

Determination of indicator genera of benthic macroinvertebrate communities in running waters in western Turkey

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ABSTRACT

1. Benthic macroinvertebrates and physicochemical data were assessed for 47 sites in Western Turkey. The research areas include Büyük Menderes River in Aegean Region, streams in Köyceğiz-Dalyan Protected Area in the Mediterranean Region, Ankara and Kirmir Streams in the western part of Middle Anatolia.
2. Relationships between macroinvertebrate assemblages and environmental variables were explored by canonical correspondence analysis.
3. Two-way indicator species analysis was used to classify sites into 16 groups based on similarities in macroinvertebrate composition and to determine indicator genera.
4. The present study establishes organic pollution impact in runningwater ecosystems and classifies the benthic communities into groups with similar latitude towards physicochemical changes and provide information on genus indicators of polluted and unpolluted sites in western Turkey.

KEY WORDS: CCA, indicators, macroinvertebrates, Mediterranean running waters, Turkey, TWINSpan, water quality.

Türkiye'nin batısındaki akarsularda bulunan bentik makroinvertebrat komünitelerine ait indikatör cinslerin belirlenmesi

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ÖZ

1. Türkiye'nin batısında yer alan bazı akarsulara ait 47 istasyonun, fiziko-kimyasal değişkenleri ve bentik makroinvertebratları birlikte su kalitesi yönünden değerlendirilmiştir. Araştırma alanı, Ege Bölgesi'nde Büyük Menderes Nehri, Akdeniz Bölgesi'nde Köyceğiz-Dalyan koruma alanındaki akarsular ile Orta Anadolu'nun batısında yer alan Ankara Çayı ve Kirmir Çayı'nı içine almaktadır.
2. Makroinvertebrat toplulukları ile çevresel değişkenler arasındaki ilişki CCA analizi ile açıklanmıştır.
3. Örneklem noktalarını bentik makroinvertebrat kompozisyonunun benzerliği açısından 16 grup halinde sınıflandırmak ve indikatör türleri belirlemek için Two-way indicator tür analizi (TWINSPAN) kullanılmıştır.
4. Bu çalışmada, akarsu ekosistemlerine organik kirliliğin etkisi saptanmış, bentik makroinvertebratlar fiziko-kimyasal değişimlere karşı gösterdikleri benzer hoşgörülerini açısından sınıflandırılmış ve Türkiye'nin batısında yer alan, organik olarak kirlenmemiş ve kirlenmiş bölgelerin cins düzeyinde indikatörleri belirlenmiştir.

ANAHTAR KELİMELER: Akdeniz akarsuları, CCA, indikatör, makroinvertebrat, su kalitesi, Türkiye, TWINSPAN.

INTRODUCTION

Routine biological assessment of running waters and of lakes has not been performed in Turkey up to recent years. Physico-chemical variables alone are inadequate for assessment and management of running water quality. The benthic macroinvertebrate communities broadly reflect environmental conditions and are used as indicators of environmental degradation or restoration (eg. Cairns and Dickson 1971, Rosenberg and Resh 1993). Multivariate methods permit considerable understanding of the community structure and relationships with corresponding environmental properties (Ormerod and Edwards 1987). Relationships between benthic macroinvertebrate communities and environmental variables have recently received considerable attention in Turkey (Kazancı et al. 1992, Girgin and Kazancı 1994, Kazancı et al. 1997, Kazancı and Girgin 1998, Kazancı and Dügel 2000, Kazancı 2001, Girgin et al. 2003, Kazancı et al. 2003a, b, Dügel and Kazancı 2004, Kazancı et al. 2004).

The research area includes tributaries of Büyük Menderes River, streams in Köyceğiz-Dalyan protected area, Ankara Stream and Kirmir Stream in Western part of Turkey. Based on multivariate techniques, the present study aims to determine pH, DO, temperature, NO₂-N, NH₄-N and PO₄-P impact on the structure of benthic macroinvertebrate communities, to classify them into groups and provide information on genus indicators of organically polluted and unpolluted sites in different running water ecosystems in Western Turkey for the first time.

METHODS

Sampling was carried out monthly from Ankara Stream and Kirmir Stream between April 1991 and November 1992, from Köyceğiz-Dalyan protected area (Yuvarlakçay, Namnam, Kocaöz, Hamitköy, Çamlıdere, Sariöz, Asar Streams) between April 1992 and April 1993 and from Büyük Menderes River between April 1998 and January 1999. Each benthic macroinvertebrate sample was a 15-minute collection standard pond-net, obtained by both kicking and sweeping all available. Samples were kept in 80% ethyl alcohol. Taxa were determined to genus level.

In each station, dissolved oxygen and temperature were measured in the field with portable instruments (HACH oxygen meter). pH, nitrite, ammonia, phosphate were measured in the laboratory according to the Standard methods of DSI (State Water and Hydraulic Works) (DSI, 1981) and protocol (Merck 1986, Snel and Snel 1957, Mohr 1856). The sampling and methods used for water analyses have been given also by Kazancı et al. (1997), Kazancı and Dügel (2000), Dügel and Kazancı (2004), Girgin et al. (2003). Data sets were classified by two-way indicator species analyses (TWINSPAN, Hill 1979) at the genus level. Relationships abundance of between macroinvertebrate assemblages and environmental variables were analysed by canonical correspondence analysis (CCA, Ter Braak 1987). The main morphometric features of the stream basins are given in Table 1.

