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Ephemeroptera (Insecta) fauna in freshwater ecosystems of the Black Sea Region of Türkiye

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Abstract

Purpose: This study presents the Ephemeroptera fauna in various freshwater habitats in the Black Sea Region of Türkiye.
Method: A total of 35 sampling stations in the Black Sea region were surveyed between 2016 and 2019.
Findings: A total of 3077 Ephemeroptera individuals from 34 taxa (totally 10325 macrozoobenthic individuals) were identified in the sampled localities at Black Sea Region, representing 8 families and 15 genera overall. The species *Caenis macrura* was found the most dominant species in the region. Diversity indices and dominance values suggest that most stations in the region reflect β- and α-mesosaprobic conditions, indicating moderate organic pollution.
Conclusion: In this study it was recorded 7 first provincial records for Ephemeroptera in Türkiye, significantly contributing to the national mayfly fauna. These findings underscore the need for continued faunal surveys and conservation efforts in Turkish freshwater ecosystems.

Keywords: Benthic macroinvertebrate, freshwater, Ephemeroptera, diversity.

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Türkiye'nin Karadeniz Bölgesi'ndeki tatlı su ekosistemlerinde bulunan Ephemeroptera (Insecta) faunası

Özet

Amaç: Bu çalışmada, Türkiye'nin Karadeniz Bölgesindeki çeşitli tatlı su habitatlarındaki Ephemeroptera faunasının bir analizi sunulmaktadır.
Metod: 2016-2019 yılları arasında 35 örnekleme istasyonu araştırılmıştır.
Bulgular: Karadeniz Bölgesi'nde 3077 bireyden (toplam 10325 makrozoobentik birey) 34 takson tespit edilmiş olup, toplamda 8 familya ve 15 cinse ait örnek teşhis edilmiştir. *Caenis macrura*, bölgede dominant tür olarak tespit edilmiştir. Çeşitlilik indeksleri ve baskınlık değerleri, bölgede çoğu istasyonun orta düzeyde organik kirliliğe işaret eden β ve α-mesosaprobik koşulları yansıttığını göstermektedir.
Sonuç: Çalışmada, Türkiye Ephemeroptera faunası için 7 yeni il kaydı tespit edilmiş ve Türkiye için Ephemeroptera faunasına önemli katkılarda bulunulmuştur. Bu bulgular, Türkiye tatlı su ekosistemlerinde fauna araştırmalarının ve koruma çalışmalarının sürdürülmesi gerekliliğini vurgulamaktadır.

Anahtar kelimeler: Bentik makroomurgasız, tatlı su, Ephemeroptera, çeşitlilik.

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1. Introduction

Approximately 2.5% of the Earth's water constitutes fresh water, with the majority of this freshwater being located in polar regions and underground. Consequently, only about 0.3% of the Earth's freshwater resources, which are easily accessible to organisms, account for a small portion of the world's water sources [1]. This underscores the importance of accurately assessing and preserving freshwater resources on Earth.

Freshwater ecosystems, which represent only a small fraction of the Earth's total water resources, play a crucial role in sustaining biodiversity and maintaining ecological balance. Given their limited availability and increasing vulnerability to pollution and habitat degradation, monitoring the health of these systems has become essential [2]. In this context, benthic macroinvertebrates, particularly members of the order Ephemeroptera, serve as valuable biological indicators for assessing freshwater quality and detecting environmental changes over time [3].

The order Ephemeroptera is one of the most common groups living in aquatic ecosystems among benthic macroinvertebrates. The group Ephemeroptera is found in various aquatic habitats including lakes, rivers, wetlands, and streams. However, they are most common and diverse in lotic systems. Members of the Ephemeroptera order are generally indicators of the ecological quality of aquatic ecosystems because they mostly include oligosaprobic (rarely mesosaprobic) species. Therefore, they are suitable organisms to be used as bioindicators for assessing water resources in terms of environmental quality by determining short and long-term changes in water quality. Additionally, due to their inability to select a new biotope if their habitat is disturbed for any reason, they are eliminated from their environment. The completion of the nymph stage of Ephemeroptera individuals within 6 months to 3 years and their complete adaptation to aquatic environments during this stage make them recognizable as nymphs in taxonomic studies, making members of this order suitable for use as bioindicators [4].

