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# Seasonal Variations in Water Quality and Benthic Macroinvertebrate Community Structure in Akçay Stream of Aydın, Türkiye

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**Research Article**

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## Abstract

This study was conducted to ecologically evaluate the seasonal variation in water quality and benthic macroinvertebrate community structure in Akçay Stream, an important tributary of the Büyük Menderes River. Sampling was carried out at eight stations along the stream during four seasonal periods throughout 2023. Physicochemical water quality parameters were measured both *in situ* and in the laboratory and evaluated using the Oregon Water Quality Index (OWQI). Benthic macroinvertebrates, consisting of aquatic insects, were collected using an Ekman-Birge grab, passed through a 500 µm mesh sieve, and identified at the family level under a stereomicroscope. OWQI results indicated that water quality remained at the "good" level during all sampling periods. A total of 14 families belonging to the orders Trichoptera, Diptera, Ephemeroptera, Coleoptera, and Odonata were recorded. The most dominant families were Heptageniidae (72 individuals), Ephydridae (69 individuals), Gomphidae (57 individuals), and Chironomidae (54 individuals), whereas Philopotamidae (14 individuals) and Glossosomatidae (13 individuals) were represented at low abundance. The highest number of individuals was observed in spring (214 individuals) and the lowest in winter (97 individuals). Biological assessment based on benthic macroinvertebrates using the Biological Monitoring Working Party (BMWP) and Average Score Per Taxon (ASPT) indices indicated that the study area generally ranged between moderate and good biological quality classes. Overall, the results show that Akçay Stream maintains generally good ecological conditions, and that the combined use of biological indices (BMWP, ASPT) and physicochemical indices such as OWQI provides a reliable approach for the integrated assessment of river ecosystems.

**Keywords:** *Biomonitoring, OWQI, BMWP, ASPT, macrozoobenthic communities, Akçay Stream.*



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## Introduction

Macrozoobenthic invertebrates are considered one of the most important biological indicator groups reflecting the ecological status of stream ecosystems due to their rapid and measurable responses to environmental pressures (Metcalfe, 1989; Dahl et al., 2004; Varnosfaderany et al., 2010). Among these, aquatic insects play a key role in freshwater ecosystems, serving as a major food source for nekton and helping break down organic matter (Bouchard, 2004). Because of this, they are often used as biological indicators to survey ecosystem stability and water quality (El Husseiny et al., 2015). Many aquatic insects cannot tolerate different kinds of stress, so when pollution increases, it is common to see reduced diversity (Zequi et al., 2019).

Research comparing various macroinvertebrate indices shows that simply counting species, especially sensitive ones, is often the best way to assess water body degradation (Couceiro et al., 2012; Edegbene et al., 2019). Changes in community structure, taxonomic richness, and dominance patterns of these organisms can reveal the effects of organic load, habitat degradation, flow-regime changes, and other environmental stressors (Vitecek et al., 2021). Therefore, the assessment of benthic macroinvertebrate communities has become a fundamental component of biological monitoring studies in stream systems and is widely used in ecological quality classifications (Poikane et al., 2016; Tubic et al., 2024).

In recent years, the assessment of ecological health in aquatic ecosystems has increasingly moved beyond the mere measurement of physical and chemical parameters. Instead, integrative index-based approaches that combine these variables to provide a holistic representation of water quality have become widely adopted. Within this framework, several methods have been developed to synthesize diverse physicochemical variables into a single index value, thereby enabling an overall evaluation of water quality status. A prominent example is the Oregon Water Quality Index (OWQI), which consolidates eight key water quality parameters into a single score and is widely used in monitoring and managing water resources (Cude, 2001). Nevertheless, it has been emphasized that assessments relying solely on physicochemical measurements may not fully capture the actual condition of ecosystems, underscoring the necessity of incorporating biological monitoring approaches into water quality studies (Bonada et al., 2006; Poikane et al., 2016).

Biological monitoring approaches evaluate ecosystem health by assessing aquatic organisms’ responses to environmental changes, thereby providing more reliable insights. In this context, benthic macroinvertebrate communities are widely recognized as one of the most effective biological indicator groups, owing to their extended life cycles in aquatic environments and sensitivity to environmental stressors (Ochieng et al., 2019; Tampo et al., 2021). Among the indices developed on the basis of benthic macroinvertebrates, the Biological Monitoring Working Party (BMWP) index and its derivative, the Average Score Per Taxon (ASPT), are widely used and reliable tools for biological assessment of water quality. The ASPT value reflects the average sensitivity of the taxa present in a sample, and when used in conjunction with BMWP, enhances the accuracy of biological quality evaluations (Payakka and Prommi, 2014; Zeybek et al., 2014; Ochieng et al., 2020; Yorulmaz et al., 2024).

The combined application of physicochemical and biological indices allows for a more comprehensive, comparable, and reliable assessment of the ecological status of river ecosystems (Bonada et al., 2006; Poikane et al., 2016). Therefore, this study aimed to investigate the seasonal physicochemical water quality parameters and the structure of the macrozoobenthic fauna formed by aquatic insects in Akçay Stream (Aydın, Türkiye), one of the major tributaries of the Büyük Menderes River. The findings are intended to contribute to monitoring studies on the ecological status of water resources and to provide usable data for regional water management strategies.

## Material and Methods

### *Study area*

This study took place in the Akçay Stream, located in the Bozdoğan district of Aydın province, an important tributary of the Büyük Menderes River. The stream shows varying hydromorphological features along its course from the Kemer Dam outlet to the Bozdoğan Plain. Sampling stations were chosen in spots with high dissolved oxygen levels and clear flow patterns, spaced about 350 meters apart along the streambed (Figure 1).