Table 1. The main morphometric features and water quality measures of the stream basins

	Basin variables		
	Drainage area km ²	Stream order	altitude m
Ankara Stream	7140	1-2	850
Kirmir Stream	3942	1-2	450-1600
Menderes River	23873	1-4	0-50
Streams in Köyceğiz Basin	1072.7	1-2	0-50

RESULTS AND DISCUSSION

Physico-chemical characteristics

The variations of mean of six physico-chemical parameters for running waters are shown in Figures 1a and b. The lowest values of organic pollution were measured in the streams in Köyceğiz Basin (sites Y1-Y14) and in the Menderes Stream (M3-M7) (Figure 1a).

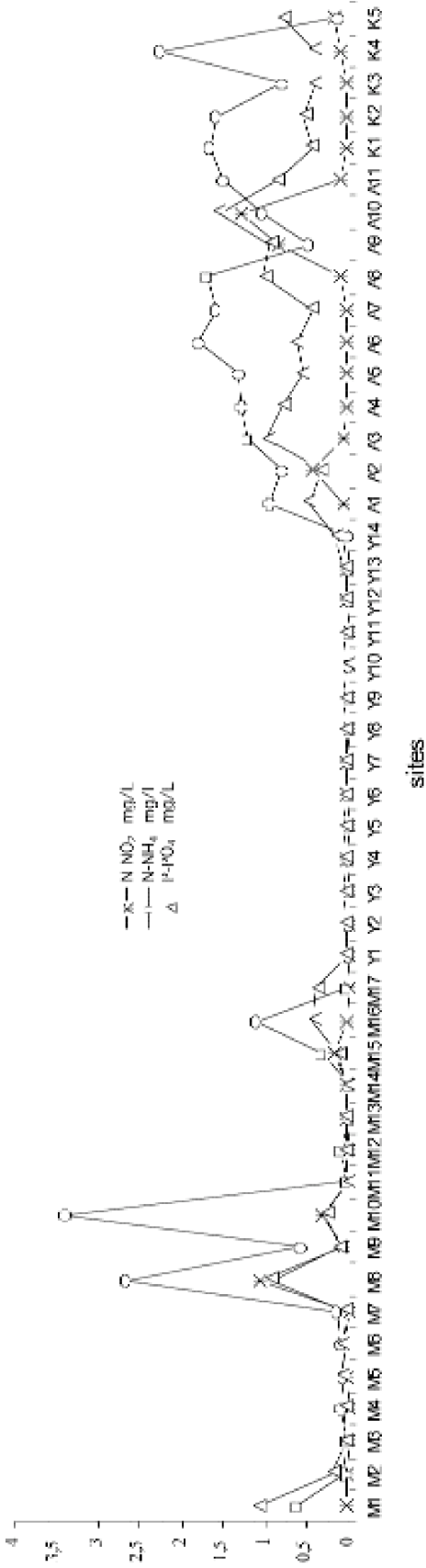


Figure 1a. Annual variations of $\text{NO}_2\text{-N}$, $\text{NH}_4\text{-N}$ and $\text{PO}_4\text{-P}$ values in Büyük Menderes River (M1-M17), Streams of Köyceğiz Basin (Y1-Y14), Ankara Stream (A1-A11) and Kirmir Stream (K1-K5).