The aquatic habitats in Türkiye have a high level of microhabitat diversity due to the different geographical structures and various topographic features it possesses from west to east and south to north. Therefore, the potential for endemism in rivers and lakes is also high. Despite the ongoing identification of new species in aquatic habitats, the information about the diversity of existing aquatic invertebrate fauna is still not sufficient [5]. This underscores the necessity of promptly identifying and documenting the biological species diversity that we possess but may not yet be aware of.

The Black Sea Region is accepted as a biodiversity hotspot (especially Eastern Black Sea Region) with other part of Caucasus Region [6]. There are many streams flowing from the mountains in this region. The Black Sea basin in Türkiye measures 246525 km^2 in total. There are five major rivers (Sakarya, Filyos, Kızılırmak, Yeşilırmak, and Çoruh) and a total of eighteen rivers in the basin region. The Black Sea Region receives water from five major river basins, including Yeşilırmak (39693 km^2) [7]. The Western Black Sea River Basin is made up of a number of small streams that run into the Black Sea from precipitation areas. The area of the basin is roughly 2,892,239 hectares. The basin's proportion to Türkiye's total area is 3.69%. The Black Sea region of Türkiye is home to the Eastern Black Sea River Basin. The basin has borders with Yeşilirmak basin in the west and south, and Çoruh basin in the east. The extent of the Eastern Black Sea River Basin is roughly 2.284.439 hectares, or 2.92% of Türkiye's total land area [8]. Because of its topography and rainy environment, the Eastern Black Sea Region contains a lot of rivers and streams. This characteristic is also necessary for the region's highly diverse aquatic biodiversity [6].

In Türkiye, studies related to the Ephemeroptera fauna have been conducted, yet there are still many aquatic systems that have been poorly researched or not researched at all. Studies on the Ephemeroptera fauna in the Black Sea Region have generally evaluated the region separately as eastern and western parts. However, although the publication years are between 2015 and 2022, the methods of sample collection vary between 2008 and 2015 [8-11]. In this study, the samples were collected more recently. Furthermore, Ephemeroptera samples were collected from different streams than in previous studies. This research was aimed to reveal the diversity of Ephemeroptera species in different aquatic systems (such as rivers, lakes, waterfalls, etc.) in the Black Sea region of Türkiye.

2. Materials and methods

Between 2016 and 2019 years, samples were collected to identify the species diversity and distributions of Ephemeroptera fauna in different aquatic habitats in Black Sea Region of Türkiye. A total of 35 stations were sampled from the region as indicated in Figures 1a and 1b. The nymphs of Ephemeroptera were collected by using standard hand net method and from under the stones with the help of forceps. The collected benthic samples were sieved using sieves decreasing mesh sizes of 2 mm, 1 mm, and 0.5 mm. After sieving, samples were fixed with %70 alcohol. The Ephemeroptera specimens obtained from stations were evaluated. The basin, province and coordinate information for the stations in the Black Sea Region is provided in Table 1.

Figure 1a. Geographical locations of the Eastern Black Sea Region sampling stations in Türkiye

Figure 1b. Geographical locations of the Western and Middle Black Sea Region sampling stations in Türkiye