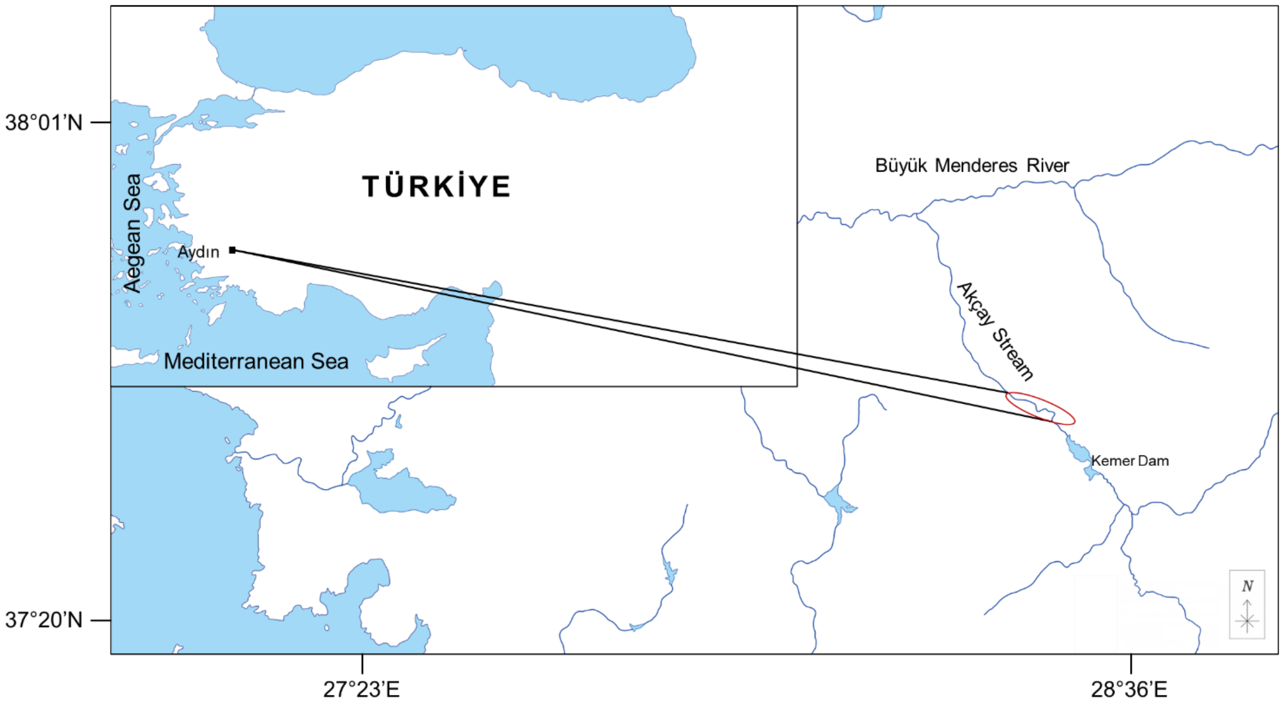


Figure 1. Sampling area on Akçay Stream (Aydın, Türkiye).

### *Sampling design*

Between January and October 2023, water quality tests and macrozoobenthic fauna studies were carried out across all four seasons. During each sampling period, biotic and abiotic data were collected from eight different stations, with the coordinates of these locations listed in Table 1. Sampling, preservation, and transportation procedures were carried out in accordance with the Standard Methods for the Examination of Water and Wastewater (APHA, 2017) procedures.

Table 1. Geographical coordinates of sampling sites along the Akçay Stream.

| Sampling sites | Latitude (°N) | Longitude (°E) |
|---|---|---|
| Site 1 | 37.3519 | 28.3019 |
| Site 2 | 37.3525 | 28.3070 |
| Site 3 | 37.3530 | 28.2953 |
| Site 4 | 37.3543 | 28.2956 |
| Site 5 | 37.3546 | 28.3070 |
| Site 6 | 37.3546 | 28.3025 |
| Site 7 | 37.3553 | 28.3033 |
| Site 8 | 37.3650 | 28.3027 |

***Physicochemical water quality analyses***

Specific physicochemical parameters were measured in situ at each sampling station during fieldwork. This included water temperature (°C), pH, dissolved oxygen (mg/L), oxygen saturation (%), and electrical conductivity (µS/cm), all recorded in real-time at the field using portable multiparameter water quality measuring devices. Additionally, water samples were collected from each station for laboratory analysis. The collected water samples were analyzed for total Kjeldahl nitrogen (TKN; SM 4500-Norg B), total phosphorus (SM 4500-P B), biochemical oxygen demand – BOD (SM 5210 B), suspended solids (SM 2540 D), and coliform bacteria (SM 9222). All analyses were performed according to the Standard Methods for the Examination of Water and Wastewater procedures (APHA, 2017). Appropriate preservative chemicals (e.g., $H_2SO_4$) were used during sampling and transportation to protect the chemical and biological properties of the samples, and the samples were stored under appropriate conditions until analysis was performed.

***Oregon Water Quality Index (OWQI)***

All physical and chemical parameters were assessed using the Oregon Water Quality Index (OWQI) protocol (Cude, 2001). This index is calculated as a weighted average of sub-indices derived from logarithmic transformations of pH, temperature, $DO_2$, conductivity, suspended solids, $BOD_5$, total nitrogen, phosphorus, and coliform bacteria. The Oregon index was calculated using the following formula:

$$OWQI = \sqrt{\frac{n}{\sum_{i=1}^{n} \frac{1}{SI_i^2}}}$$

where $n$ represents the number of parameters and $SI_i$ represents the value of the parameter $i$. An OWQI score was determined for each sampling period to track changes over time. The results were then classified according to literature guidelines: 90-100 as “excellent,” 85-89 “very good,” 80-84 “good,” 60-79 “fair,” and below 60 as “poor” water quality.

***Sampling and taxonomic characterization of benthic macroinvertebrates***

Benthic macroinvertebrate specimens, with aquatic insects preferred as bioindicators, were collected in three replicates at each station using an Ekman-Birge grab (15 × 15 cm) and then sieved through a 500 µm mesh. Specimens were fixed in the field with a 4% formaldehyde solution, transported to the laboratory, rinsed thoroughly with water, and preserved in 70% ethyl alcohol. Taxonomic identification at the family level has been carried out using stereomicroscopes and binocular microscopes and with reference to Latreille (1804), Leach (1815), Stephens (1829), Curtis (1835), Kolenati (1848), Selys (1854), and Hatschek (1888).

