Oligo-Betamesosprob	Oligo-Betamesosprob
21. Dim Stream (Upstream)	III	II	Betamesosprob	Oligo-Betamesosprob
22. Dim (Downstream)	III	II	Oligo-Betamesosprob	Oligosaprob

D.Statistical Analyses

In the study, 22 sampling points were determined. How strongly the NMDS application determines the differences between taxa belonging to sampling points was evaluated in the first NMDS application. The result came up as $r^2 = 0.965$ and it was strongly meaningful. Hereby, for dissimilarity analysis between taxa, Wisconsin-Bray Curtis was used. Detrended Correspondence Analysis was applied to look for the gradient between ordination axes. Correspondingly, the gradient ratio between axes was determined as 3.36. This value is enough to use Canonical Correspondence Analysis (CCA) in the upcoming stages. Afterwards, by keeping the non-dominant taxa of no effect in the background, dominant taxa were highlighted on ordination graphics. Hereunder, highlighted taxa were; Oligochaeta, Ancylidae, Physidae, Acarina, Lymnaeidae, Simuliidae, Stratiomyidae, Notonectidae, Chironomidae, Asellidae, Gerridae, Sphaeriidae, Caenidae, Nemouridae, Corixidae, Aeshnidae, Perlodidae, Perlidae, Hydropsychidae, Athericidae, Calopterygidae, Melanopsidae, Euphaeridae, Leuctridae, Limoniidae, Gyrnidae, Platisenemidae, Potamonthidae, Planaridae, Ephemerellidae, Gammaridae, Glossomatidae, Tabanidae and Paleomonidae.

The CCA ordination graphic, carried out by the usage of meaningful environmental parameters belonging to stations, taxon and environmental parameters, gave significant results according to ANOVA test in the level of $p<0.05$. However, when the graphic was evaluated, it can be clearly seen that the 6th station was separated from others and Oligochaete was the indicator group for this station. The environmental parameters of PO_4-P and NO_3-N were found as distinctive factors for this sampling point. Among the sampling points, the 6th station can be considered as a polluted reference point in the view of water quality. High values of orthophosphate and the nitrate nitrogen were common for this sampling point.

The physical and chemical parameters and the benthic community belonging to the remaining stations were similar to each other. Because of this, the 6th station was removed from the data set and the same processes were done again. In the second NMDS application, it was found highly significant in the level of $r^2 = 0.965$. To find the gradient between ordination axes Detrended Correspondence Analyze was performed. According to this, the gradient difference was found 3.80. The first result of DCA was found 3.36 while the 6th station was included. When the 6th station was removed, in the advanced choosing technique, DO, BOD_5, temperature and the altitude were found significant in the level of $p<0.05$.