Table 1. Details of sampling stations in Black Sea Region

Station	Station Code	Coordinates	Basin	Province
Aksu Stream	St1	40°52'50.76" N-38°26'16.79" E	Eastern Black Sea	Giresun
Doğankent Stream	St2	40°50'59.29" N-38°52'18.24" E	Eastern Black Sea	Giresun
Lake Sera	St3	40°59'13.91" N-39°36'58.37" E	Eastern Black Sea	Trabzon
Solaklı Stream	St4	40°55'2.23" N-40°16'43.03" E	Eastern Black Sea	Trabzon
İkizdere Stream	St5	40°47'4.84" N-40°33'19.45" E	Eastern Black Sea	Rize
Çataklıhoca Stream	St6	41° 4'28.49" N-40°47'3.68" E	Eastern Black Sea	Rize
Tar Stream	St7	40°59'48.42" N-41°3'30.80" E	Eastern Black Sea	Rize
Fırtına Stream-1	St8	40°59'47.99" N-40°58'26.73" E	Eastern Black Sea	Rize

Table 1. Continued

Fırtına Stream-2	St9	41°4'39.79" N-41°0'57.58" E	Eastern Black Sea	Rize
Fırtına Stream-3	St10	41° 8'48.56" N-41°0'34.06" E	Eastern Black Sea	Rize
Tahiroğlu Stream	St11	41°14'50.14" N-41°9'32.33" E	Eastern Black Sea	Rize
Sümer Stream	St12	41°17'27.87" N-41°13'21.97" E	Eastern Black Sea	Rize
Orçi Stream	St13	41°18'28.78" N-41°19'47.56" E	Eastern Black Sea	Artvin
Karaosmaniye Stream	St14	41°28'15.98" N-41°31'0.19" E	Eastern Black Sea	Artvin
Hopa Stream	St15	41°23'24.71" N-41°28'16.48" E	Eastern Black Sea	Artvin
Lake Karagöl	St16	41°13'28.72" N-41°36'32.01" E	Eastern Black Sea	Artvin
Karadere Stream	St17	40°53'55.69" N-38°31'28.06" E	Eastern Black Sea	Ordu
Gülyalı Stream	St18	40°57'51.31" N-38° 3'41.57" E	Eastern Black Sea	Ordu
Kumru Stream	St19	41° 5'24.01" N-37°19'43.39" E	Eastern Black Sea	Ordu
Turnasuyu Stream	St20	40°56'57.48" N-38° 0'17.60" E	Eastern Black Sea	Ordu
Elekçi Stream	St21	40°58'24.74" N-37°25'36.94" E	Eastern Black Sea	Ordu
Çamaş Canyon	St22	40°55'24.81" N-37°32'55.01" E	Eastern Black Sea	Ordu
Bolaman Stream	St23	40°58'52.77" N-37°30'15.17" E	Eastern Black Sea	Ordu
Terme Stream	St24	41° 9'44.06" N-36°53'40.83" E	Eastern Black Sea	Ordu
Kabaceviz Waterfall	St25	41° 3'34.78" N-36°31'33.54" E	Yeşilırmak	Samsun
Abdal Stream	St26	41°12'16.10" N-36°36'53.15" E	Yeşilırmak	Samsun
Yeşilırmak River	St27	41°11'8.60" N-36°43'3.94" E	Yeşilırmak	Samsun
Sarımsak Stream	St28	41°47'21.16" N-35° 6'48.38" E	Yeşilırmak	Samsun
Akçay Stream	St29	41°52'7.94" N-34°16'12.57" E	Western Black Sea	Sinop
Erfelek Waterfall	St30	41°50'25.98" N-34°46'48.14"E	Western Black Sea	Sinop
Ayancık Stream	St31	41°52'30.35" N-34°37'21.78" E	Western Black Sea	Sinop
Ilıca Waterfall	St32	41°39'13.88" N-33° 8'28.00" E	Western Black Sea	Kastamonu
Horma Canyon	St33	41°38'12.66" N-33° 8'37.33" E	Western Black Sea	Kastamonu
Bartın Stream	St34	41°38'21.41" N-32°19'55.66" E	Western Black Sea	Bartın
Mengen Stream	St35	40° 56'07.13" N-32° 03'39.35" E	Western Black Sea	Bolu

When the samples were transported to the laboratory, they were sorted under a stereomicroscope (Stemi 305, Zeiss) and Ephemeroptera specimens were prepared for identification at species level. Malzacher [12], Harker [13], Sauter [14], and Eiseler [15] were used for identification of the specimens. All samples were stored in the ESOGU Hydrobiology Laboratory.