***Data analysis***

Statistical analyses were carried out using IBM SPSS Statistics version 19.0 (IBM Corp., Armonk, NY, USA). The Biological Monitoring Working Party (BMWP) index was used to assess benthic macroinvertebrate communities. It works by assigning tolerance scores, as outlined in the literature, to the families found in the samples, with each family evaluated based solely on its presence. For each sample, the BMWP score was calculated by summing the tolerance scores of the families present in the sample and using the following formula:

$$BMWP = \sum_{i=1}^{n} s_i$$

where *si* represents the tolerance score of the *i*-th benthic macroinvertebrate family, and *n* represents the total number of families present in the sample.

To mitigate the effects of differences in sampling density and taxon number, the Average Score Per Taxon (ASPT) was also calculated. The ASPT value was determined according to the following formula:

$$ASPT = \frac{BMWP}{S}$$

where *S* represents the number of families identified in the sample. The BMWP and ASPT values were assessed based on classifications found in the literature. For BMWP, scores over 100 mean “very good” water quality, 71-100 is “good,” 41-70 is “medium,” 11-40 is “poor” and 0-10 is “very poor.” For ASPT, values above 6 indicate “very good,” 5-6 is “good,” 4-5 is “medium,” 3-4 is “poor,” and below 3 is “very poor.” BMWP and ASPT values were calculated separately for each station and season to evaluate the benthic macroinvertebrate community structure.

**Results and Discussion**

In this study, the seasonal macrozoobenthic fauna structure and water quality parameters of Akçay Stream were evaluated by sampling in four seasons and eight stations. Seasonal quality was monitored using the Oregon Water Quality Index (OWQI) along with physicochemical analysis, and biological monitoring was carried out on macrozoobenthic fauna.

Significant seasonal variations were observed in the physicochemical and microbiological parameters measured in the water samples. Water temperature showed the most pronounced seasonal variation, averaging 5.73°C in winter, rising to 23.43°C in summer, and then decreasing again in autumn to an average of 10.79°C. pH values ranged from 7.28 to 8.43; the highest average value was recorded in spring (8.09), and the lowest in summer (7.52). $DO_2$ concentrations ranged from 7.65 to 9.18 mg/L, with the lowest average recorded in winter and the highest in spring. $DO_2$ saturation, which ranged from 90.82% to 92.35%, was found to be relatively lower in spring compared to other seasons. Electrical conductivity averaged 363.50 µS/cm in winter, increasing to 456 and 525.87 µS/cm in spring and summer, respectively, and decreasing to 441.62 µS/cm in autumn. Suspended solids concentrations ranged from 5.18 to 6.52 mg/L, showing relatively higher values in summer. $BOD_5$ values ranged from 4.99 to 6.50 mg/L, showing limited variation between seasons. Total nitrogen concentrations reached their highest average value in spring (0.48 mg/L) and decreased to 0.25 mg/L in autumn. In contrast, phosphorus concentrations varied relatively low throughout the year (0.020-0.029 mg/L). Coliform bacteria counts showed significant seasonal variation; the lowest average value was recorded in winter (3.63 cfu/100 mL), and the highest average value was recorded in summer (27.88 cfu/100 mL). The mean and standard deviation values of the measured parameters according to seasons were given in Table 2. The one-way ANOVA results showed statistically significant seasonal differences in all parameters, except for phosphorus concentrations ($p < 0.05$).

Table 2. Mean ± standard deviation values of water quality parameters by season and one-way ANOVA results.

| Parameter | Winter | Spring | Summer | Autumn | *p*-value |
|---|---|---|---|---|---|
| pH | 7.75 ± 0.44 | 8.09 ± 0.13 | 7.52 ± 0.08 | 7.91 ± 0.17 | <0.001 |
| Temperature (°C) | 5.73 ± 0.13 | 9.87 ± 0.41 | 13.72 ± 0.42 | 10.79 ± 1.32 | <0.001 |
| $DO_2$ (mg/L) | 7.92 ± 0.08 | 8.95 ± 0.13 | 8.24 ± 0.12 | 8.07 ± 0.26 | <0.001 |
| $DO_2$ Saturation (%) | 92.08 ± 0.07 | 92.53 ± 0.16 | 92.21 ± 0.15 | 91.93 ± 0.26 | <0.001 |
| Conductivity (µS/cm) | 363.50 ± 19.68 | 456.00 ± 26.37 | 525.88 ± 19.92 | 441.62 ± 15.99 | <0.001 |
| Suspended Solids (mg/L) | 5.58 ± 0.33 | 5.47 ± 0.18 | 6.05 ± 0.22 | 5.96 ± 0.36 | 0.003 |
| $BOD_5$ (mg/L) | 5.66 ± 0.54 | 5.22 ± 0.08 | 6.17 ± 0.15 | 5.67 ± 0.22 | <0.001 |
| Total Nitrogen (mg/L) | 0.351 ± 0.010 | 0.483 ± 0.045 | 0.389 ± 0.031 | 0.246 ± 0.021 | <0.001 |
| Phosphorus (mg/L) | 0.023 ± 0.002 | 0.024 ± 0.003 | 0.025 ± 0.002 | 0.022 ± 0.001 | 0.32 |
| Coliform Bacteria (cfu/100 mL) | 3.63 ± 1.51 | 19.50 ± 6.78 | 27.88 ± 3.83 | 7.00 ± 2.62 | <0.001 |

OWQI results from four sampling periods showed that water quality at all stations was at a "good" level, suggesting that Akçay Stream maintains a fairly balanced quality in terms of basic physical and chemical parameters despite human influence. Water quality indices are useful tools for assessing the overall state of aquatic ecosystems, as they combine multiple physical and chemical parameters into a single value (Cude, 2001; Abbasi and Abbasi, 2012). In this context, the OWQI results indicated that the water quality in the study area maintained an ecologically functional system structure. Furthermore, Figure 2 highlighted seasonal changes in OWQI values, offering valuable insight for tracking water quality and assessing temporal shifts.