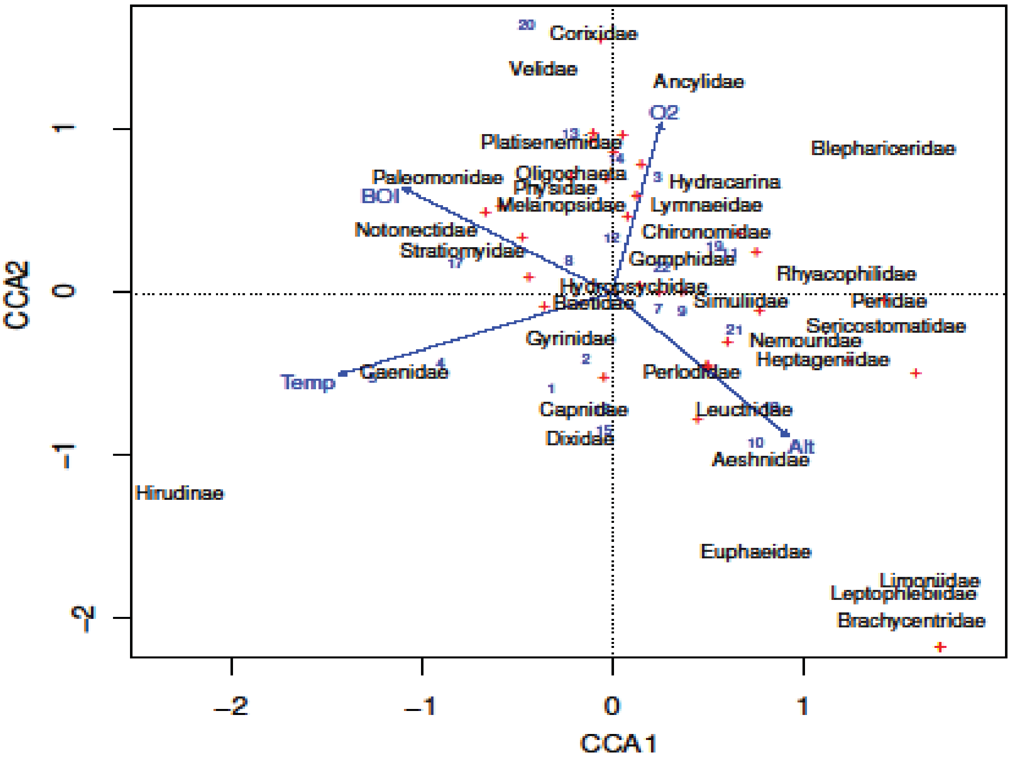

Fig. 2 CCA ordination graphic of significant environmental parameters, sampling points and dominant taxa

Eventually, the CCA ordination graphic was done belonging to dominant groups, meaningful environmental parameters and sampling points. According to this, the first axis shows high positive relation with altitude while a high negative relation was found with temperature and BOD_5. The second axis was in a high positive relation with dissolved oxygen. In the first axes, it was observed that as a primer feature, the high altitude was preferred by especially Perlodidae, Heptagenidae, Euphaeidae, Limoniidae, Leptophlebiidae and Brachycentridae. The stations 10, 15, 18, and 21 reflect these features. Especially members of Hirudinae and Caenidae groups prefer high values in the view of temperature. The stations 1, 2, 4 and 5 have higher temperature values than the other sampling points. A high positive relation was found between the temperature and BOD_5. High BOD_5 values can be associated with richness of organic pollution. Stations 17 and somewhat 18 can be evaluated in this way. Paleomonidae, Notonectidae, Melanopsidae, Oligochaeta, Stratiomyidae and Velidae can be considered as indicator groups of organic pollution. According to BMWP and ASPT score systems, Oligochaeta and Notonectidae are among pollution-tolerant taxa [26]. Paleomonidae, Melanopsidae, Stratiomyidae and Velidae are evaluated in BMWP and ASPT score systems. Perlidae, Sericostomatidae, Nemouridae and Rhyacophilidae can be example to the groups that prefer high altitudes, non-temperature tolerant and prefer high oxygen levels. These taxa are known as pollution-sensitive taxa in BMWP and ASPT score systems [26].

IV. CONCLUSION

Water quality assessments were made by physicochemical parameters of the samples from 22 determined stations on the streams in Antalya Basin. Besides, BMWP and ASPT were applied to the data obtained from the sampling of benthic macroinvertebrates which collected in the same period. Taxa of Velidae, Euphaeidae, Hydraenidae, Noteridae, Dixidae, Stratiomyidae, Ceratopogonidae, Limoniidae, Athericidae, Empididae, Culicidae, Blephariceridae, Tabanidae, Isomychiidae, Paleomonidae and Melanopsidae were disused in the BMWP index calculations because of these taxa are excluded from the original BMWP index.

According to both of the assessments, when the station on the Isparta Stream was determined as the most polluted station, it was followed by 13th station which was on the upstream of Manavgat Stream; 5th station which takes place on downstream of Boğa Stream, according to physicochemical parameters. Due to the low water levels and morphological deterioration, insufficient number of family was obtained from 13th station and because of this, in this exact station, BMWP and ASPT values indicated quality class IV. This station takes place on down side of Manavgat stream and located as lake outlet. The data obtained from physicochemical variables give more reliable results for this particular station. Especially in clean areas, ASPT and physicochemical variables support each other and by increasing of pollution, deviation of one level of water quality class was monitored. The highest deviation was determined at 5th station. Pollution in this station was determined, according to ASPT values, increasing over quality class II, as to physicochemical parameters, Alpha-betamesosaprobic and as to WFD evaluations, polysaprobic. The results obtained from BMWP index were deviated more. Biotic indices were deviated negatively and pointed higher pollution load in this study.

BMWP and ASPT indices were revised in most of the countries to their own conditions as well used as original version [2]-[6]. In these revisions, both originally listed organism values were revised and the existing but non-listed organism were added. In this study, excluding of the 16 taxa from index calculations, was caused inaccuracy in the results. Therefore, BMWP and ASPT indices need to be adapted and revised to the conditions of Turkey.

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