3. Results

As a result of examination of the samples obtained from the stations, 3077 Ephemeroptera specimens (total zoobenthic members: 10266) from the Black Sea Region were determined. A total of 8 families, 15 genera and 34 species belonging to the Ephemeroptera order were identified. Individuals of 5 genera belonging to these families were young and were left at the sp. level because their taxonomic characters were not fully developed. In the region, all zoobenthos members also were identified to the family/order level, and Ephemeroptera members were identified to the species level. End of this study, a total of 60 taxa were identified in zoobenthos from the sampled localities in Black Sea Region.

Distributions of benthic macroinvertebrates in the regions were shown in Figure 2. In the region, Clitellata was the dominant taxon with 31.79% dominancy value and followed by Ephemeroptera and Diptera with 29.97% and 27.48%, respectively. The lowest taxa were determined as Decapoda and Bivalvia with 0.02% and 0.09% dominancy values, respectively.

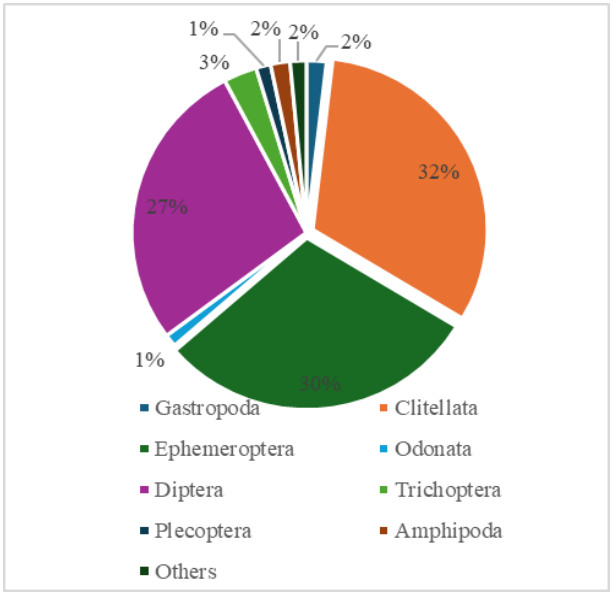

Figure 2. The total number of benthic macroinvertebrates collected in sampled localities in Black Sea Region (Others: Bivalvia, Hemiptera, Coleoptera, Isopoda, Decapoda)

When evaluated in terms of macroinvertebrate samples, Doğankent Stream was found to have richest fauna with 14.85% dominancy value and the lowest benthic samples was identified in Tahiroğlu Stream with 0.15% value (Figure 3).