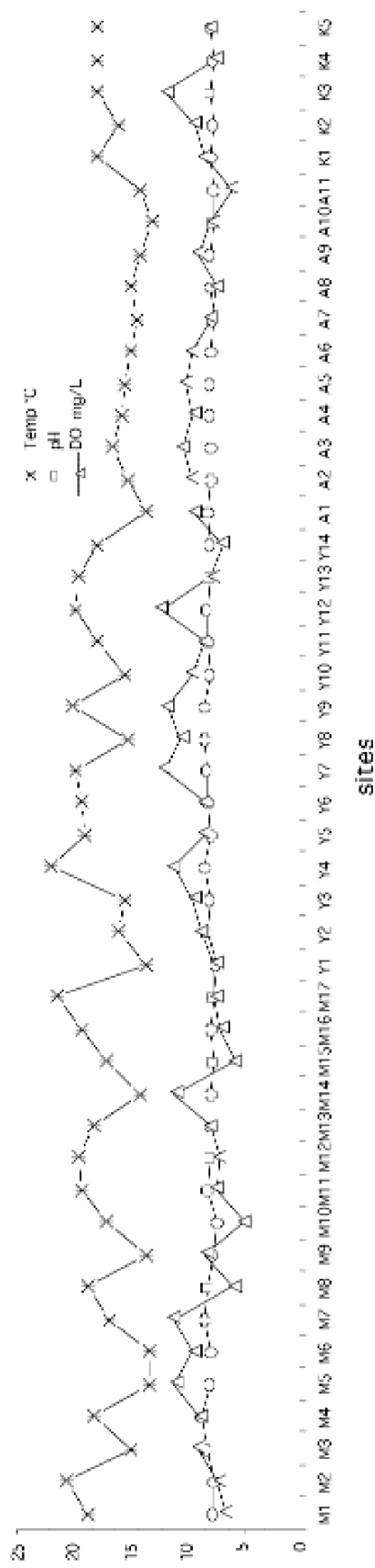


Figure 1b. Annual variations of temperature, pH and DO values in Büyük Menderes River (M1-M17), Streams of Köyceğiz Basin (Y1-Y14), Ankara Stream (A1-A11) and Kirmir Stream (K1-K5).

Abbreviations of sites:

M1 Çine Stream Kayırılı; M2 Çine Stream-Çakırbeyli; M3 Mortuma Stream-Yemişendere; M4 Akçay-Değirmenalani; M5 Sarhoş Stream-Göktepe; M6 Yenidere Çalılıköy; M7 Akçay Anayasa; M8 Gökpınar Akhan; M9 Banaz Stream-Azizler; M10 Banaz Stream-Dörtdeğirmenler; M11 Outlet of Işık Lake; M12 Büyük Menderes River-Çırak; M13 Bekilli Santral; M14 Büyük Menderes River, South; M15 Büyük Menderes River Burhaniye; M16 Aydın Köprüsü; M17 Delta of Büyük Menderes River
 Y1 Yuvarlakçay, source; Y2 Yuvarlakçay, before Alabalık site; Y3 Yuvarlakçay, after Alabalık site; Y4 Yuvarlakçay, before Nasıfdele site; Y5 Nasıfdele; Y6 Yuvarlakçay, after Nasıfdele site; Y7 mouth of Yuvarlakçay; Y8 Nannam, old bridge; Y9 Nannam, new bridge; Y10 Asar; Y11 Kocaöz; Y12 Hamitköy; Y13 Sarıöz; Y14 Çamlidere
 A1 Kocaçay Stream; A2 Outlet of Çubuk I Dam; A3 Outlet of Çubuk II Dam; A4 İncesu Stream, outlet of Eymir Lake; A5 İncesu Stream, before-garbage dump; A6 Inlet of Bayındır Dam; A7 Outlet of Bayındır Dam; A8 Hatip Stream; A9 Outlet of Kurtboğazi Dam; A10 Inlet of Kurtboğazi Dam; A11 Zir Stream
 K1 Sey Stream, inlet of Eğrekkaya Dam; K2 Sey Stream, outlet of Eğrekkaya Dam; K3 Celfikci Stream; K4 before Ayaş Town; K5 Karadere Stream, Ayaş.