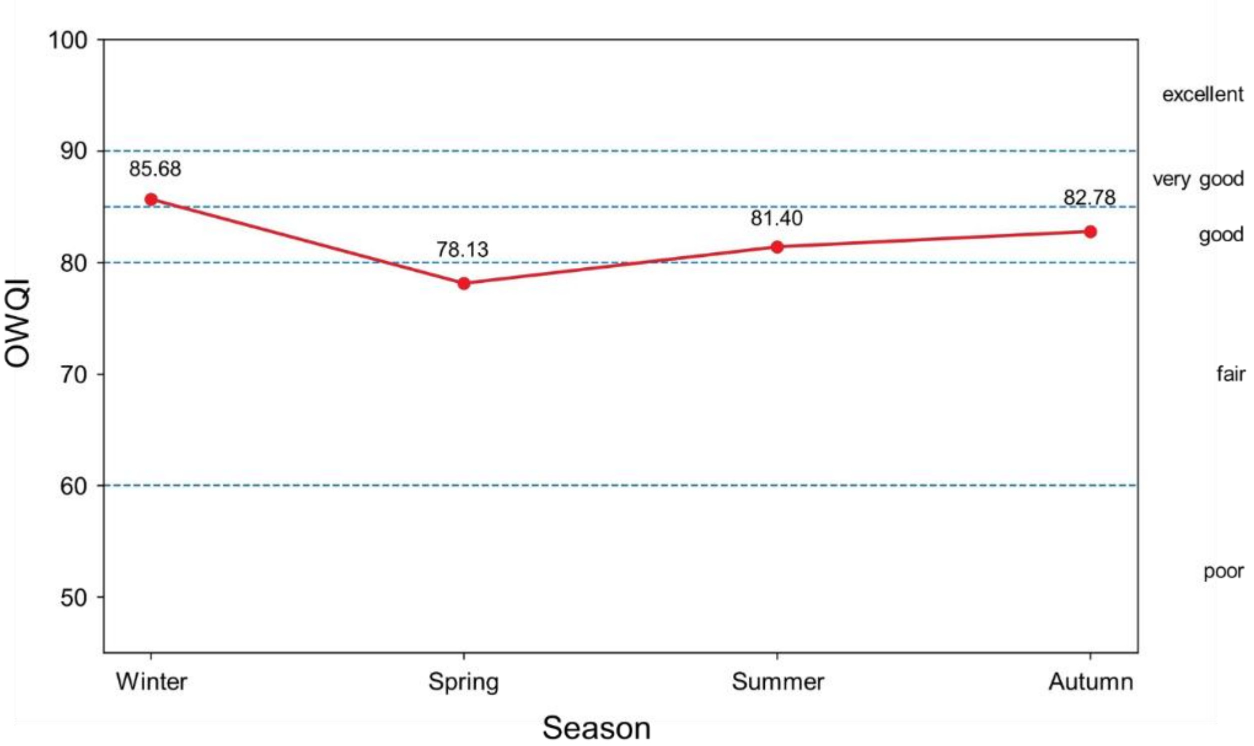


Figure 2. Seasonal variation of the Oregon Water Quality Index in the Akçay Stream.

The macrozoobenthic specimens collected during the study conducted at eight different stations in Akçay Stream were classified into 14 families under 5 orders belonging to aquatic insects: Trichoptera (4 families), Diptera (3 families), Ephemeroptera (3 families), Coleoptera (2 families), and Odonata (2 families). The highest number of individuals was recorded in the orders Ephemeroptera (161 individuals) and Diptera (158 individuals), while the lowest was in the order Coleoptera (66 individuals).

Table 3. Seasonal individual numbers and total abundance values of benthic macroinvertebrate orders belonging to aquatic insects identified in the Akçay Stream.

| Order | Winter | Spring | Summer | Autumn | Total Individuals |
|---|---|---|---|---|---|
| Ephemeroptera | 24 | 71 | 29 | 37 | 161 |
| Diptera | 27 | 61 | 43 | 27 | 158 |
| Odonata | 16 | 27 | 25 | 22 | 90 |
| Trichoptera | 17 | 35 | 20 | 17 | 89 |
| Coleoptera | 13 | 20 | 15 | 18 | 66 |
| **Seasonal Abundance** | **97** | **214** | **132** | **121** | **564** |

During the sampling periods, the highest abundance was observed in spring (214 individuals), and the lowest in winter (97 individuals) (Table 3). This situation might be linked to the fact that pleasant spring temperatures promote the growth and development of aquatic insects, while high dissolved oxygen levels create ideal habitat conditions for more sensitive species. Added organic matter and nutrients also boost resource availability for the benthic community. However, the nutrient salts, particularly nitrogen and phosphorus, on these communities depends on enrichment levels, as excessive nutrient input can cause harmful shifts in community composition (Wallace and Webster, 1996; Merritt et al., 2017).

The dominance of Ephemeroptera families, due to the high oxygen requirements of these species and their sensitivity to water quality degradation (Snyder et al., 2014; Ramulifho et al., 2020), indicates that Akçay Stream generally has a healthy ecological condition. Similarly, several studies documenting the high concentration of mayfly nymphs in the spring months have also corroborated the current study (McCafferty, 1983; Shin et al., 2011; Snyder et al., 2014; Majeed et al., 2022).

The seasonal distribution of aquatic insect families revealed remarkable differences in community structure across seasons (Figure 3). In winter, the families Ephydridae (16%) and Caenidae (13%) were most dominant. This pattern can be attributed to the fact that Ephemeroptera larvae thrive in cold, oxygen-rich stream conditions, with many species continuing their larval development during the winter months (Veras et al., 2026). Moreover, low temperatures and relatively stable flow regimes favor the persistence of certain Ephemeroptera families within benthic assemblages. In spring, Heptageniidae (16%) and Chironomidae (14%) became more prominent. Rising water temperatures, increased nutrient inputs, and high flow conditions promote the growth of Ephemeroptera larvae, while organic matter accumulation and enhanced productivity support the proliferation of Chironomidae larvae belonging to Diptera (Zivic et al., 2021). During summer, Ephydridae (14%) and Gomphidae (12%) were dominant. Elevated water temperatures, reduced flow rates, and shifts in habitat heterogeneity create favorable conditions for Odonata larvae (Pastorino et al., 2020). Additionally, increased primary production and organic matter inputs during summer enhance the abundance of Diptera and Odonata larvae (Henri, 2021). In autumn, Heptageniidae (13%) and Caenidae (11%) re-emerged as dominant families. This seasonal shift can be explained by improved developmental conditions for Ephemeroptera larvae, associated with declining water temperatures and rising dissolved oxygen concentrations (Contador et al., 2012). Furthermore, the influx of leaf litter and other allochthonous organic matter alters benthic habitats, thereby increasing the abundance of certain taxa (Aguiar et al., 2018).