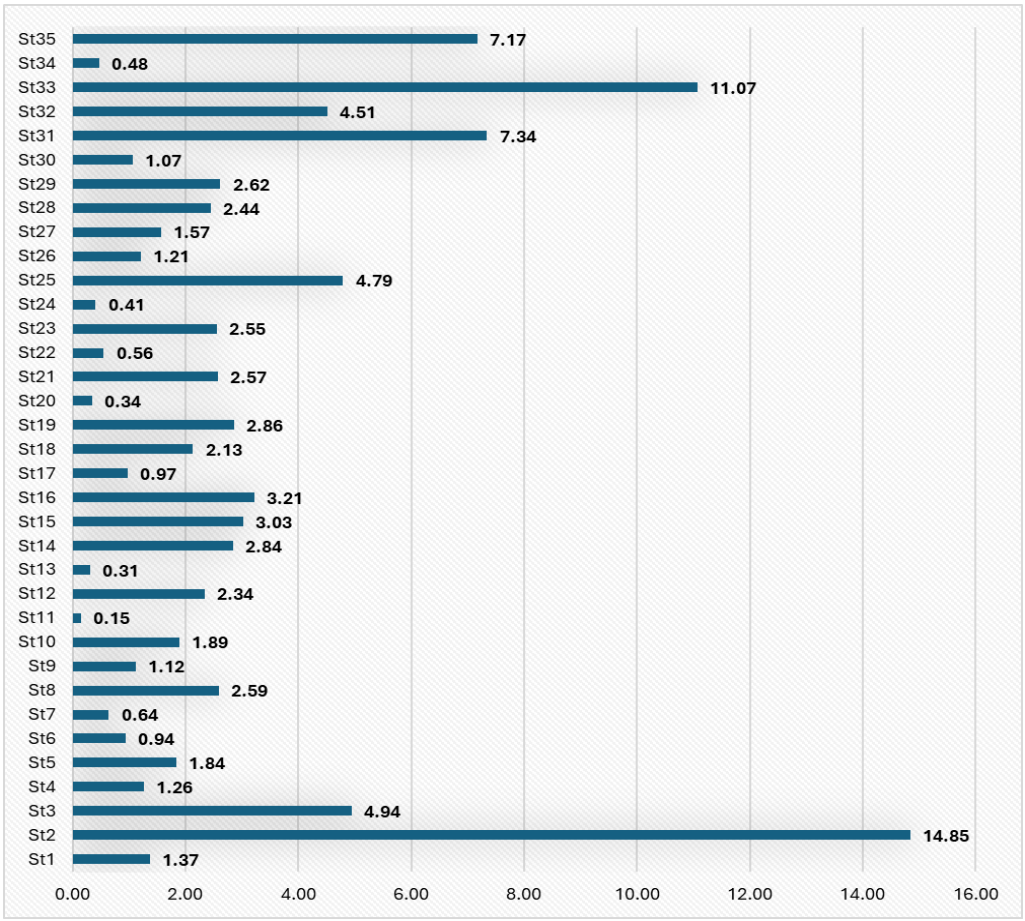

Figure 3. The rate of macrozoobentic samples collected in Black Sea region according to stations

A total of 34 species belonging to Order Ephemeroptera were identified in the studied area (supplementary file Table 1). Among the identified Ephemeroptera species, it can be classified as four species which are *Caenis luctuosa, C. macrura, C. pseudorivulorum* and *C. robusta* belong to Family Caenidae, fifteen species which are *Baetis* sp., *B. buceratus, B. digitatus, B. fuscatus, B. lutheri, B. muticus, B. niger, B. rhodani, B. vardarensis, Cloeon simile*, *C. dipterum, Centroptilum luteolum*, *Procloeon* sp., *P. bifidum* and *P. pennulatum* belong to Family Baetidae, nine species which are *Ecdyonurus* sp., *E. picteti, Electrogena* sp., *E. affinis, E. lateralis, E. quadrilineata, Epeorus znojkoi, Rhithrogena* sp. and *R. beskidensis* belong to Family Heptageniidae, one species which is *Serratella ignita* belong to Family Ephemerellidae, one species which is *Ephemera vulgata* belong to Ephemeridae, two species which are *Choroterpes picteti*, *Habrophlebia lauta* belong to Family Leptophlebiide, one species which is *Potamanthus luteus* belong to Family Potamanthidae and one species which is *Isonychia ignota* belong to Isonychiidae (as supplementary file Table 1). Dominancy values of Ephemeroptera species at the region were shown in Figure 4. It was found that the species *Caenis macrura* was the dominant species with 46.47% value followed by *Baetis rhodani* with 15.53% in this study. The lowest dominancy value was belonging to *Caenis luctuosa, Caenis robusta* and *Ecdyonurus* sp. with 0.03% dominancy value.