CCA ordination

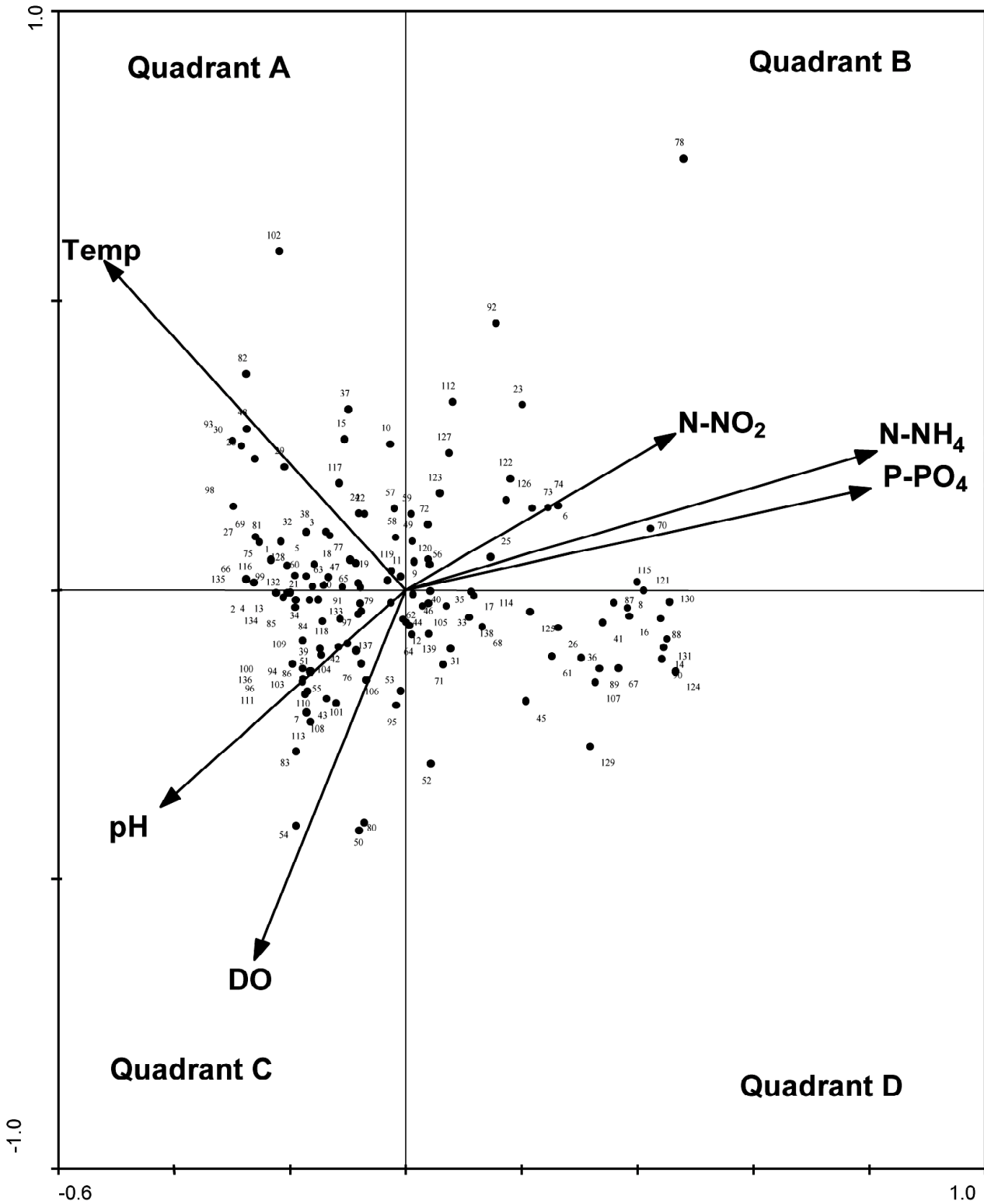


Figure 2. CCA diagram with selected environmental variables and macroinvertebrates from sites. Abbreviations: NH₄-N: Ammonia nitrogen; NO₂-N: Nitrite nitrogen; PO₄-P: Phosphate phosphorus; DO: Dissolved oxygen; Temp: temperature.

Table 2. List of the taxa found in quadrants in the CCA diagram

Number	Quadrant A	Number	Quadrant B	Number	Quadrant C	Number	Quadrant D
1	<i>Dugesia</i>	6	<i>Physa</i>	2	<i>Theodoxus</i>	8	<i>Galba</i>
3	<i>Valvata</i>	9	<i>Radix</i>	4	<i>Bithynia</i>	12	<i>Ancylus</i>
5	<i>Melanopsis</i>	23	<i>Tubifex</i>	7	<i>Lymnaeidae</i>	14	<i>Planorbis</i>
10	<i>Planorbidae</i>	25	<i>Glossiphonia</i>	13	<i>Acroloxus</i>	16	<i>Succinea</i>
11	<i>Gyraulus</i>	49	<i>Potamanthus</i>	34	<i>Siphonurus</i>	17	<i>Pisidium</i>
15	<i>Unio</i>	56	<i>Calopteryx</i>	39	<i>Rhithrogena</i>	26	<i>Helobdella</i>
18	<i>Sphaerium</i>	59	<i>Ischnura</i>	42	<i>Heptagenia</i>	31	<i>Asellus</i>
19	<i>Hirudidae</i>	70	<i>Nepa</i>	43	<i>Iron</i>	33	<i>Gammarus</i>
20	<i>Erpobdella</i>	72	<i>Gerris</i>	50	<i>Nemoura</i>	35	<i>Baetis</i>
21	<i>Oligochaeta</i>	73	<i>Hydrometra</i>	51	<i>Protonemoura</i>	36	<i>Epeorus</i>
22	<i>Eiseniella</i>	74	<i>Mesovelgia</i>	53	<i>Perla</i>	40	<i>Ecdyonurus</i>
24	<i>Naididae</i>	78	<i>Noterus</i>	54	<i>Chloroperla</i>	41	<i>Electrogena</i>
27	<i>Acarina</i>	92	<i>Chrysomelidae</i>	55	<i>Epallaga</i>	44	<i>Ephemerella</i>
28	<i>Ostracoda</i>	112	<i>Acentropus</i>	76	<i>Gyrinus</i>	45	<i>Torleya</i>
29	<i>Palaemonetes</i>	115	<i>Pericoma</i>	79	<i>Laccophilus</i>	46	<i>Caenis</i>
30	<i>Mysis</i>	120	<i>Simulium</i>	80	<i>Agabus</i>	52	<i>Leuctra</i>
32	<i>Corophium</i>	121	<i>Pentaneurella</i>	83	<i>Hydrophilus</i>	61	<i>Anax</i>
37	<i>Cloeon</i>	122	<i>Brilla</i>	84	<i>Dryops</i>	62	<i>Sympetrum</i>
38	<i>Oligoneuriella</i>	123	<i>Eukiefferiella</i>	85	<i>Elmidae</i>	64	<i>Onychogomphus</i>
47	<i>Haprophlebia</i>	126	<i>Chironomus</i>	86	<i>Elmis</i>	67	<i>Libellula</i>
48	<i>Ephemera</i>	127	<i>Polypedilum</i>	91	<i>Limnius</i>	68	<i>Corixa</i>
57	<i>Platycnemis</i>			94	<i>Helodes</i>	71	<i>Notonecta</i>
58	<i>Coenagrion</i>			95	<i>Rhyacophila</i>	87	<i>Hydroporus</i>
60	<i>Aeshna</i>			96	<i>Agapetus</i>	88	<i>Ilybius</i>
63	<i>Gomphus</i>			97	<i>Hydroptilidae</i>	89	<i>Hydrochus</i>
65	<i>Ophiogomphus</i>			99	<i>Hydroptila</i>	90	<i>Dupophilus</i>
66	<i>Orthetrum</i>			100	<i>Polycentropus</i>	105	<i>Hydropsyche</i>
69	<i>Aphelocheirus</i>			101	<i>Psychomyia</i>	107	<i>Oligoplectrum</i>
75	<i>Peltodytes</i>			103	<i>Limnephilidae</i>	114	<i>Tipula</i>
77	<i>Haliphus</i>			104	<i>Diplectrona</i>	124	<i>Psectrocladius</i>
81	<i>Dytiscidae</i>			106	<i>Cheumatopsyche</i>	125	<i>Orthocladinae</i>
82	<i>Hydrobius</i>			108	<i>Tinodes</i>	129	<i>Paratanytarsus</i>
93	<i>Curculionidae</i>			109	<i>Lepidostoma</i>	130	<i>Stratiomys</i>
98	<i>Oxyethira</i>			110	<i>Leptocerus</i>	131	<i>Odontomyia</i>
102	<i>Ecnomus</i>			111	<i>Sericostoma</i>	138	<i>Tabanus</i>
117	<i>Psychoda</i>			113	<i>Liponeura</i>	139	<i>Atherix</i>
119	<i>Dixa</i>			116	<i>Pedicia</i>		
128	<i>Chirominae</i>			118	<i>Dicranota</i>		
132	<i>Culicoides</i>			133	<i>Chelifera</i>		
135	<i>Tabanidae</i>			134	<i>Empididae</i>		
				136	<i>Chrysops</i>		
				137	<i>Haematopota</i>		