Overall, these findings demonstrate that the family-level composition of benthic macroinvertebrate communities, consisting of aquatic insects, is strongly influenced by seasonal environmental variables, including water temperature, flow regime, dissolved oxygen, and organic matter inputs, with specific families exhibiting seasonal dominance (Bonada et al., 2006).

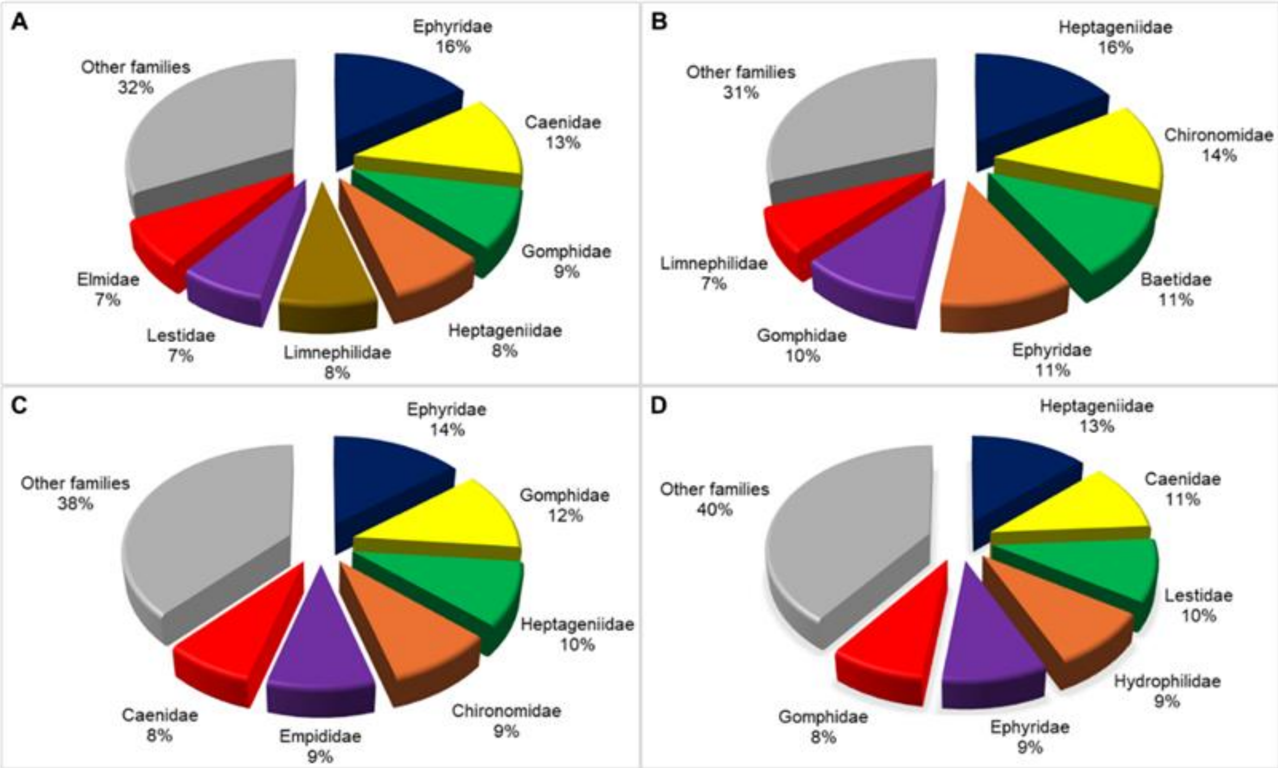


Figure 3. Percentage distribution of benthic macroinvertebrate families observed in the Akçay Stream during winter (A), spring (B), summer (C) and autumn (D) seasons.

Table 4. BMWP tolerance scores and total abundances of benthic macroinvertebrate families formed by aquatic insects recorded in the Akçay Stream.

| Order | Family | BMWP score | Total abundance |
|---|---|---|---|
| Trichoptera | Limnephilidae | 10 | 37 |
| | Philopotamidae | 10 | 14 |
| | Glossosomatidae | 10 | 13 |
| | Hydropsychidae | 5 | 25 |
| Diptera | Empididae | 4 | 35 |
| | Ephydridae | 2 | 69 |
| | Chironomidae | 2 | 54 |
| Ephemeroptera | Heptageniidae | 10 | 72 |
| | Caenidae | 7 | 47 |
| | Baetidae | 4 | 42 |
| Coleoptera | Elmidae | 10 | 29 |
| | Hydrophilidae | 3 | 37 |
| Odonata | Lestidae | 8 | 33 |
| | Gomphidae | 8 | 57 |

Of the 14 aquatic insect families observed, the highest total abundance values belonged to Heptageniidae (72 individuals), Ephydridae (69 individuals), Gomphidae (57 individuals), and Chironomidae (54 individuals), while Philopotamidae (14 individuals) and Glossosomatidae (13 individuals) were represented by relatively lower abundance values. Considering the BMWP tolerance scores, the presence of Heptageniidae, Elmidae, Glossosomatidae, Limnephilidae, and Philopotamidae families (10 points), which have high sensitivity scores, in the study area indicates that the benthic community structure reflects good ecological conditions. In contrast, the Chironomidae and Ephydridae families had low tolerance scores (2 points), while other families had medium tolerance scores (e.g., Baetidae and Empididae: 4 points; Hydropsychidae: 5 points; Caenidae: 7 points; Gomphidae and Lestidae: 8 points). This distribution showed that the macrozoobenthic communities identified in the study included taxa with different tolerance levels (Table 4).

Seasonal average BMWP values showed that the highest average value was recorded in spring (68.88), and the lowest average value in summer (54.75). In winter and autumn, the average BMWP values were calculated as 56.62 and 58.38, respectively. These results indicated that, in a biological assessment of the benthic macroinvertebrate community structure based on aquatic insects, the study area generally falls between medium and good biological quality classes (Figure 4). Similarly, ASPT values showed limited variation between seasons. The average ASPT value was calculated as 6.58 in winter, 6.34 in spring, 6.25 in summer, and 6.56 in autumn. ASPT values above 6 in all seasons revealed that benthic macroinvertebrate communities of aquatic insects generally represent “very good” biological quality (Figure 5). Considering these results together, it can be attributed to the fact that the benthic community structure in the study area, while showing limited variation between seasons, generally reflects good ecological conditions.