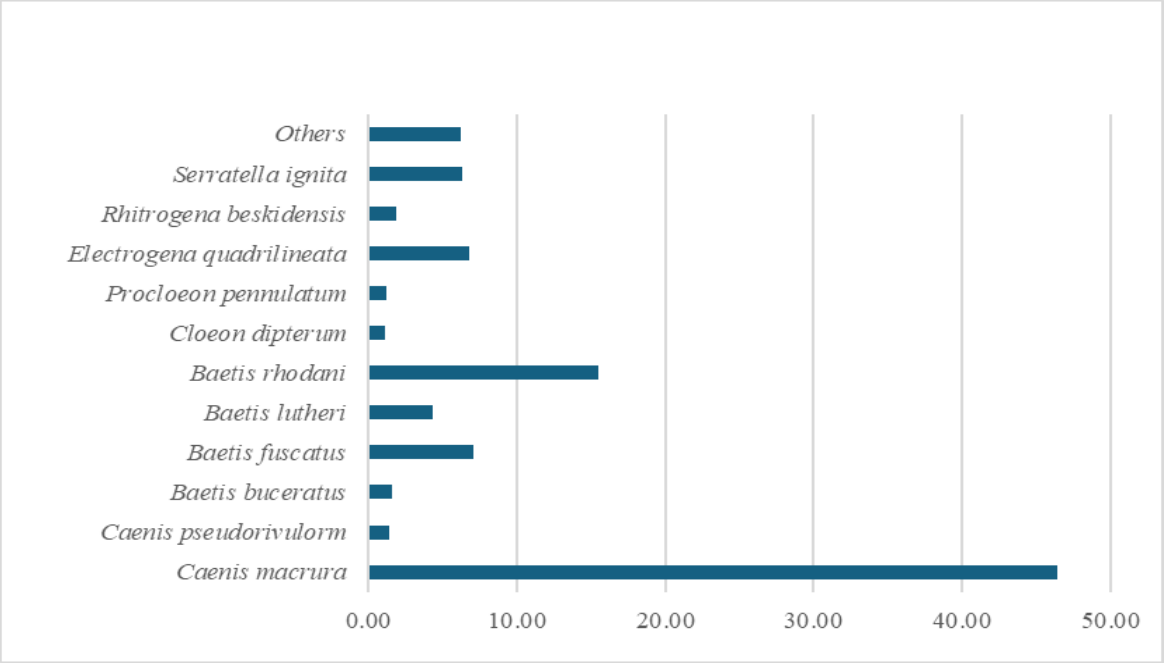

Figure 4. The rate of Ephemeroptera dominancy in Black Sea Region (Values below 1% are given as others. Others: *Caenis luctuosa, C. robusta, Baetis* sp., *Baetis digitatus, B. muticus, B. niger, B. vardarensis, Cloeon simile, Centroptilum luteolum, Procloeon* sp., *P. bifidum, Ecdyonurus picteti, Electrogena* sp., *E. affinis, E. lateralis, Epeorus znojkoi, Rhithrogena* sp., *Ephemera vulgata, Choroterpes picteti, Habrophlebia lauta, Potamanthus luteus, Isonychia ignota*)

In Black Sea Region, diversity indices values according to the zoobenthic community were given in as supplementary file Table 1. Doğankent Stream had the highest individual number with 1524 specimens followed by Horma Canyon with 1136 specimens. The stations with the lowest individual number were Tahiroğlu Stream (15 specimens), Orçi Stream (32 specimens) and Turnasuyu Stream (35 specimens). The highest Shannon index values were evaluated in Turnasuyu Stream with 1.76, followed by Kumru Stream (1.67) and Kabaceviz Waterfall (1.66), respectively. The stations with the lowest Shannon value had Doğankent Stream (0.15) and Lake Karagöl (0.24).

4. Conclusions and discussion

Although many studies have focused on the aquatic fauna of Türkiye, many freshwater ecosystems remain either poorly investigated or entirely unexplored with respect to their Ephemeroptera fauna. In light of this gap, the present study aims to assess the species diversity of Ephemeroptera across various freshwater systems in the Black Sea Region.