The influence of six environmental variables on the distribution of 139 genera of benthic macroinvertebrate in running water ecosystems were assessed using CCA (Figure 2, Table 2). Interpretation of ordination diagrams more easy after four quadrants indicated distance between arrows of the environmental variables and the species points are important. If one species found near the arrow of environmental variables, optimum value with respect to this environmental variable at higher values.

The summary of CCA output is given in Table 3. The table 3 indicates all variables explain 18.6 % of the total variability in the species data. The total inertia is the total variance in the species data as measured by the chi-square of the sample-by-species table divided by the table's total. Percentage of explaining of total variability in the species data calculated from the sum of all canonical eigenvalue ($100 \times 0.855 / 4.586$). In this analysis total variance is 4.586 and Monte Carlo permutation test for all model cofirmed environmental variables is significant ($P < 0.005$). After performing partial CCA and Monte Carlo permutation tests, order of significant of environmental variables was found like that; $\text{NH}_4\text{-N}$, $\text{PO}_4\text{-P}$, temperature, DO, pH, $\text{NO}_2\text{-N}$ ($P < 0.005$).

Table 3. Summary of CCA output

Axes	1	2	3	4	Total inertia
Eigenvalues	0.325	0.173	0.126	0.091	4,586
Species environment correlations	0.916	0.834	0.854	0.854	
Cumulative percentage variance of species data	7.1	10.9	13.6	15.6	
Cumulative percentage variance of species-environment relation	38	58.3	73.1	83.7	
Sum of all eigenvalues	60				4,586
Sum of all canonical eigenvalues					0.855

The genera were placed in quadrant A positively correlated with temperature (Figure 2). While Plecoptera (Hynes 1970) prefer cool waters, Odonata prefer warmer waters (Corbet 1980). The genera of Plecoptera were not placed in quadrant A, but Odonata were represented by 6 genera. According to Chandler (1966) *Dugesia* spp. is warm stenotherm and it was found to be placed close to the temperature in this study.

The representatives of Quadrant A (Table 2) prefer oligosaprobic, β mesosaprobic and α mesosaprobic environments (Rosenberg and Resh 1993). While *Erpobdella* is an indicator for β mesosaprobic- α mesosaprobic environments, *Psychoda* is an indicator for α mesosaprobic environments.