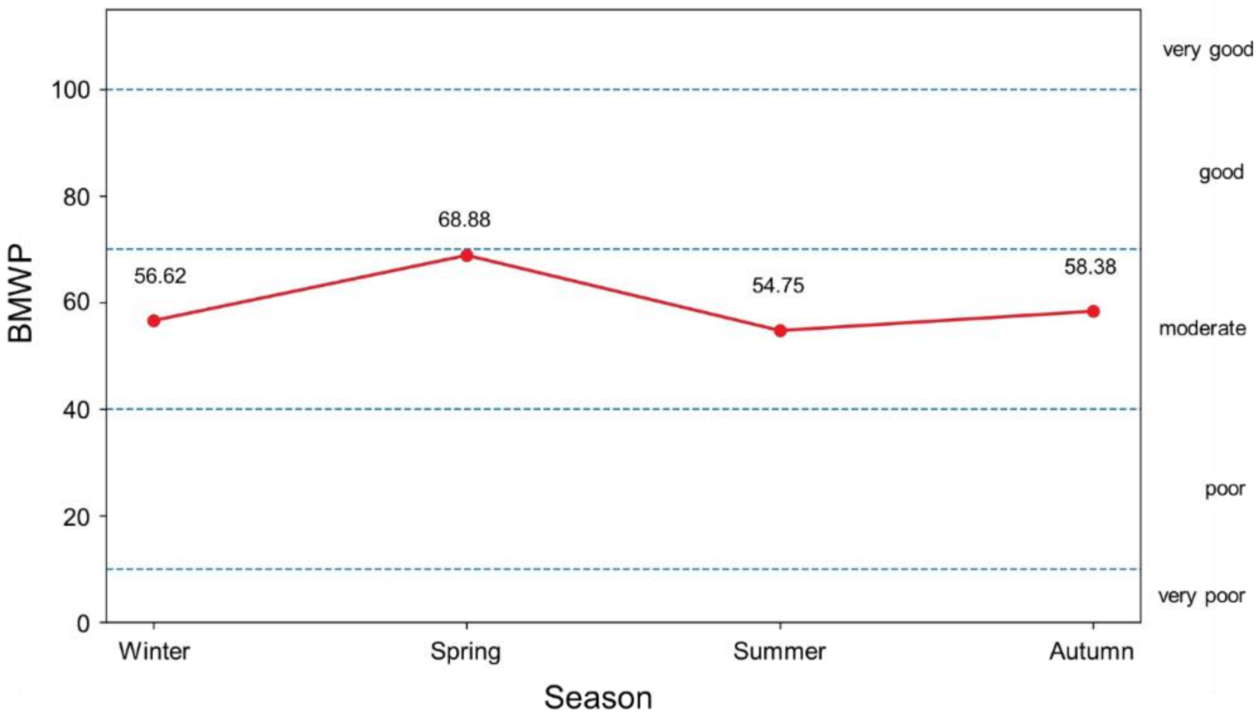


Figure 4. Seasonal variation of average BMWP values and biological water quality classes obtained from Akçay Stream during the study period.

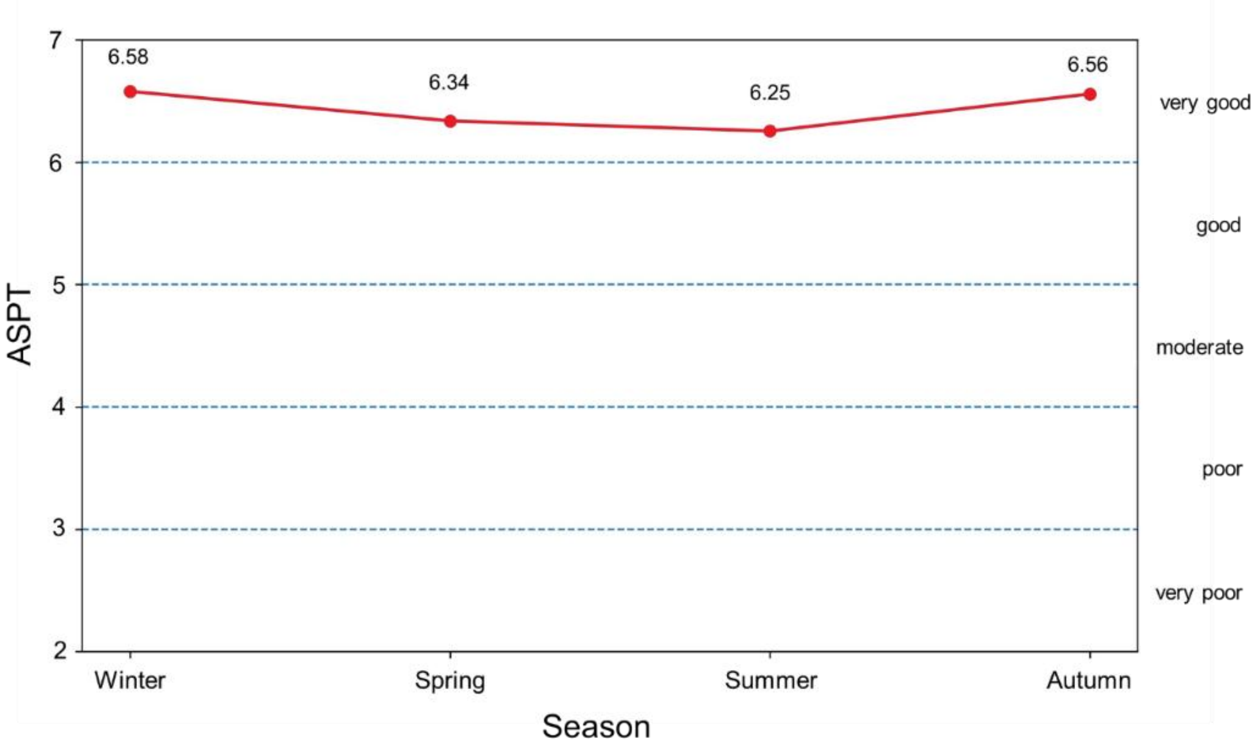


Figure 5. Seasonal variation of average ASPT values and biological water quality classes obtained from Akçay Stream during the study period.