The genera and species placed in quadrant B were positively correlated with nitrite, ammonium and orthophosphate but negatively with pH and dissolved oxygen (Figure 2). Quadrant B includes *Physa* spp. (β mesosaprobic/ α mesosaprobic), *Tubifex tubifex* (α mesosaprobic-polysaprobic), *Chironomus thummi* (α mesosaprobic-polysaprobic), *Glossiphonia* spp. β mesosaprobic- α mesosaprobic), *Potamanthus* spp. (β mesosaprobic/ α mesosaprobic) which are tolerant of organic pollution and they prefer β mesosaprobic, α mesosaprobic, and polysaprobic environments (Rosenberg and Resh 1993). *Tubifex tubifex* is an indicator species for α mesosaprobic and polysaprobic environments (Van der Hoek and Verdonshot 1994, Hörner et al. 1995, CSN 1998, Sporka 2003). The saprobic levels of the genera *Mesovelgia*, *Acentropus*, *Pericoma* and *Pentaneurella* are not clear but they were placed close to the arrows representing nitrite and orthophosphate in this study. Saprobic level of *Pentaneurella* and *Acentropus* are unknown. *Mesovelgia* has two species and *Pericoma* has fifteen species but their saprobic levels are also unknown.

The genera placed in quadrant C were associated with pH and dissolved oxygen and negatively correlated with nitrite, orthophosphate and ammonium. The representatives of Quadrant C like the genera *Rhithrogena*, *Protonemura*, *Chloroperla*, *Elmis*, *Agapetus*, *Liponeura* prefer oligosaprobic environments (Rosenberg and Resh 1993). Other genera of Quadrant C are in oligosaprobic and in β mesosaprobic level except *Gyrinus* (β mesosaprobic- α mesosaprobic), *Laccophilus* (β mesosaprobic/ α mesosaprobic) and *Agabus* (oligosaprobic- α mesosaprobic/ polysaprobic). Ephemeroptera genus *Iron* prefers oligosaprobic environments (Kazancı 2001) and it was closely related to dissolved oxygen and pH in this study. In general, the genera shown to be placed in Quadrant C and related to the dissolved oxygen such as certain stoneflies, mayflies and caddisflies are indicators of good water quality (eg. Hawkes 1963, Hynes 1970). In this study, stonefly genera except *Leuctra* and many of the caddisfly genera were representatives of Quadrant C. The genera in Quadrant D reflect the influence of factors other than these 6 variables. But some of the genera placed in Quadrant D seemed to be associate with nitrite, ammonium, orthophosphate and appeared to be tolerant of organic pollution, including *Pisidium* (oligosaprobic- α mesosaprobic), *Hydroporus* (oligosaprobic- α mesosaprobic), *Galba* (β mesosaprobic), *Helobdella* (β mesosaprobic/ α mesosaprobic), *Ilybius* (α mesosaprobic), *Ephemerella* (β mesosaprobic), *Atherix* (oligosaprobic- β mesosaprobic), *Corixa* (β mesosaprobic), *Stratiomys* (α mesosaprobic), *Odontomyia* (β mesosaprobic).

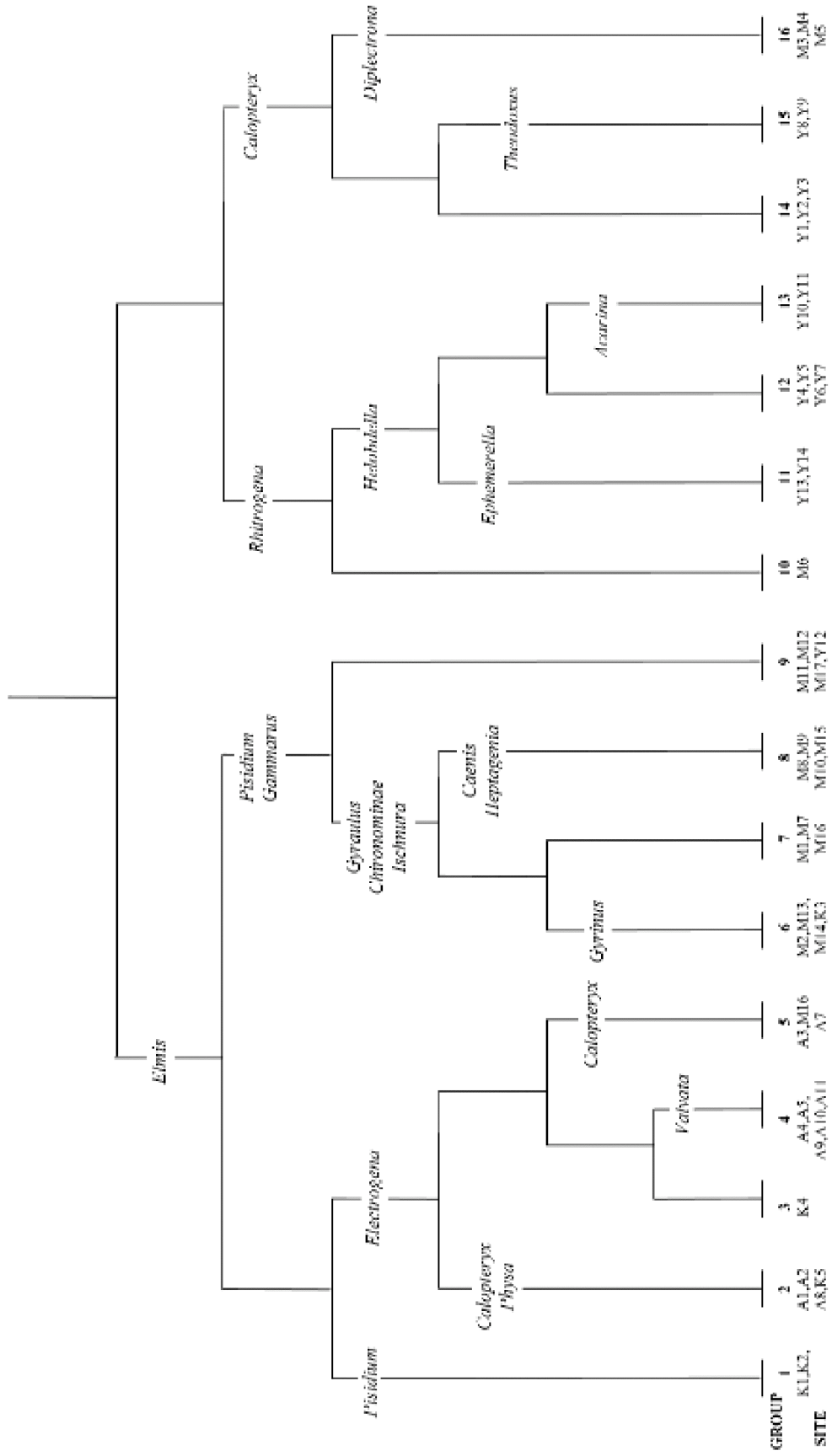


Figure 3. TWINSpan with CCA sites.

Some genera in Quadrant D such as *Leuctra* (oligosaprobic/ β mesosaprobic), *Onychogomphus* (oligosaprobic/ β mesosaprobic) were related to pH and to dissolved oxygen and appeared to be intolerant to organic pollution or tolerant to slight organic pollution. The saprobic level of *Succinea*, *Dupophilus* are not clear. In this study, these genera, *Succinea* and *Dupophilus* were related to phosphate and appeared to be tolerant of organic pollution. Mason (1983) considered molluscs generally tolerant to organic pollution.

In this study, six genera of molluscs were positively correlated with temperature in Quadrant A, one of two genera (*Physa*) with nitrite in Quadrant B, one of four genera (Lymnaeidae gen. sp.) with pH and dissolved oxygen in Quadrant C, three genera with phosphate in Quadrant D and only *Ancylus fluviatilis* with pH and DO in Quadrant D. But *Ancylus fluviatilis* prefers oligosaprobic- β mesosaprobic environments (Rosenberg and Resh 1993).

TWINSPAN Grouping

Twinspan groups are given in Figure 3. *Elmis* was indicator for the TWINSPAN Groups 1-9. According to Jach et al. (1995), *Elmis* species are indicators for oligosaprobic and β mesosaprobic environments. *Pisidium* was an indicator for the TWINSPAN Group 1, slightly and moderately polluted sites (Figure 3). According to Rosenberg and Resh (1993), this genus is tolerant of slight, moderate or heavy organic pollution (oligosaprobic- α mesosaprobic). In addition, according to CSN (1998), *Pisidium* is an indicator for oligosaprobic and β mesosaprobic environments. Group 1 stations (K1, K2) were organically polluted (Figure 1a).

Electrogena, *Calopteryx* and *Physa* were indicators for the TWINSPAN Group 2, moderately and heavily polluted sites. According to Rosenberg and Resh (1993), *Calopteryx* and *Physa* are tolerant moderate or heavy organic pollution (β mesosaprobic- α mesosaprobic). While *Physa* species are indicators for oligosaprobic and β mesosaprobic environments according to Nesemann and Reischütz (1995), CSN (1998), Sporka (2003), DEV (2003), it is indicator for oligo, β and α mesosaprobic environments according to Verdonschot (1990), Van der Hoek and Verdonschot (1994). *Calopteryx* species are indicators for oligosaprobic, β and α mesosaprobic environments (Janecek et al 1995, CSN 1998, DEV 2003, Sporka 2003). *Electrogena* species are indicators for oligosaprobic and β mesosaprobic environments (Bauernfeind et al 1995). In this study, this species was tolerant of organic pollution.

Electrogena was an indicator for the TWINSPAN Group 3-heavily polluted site, K4. Water quality variables of station K4 are given in Figure 1a.

TWINSPAN Group 4- moderately and heavily polluted sites (A4, A5, A9, A10, A11) (Figure 1a) and *Valvata* was an indicator. Genus *Valvata* (β mesosaprobic) is tolerant of moderate organic pollution (Rosenberg and Resh 1993). *Valvata* species are indicators for oligosaprobic, β and α mesosaprobic environments (Nesemann et al. 1995). According to results of this study, *Valvata* was also tolerant of heavy organic pollution. *Calopteryx* was an indicator for the TWINSPAN Group 5-moderately polluted sites (A3, A6, A7 (Figure 1a). *Calopteryx* (β mesosaprobic) is tolerant of moderate organic pollution (Rosenberg and Resh 1993).