**Conclusions**

This study assessed the physicochemical characteristics of Akçay Stream and examined the seasonal dynamics of benthic macroinvertebrate communities. OWQI results showed the water quality stayed at a "good" level during all sampling periods. The macrozoobenthic community structure, assessed through aquatic insects, has been found to change in response to seasonal environmental variables. While the number of individuals was relatively low during the winter due to low temperatures and limited nutrient cycling, increased nutrient inputs due to rainfall in the spring increased the abundance of individuals in the benthic community. Although partial decreases in dissolved oxygen levels were observed with increasing temperatures in the summer, the diversity of the benthic community remained relatively high. In the autumn, the water quality parameters and the distribution of benthic macroinvertebrates generally showed a stable structure. Throughout the study, the most dominant families within the benthic community were Heptageniidae, Ephydridae, Gomphidae, and Chironomidae, while Glossosomatidae and Philopotamidae were represented with lower abundance values. The BMWP and ASPT indices used in the biological water quality assessment showed that the study area generally falls between moderate and good biological quality classes. Overall, the findings indicate that Akçay Stream has a healthy river ecosystem in terms of macrozoobenthic community structure formed by aquatic insects used as bioindicators and basic physicochemical factors, but it is sensitive to seasonal changes. Using biological indices like BMWP and ASPT alongside physicochemical measures such as OWQI provides a solid method for assessing rivers holistically and for carrying out long-term water quality monitoring. Future research that includes longer-term data and more habitat variables could give deeper insights into how benthic macroinvertebrate communities respond to environmental shifts and support sustainable river management.

## Author Contributions

The authors performed all the experiments and drafted the main manuscript text. All authors reviewed and approved the final version of the manuscript.


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## Conflict of Interest Statement

The authors declare that for this article they have no actual, potential or perceived conflict of interest.

## Ethical Approval Statement

No ethics committee permissions are required for this study.

## Data Availability Statement

The data used in the present study are available upon request from the corresponding author.

## References


Abbasi, T., & Abbasi, S.A. (2012). Water quality indices. Elsevier.

Aguiar, A.C., Neres-Lima, V., Moulton, T.P. (2018). Relationships of shredders, leaf processing and organic matter along a canopy cover gradient in tropical streams. Journal of Limnology, 77(1), 109-120, doi: 10.4081/jlimnol.2017.1684

APHA (2017). Standard methods for the examination of water and wastewater (23rd ed.). American Public Health Association.

Bonada, N., Prat, N., Resh, V.H., Statzner, B. (2006). Developments in aquatic insect biomonitoring: a comparative analysis of recent approaches. Annual Review of Entomology, 51(1), 495-523, doi: 10.1146/annurev.ento.51.110104.151124

Bouchard, R.W. (2004). Guide to aquatic invertebrates of the Upper Midwest: identification manual for students, citizen monitors, and aquatic resource professionals. University of Minnesota.

Contador, T. A., Kennedy, J.H., Rozzi, R. (2012). The conservation status of southern South American aquatic insects in the literature. Biodiversity and Conservation, 21(8), 2095-2107, doi: 10.1007/s10531-012-0299-x

Couceiro, S.R., Hamada, N., Forsberg, B.R., Pimentel, T.P., Luz, S.L.B. (2012). A macroinvertebrate multimetric index to evaluate the biological condition of streams in the Central Amazon region of Brazil. Ecological Indicators, 18, 118-125, doi: 10.1016/j.ecolind.2011.11.001

Cude, C.G. (2001). Oregon water quality index: A tool for evaluating water quality management effectiveness. Journal of the American Water Resources Association, 37(1), 125-137. doi:10.1111/j.1752-1688.2001.tb05480.x

Curtis, J. (1835). British entomology: Being illustrations and descriptions of the genera of insects found in Great Britain and Ireland. Harvard University.

Dahl, J., Johnson, R.K., Sandin, L. (2004). Detection of organic pollution of streams in southern Sweden using benthic macroinvertebrates. Hydrobiologia, 516(1), 161-172, doi: 10.1023/B:HYDR.0000025264.35531.cb

Edegbene, A.O., Elakhame, L.A., Arimoro, F.O., Osimen, E.C., Odume, O.N. (2019). Development of macroinvertebrate multimetric index for ecological evaluation of a river in North Central Nigeria. Environmental Monitoring and Assessment, 191(5), 274, doi: 10.1007/s10661-019-7438-8

El Husseiny, I.M., Mona, M.H., Seif, A.I., Yassin, M.T. (2015). Aquatic insects as bio indicators for pollution in some Egyptian streams. Sci-Afric Journal of Scientific Issues, Research and Essays, 3(2), 607-615.

Hatschek, B. (1888). Lehrbuch der Zoologie: Eine morphologische Übersicht des Thierreiches. Hansebooks.

Henri, Z. (2021). Ecological status of a newly impounded sub-saharan reservoir based on benthic macroinvertebrates community (Burkina Faso, West Africa). Journal of Ecology and The Natural Environment, 13(1), 1-10, doi: 10.5897/JENE2020.0871

Kolenati, F. A. (1848). Genera et species Trichopterorum. Legare Street Press.

Latreille, P. A. (1804). Histoire naturelle générale et particulière, des crustacés et des insectes (Vol. 7). Nabu Press.

Leach, W.E. (1815). Entomology. *In*: The Edinburgh Encyclopedia (Vol. 9). William Blackburn, Scotland, 57-172.

Majeed, L.R., Rashid, S., Nisar, B. (2022). Response of freshwater macroinvertebrate communities to various anthropogenic stressors in lolab streams-a lotic system of the Indian Himalayan Region. International Journal of Environment and Climate Change, 12(11), 1895-1905, doi: 10.9734/IJECC/2022/v12i1131177

McCafferty, W.P. (1983). Mayflies. *In*: Aquatic Entomology: The Fishermen's and Ecologists' Illustrated Guide to Insects and Their Relatives. Jones & Bartlett Learning, USA, 91-123.

Merritt, R.W., Cummins, K.W., Berg, M.B. (2017). Trophic relationships of macroinvertebrates. In: Methods in Stream Ecology (Vol. 1). Academic Press, USA, 413-433.

Ochieng, H., Odong, R., Okot-Okumu, J. (2020). Comparison of temperate and tropical versions of Biological Monitoring Working Party (BMWP) index for assessing water quality of River Aturukuku in Eastern Uganda. Global Ecology and Conservation, 23, e01183, doi: 10.1016/j.gecco.2020.e01183

Ochieng, H., Okot-Okumu, J., Odong, R. (2019). Taxonomic challenges associated with identification guides of benthic macroinvertebrates for biomonitoring freshwater bodies in East Africa: A review. African Journal of Aquatic Science, 44(2), 113-126, doi: 10.2989/16085914.2019.1612319

Pastorino, P., Zaccaroni, A., Doretto, A., Falasco, E., Silvi, M., Dondo, A., Elia, A.C., Prearo, M., Bona, F. (2020). Functional feeding groups of aquatic insects influence trace element accumulation: findings for filterers, scrapers and predators from the Po basin. Biology, 9(9), 288, doi: 10.3390/biology9090288

Payakka, A., Prommi, T.O. (2014). The use of BMWP and ASPT biotic score as biological monitoring of streams in northern Thailand. Journal of Applied Sciences in Environmental Sanitation, 9(1), 7-16.

Poikane, S., Johnson, R.K., Sandin, L., Schartau, A.K., Solimini, A.G., Urbanic, G., Arbaciauskas, K., Aroviita, J., Gabriels, W., Miler, O., Pusch, M.T., Timm, H., Böhmer, J. (2016). Benthic macroinvertebrates in lake ecological assessment: A review of methods, intercalibration and practical recommendations. Science of the Total Environment, 543, 123-134, doi: 10.1016/j.scitotenv.2015.11.021

Poonam, T., Bhattacharya, T., Chakraborty, S. (2015). Water quality indices—Important tools for water quality assessment: A review. International Journal of Advances in Chemistry, 1(1), 15-29.

Ramulifho, P.A., Foord, S.H., Rivers-Moore, N.A. (2020). The role of hydro-environmental factors in Mayfly (Ephemeroptera, Insecta) community structure: Identifying threshold responses. Ecology and Evolution, 10(14), 6919-6928, doi: 10.1002/ece3.6333

Selys, L. E. de. (1854). Synopsis des Gomphines. *In*: Bulletin de l'Académie Royale des Sciences de Belgique. Bruxelles, Belgium, 23-112.

Shin, I.K., Yi, H.B., Bae, Y.J. (2011). Colonization and community changes in benthic macroinvertebrates in Cheonggye Stream, a restored downtown stream in Seoul, Korea. Journal of Ecology and Environment, 34(2), 175-191, doi: 10.5141/JEFB.2011.020

Snyder, C.D., Hitt, N.P., Smith, D.R., Daily, J.P. (2014). Evaluating bioassessment designs and decision thresholds using simulation techniques. *In*: Application of Threshold Concepts in Natural Resource Decision Making. Springer, USA, 157-197.

Stephens, J.F. (1829). The nomenclature of British insects: A compendious list of species as in the Systematic Catalogue of British Insects. Baldwin & Cradock.

Tampo, L., Kabore, I., Alhassan, E.H., Oueda, A., Bawa, L.M., Djaneye-Boundjou, G. (2021). Benthic macroinvertebrates as ecological indicators: their sensitivity to the water quality and human disturbances in a tropical river. Frontiers in Water, 3, 662765, doi: 10.3389/frwa.2021.662765

Tubic, B., Andjus, S., Zoric, K., Vasiljevic, B., Jovicic, K., Canak Atlagic, J., Paunovic, M. (2024). Aquatic insects (Ephemeroptera, Plecoptera and Trichoptera) metric as an important tool in water quality assessment in hilly and mountain streams. Water, 16(6), 849, doi: 10.3390/w16060849

Varnosfaderany, M.N., Ebrahimi, E., Mirghaffary, N., Safyanian, A. (2010). Biological assessment of the Zayandeh Rud River, Iran, using benthic macroinvertebrates. Limnologica-Ecology and Management of Inland Waters, 40(3), 226-232, doi: 10.1016/j.limno.2009.10.002

Veras, D.S., Ferreira, M.F.R., Lustosa, G.S., Castro, E.R., de Azevedo, C.A.S., Juen, L. (2026). Ephemeroptera, Trichoptera, and Plecoptera with bioindicator potential in streams across a mosaic of land uses. Hydrobiologia, 1-13, doi: 10.1007/s10750-026-06173-4

Wallace, J.B., Webster, J.R. (1996). The role of macroinvertebrates in stream ecosystem function. Annual Review of Entomology, 41(1), 115-139, doi: 10.1146/annurev.en.41.010196.000555

Yorulmaz, B., Ertaş, A., Öztürk, S., Mamanovna, N.N., Sayim, F. (2024). Determination of water quality profile of an urban stream in Gediz River Basin (West Anatolia, Türkiye) and comparative analysis of biotic indices. Biologia, 79(6), 1817-1826, doi: 10.1007/s11756-024-01673-x

Zequi, J.A.C., Espinoza, A.A., de Almeida Paccola, J., Lopes, J. (2019). Aquatic insect communities in small stream in the south of Brazil. Environmental Monitoring and Assessment, 191(7), 408, doi: 10.1007/s10661-019-7536-7

Zeybek, M., Kalyoncu, H., Karakaş, B., Özgül, S. (2014). The use of BMWP and ASPT indices for evaluation of water quality according to macroinvertebrates in Değirmendere Stream (Isparta, Turkey). Turkish Journal of Zoology, 38(5), 603-613, doi: 10.3906/zoo-1310-9

Zivic, I., Stojanovic, K., Markovic, Z. (2021). Springs and headwater streams in Serbia: the hidden diversity and ecology of aquatic invertebrates. *In*: Small Water Bodies of the Western Balkans. Springer, Switzerland, 189-210.