Pisidium and *Gammarus* were indicators for the TWINSPAN Groups 6-9. *Gyraulus*, *Chironominae* and *Ischnura* were indicators for the TWINSPAN Groups 6-8. While *Pisidium* is an indicator for oligosaprobic and β mesosaprobic environments, *Gammarus* is an indicator for oligosaprobic, β and α mesosaprobic environments (Verdonschot 1990, Van der Hoek and Verdonschot 1994, Eder et al 1995, CSN 1998). *Gyrinus* was an indicator for the TWINSPAN Group 6- moderately polluted sites, M2, M13, M14, K3 (Figure 1a). According to Rosenberg and Resh (1993), *Gyrinus* is tolerant moderate and heavy organic pollution (β mesosaprobic- α mesosaprobic). *Gyrinus* is an indicator for oligosaprobic, β and α mesosaprobic environments (Verdonschot 1990, Van der Hoek and Verdonschot 1994, Jäch et al 1995, Sporcka 2003).

Gyraulus, *Chironominae* and *Ischnura* were indicators for the TWINSPAN Group 7, moderately and heavily polluted sites M1, M7, M16 (Figure 1a). *Gyraulus* and *Ischnura* (β mesosaprobic) were tolerant of moderate organic pollution (Rosenberg and Resh 1993). *Gyraulus* and *Ischnura* species are indicators for oligosaprobic, β and α mesosaprobic environments (Verdonschot 1990, Van der Hoek and Verdonschot 1994, Nesemann and Reischütz 1995, CSN 1998, Sporcka 2003). According to results of this study, *Gyraulus* and *Ischnura* were also tolerant of heavy organic pollution.

Caenis and *Heptagenia* were indicators for the TWINSPAN Group 8- heavily polluted sites M8, M9, M10, M15 (Figure 1a). These genera are tolerant (β mesosaprobic- α mesosaprobic) of moderate and heavy organic pollution (Rosenberg and Resh 1993). While *Caenis* is an indicator for oligosaprobic, β and α mesosaprobic environments, *Heptagenia* is an indicator for β and α mesosaprobic environments (Bauernfeind et al 1995).

Pisidium and *Gammarus* were indicators for the TWINSPAN Group 9-slightly polluted sites M11, M12, M17, Y12 (Figure 1a). While *Gammarus* is an indicator for slight and moderate organic pollution (oligosaprobic- β mesosaprobic), *Pisidium* is an indicator (oligosaprobic- α mesosaprobic) for slight, moderate and heavy organic pollution (Rosenberg and Resh 1993).

While *Rhithrogena* was an indicator for the TWINSPAN Groups 10-13, *Helobdella* was an indicator for the TWINSPAN Groups 11-13. *Rhithrogena* is an indicator for xeno-, oligo- and β mesosaprobic environments (Bauernfeind et al 1995). *Ephemerella* was a specific indicator for the TWINSPAN Group 11 (Y13, Y14) moderately polluted sites (Figure 1a). Species of *Ephemerella* are indicators for slight and moderate organic pollution (oligosaprobic- β mesosaprobic) (Rosenberg and Resh 1993). In addition according to Bauerfeind et al (1995), *Ephemerella* species are indicators of oligosaprobic- β mesosaprobic environments.

Helobdella was an indicator for TWINSPAN Group 12 (moderately polluted sites Y4, Y6 and polluted sites Y5, Y7). *Helobdella* is an indicator of (β mesosaprobic and α mesosaprobic) moderate and heavy organic pollution (Rosenberg and Resh 1993). TWINSPAN Group 13 with indicator *Acarina* (saprobic level of *Acarina* is not clear and related to temperature in Quadrant A) for slightly polluted site Y10 and polluted site Y11.

Calopteryx was an indicator for the TWINSPAN Groups 14-16. According to Rosenberg and Resh (1993), species of this genus are indicators for slight and moderate organic pollution. TWINSPAN Group 14 (unpolluted sites Y1, Y2 and moderately polluted site Y3) is without specific indicator. TWINSPAN Group 15 with indicator *Theodoxus* (β mesosaprobic, in Quadrant C and related to temperature and pH) is for moderately polluted sites Y8 and Y9 (Figure 1a). TWINSPAN Group 16 with indicator *Diplectrona* is for unpolluted sites M3, M5 and slightly polluted site M4. The saprobic level of *Diplectrona* is unknown. In this study, *Diplectrona* was related to dissolved oxygen and pH in Quadrant C.

CONCLUSION

The results of this study determined the benthic macroinvertebrate assemblages for the assessment of water quality in polluted and unpolluted sites in Western Turkey. It is apparent that the strong relationships existed between the environmental conditions of the sites and their benthic macroinvertebrate assemblages. Further studies are necessary to combine the results obtained from different geographical regions and compare various sites with various water quality states based on benthic macroinvertebrate assemblages for different ecoregions in Turkey. The structures of benthic macroinvertebrate assemblages in the similar type of habitats in different regions are much more similar than the different habitats in the same region. It is necessary to combine the experiences obtained from various physical, geographical regions and compare the various water quality states based on benthic macroinvertebrates for different running waters and ecoregions.

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