In the Black Sea Region was examined in terms of zoobenthic community, Chironomidae and Ephemeroptera taxa were observed at every station. Oligochaeta and Trichoptera taxa were the second highest frequency taxa with a frequency rate of 74.29%. It has been reported that individuals belonging to Ephemeroptera, Plecoptera and Trichoptera are generally intolerant of organic pollution, but some species from the Trichoptera order may be more tolerant to

pollution and can be found in organically polluted waters [16]. Chironomidae larvae are important indicator organisms in water quality studies in aquatic systems because they are found in almost all aquatic habitats [17] and have very different ecological preferences (especially oligosaprobic, β-mesosaprobic and α-mesosaprobic waters) [18]. Freshwaters in the region show moderate pollution in terms of the identified taxa.

Within this study, a total of 3077 Ephemeroptera individuals (total zoobenthic members: 10266) belonging to 8 families, 15 genera and 34 taxa in the Black Sea Region were identified. The number of species identified in the region was lower than expected. Biodiversity in aquatic ecosystems changes depending on environmental variables. During the historical development process of Türkiye, the Black Sea Region remained an inland sea with no connection to other seas for many years, and its water character has also differentiated. In the waters studied in the Black Sea Region, many negative pressures such as change in habitat structure, water withdrawal for irrigation and recreation purposes, and industrial or urban wastewater discharge because of anthropogenic factors have been observed. In the Black Sea Region, it is thought that the hydroelectric power plants constructed and operated on the streams of the Eastern Black Sea Region, especially in recent years, have caused changes in the structures of the streams and therefore in the macroinvertebrate communities.

Türkiye has a remarkably varied mayfly biodiversity. Western and Eastern Palaearctic fauna are found in the Middle East, which is considered a transitional zone [19]. This explains the high diversity of Türkiye's mayfly fauna, which includes 165 species listed in the most recent study [20]. A significant percentage of Turkish mayfly species display a wide Palearctic or West Palearctic range in terms of biogeographic patterns. European species with ranges into the Middle East make up a significant portion of the fauna [21].

The specimens belonging to *Caenis macrura* was determined as the species with the highest dominance rate with an average rate of 46.47% from 35 sampling stations in the Black Sea Region. This species has very wide distribution in Türkiye. In this study, it is one of the species detected with the highest dominance rate in a total of 13 stations in the Black Sea Region (Aksu Stream, Terme Stream, Kumru Stream, Karadere Stream, Gülyalı Stream, Bolaman Stream, Kabaceviz Waterfall, Abdal Stream, Ayancık Stream, Ilıca Waterfall, Horma Canyon, Bartın Stream, Mengen Stream). The specimens *Caenis macrura* lives in clean to moderately contaminated running freshwater, but not in highly polluted water [22]. It is usually found in lakes, streams and stagnant waters [23]. They reported that this species is found at altitudes between 0 and 1400 m and is distributed between the epirhithron and hippotamon zones of streams [24]. It is known that it can be found from xenosaprobic zones to alpha-mesosaprobic zones and most prefer beta-mesosaprobic zones [25]. The stations where *C. macrura* species was detected in the study vary from clean to moderately polluted environments, and Gülyalı Stream in the Black Sea Region, where the species has the highest dominance rate, is slightly polluted waters. In this respect, our findings are compatible with the other findings.

The specimens belonging to *Baetis rhodani* was found to have the 2nd highest dominance rate with an average rate of 15.53% in the Black Sea Region, is a species with a fairly wide distribution in our country. It was recorded in 21 stations in the Black Sea Region viz., Solaklı Stream, Tar Stream, Orçi Stream, Çataklıhoca Stream, Fırtına Stream-1, Fırtına Stream-2, Sümer Stream, Karaosmaniye Stream, Hopa Stream, Kumru Stream, Karadere Stream, Gülyalı Stream, Bolaman Stream, Kabaceviz Waterfall, Abdal Stream, Akçay Stream, Erfelek Waterfall, Ayancık Stream, Ilıca Waterfall, Horma Canyon, Mengen Stream. This species is found at altitudes between 0 and 2000 m and is distributed in every region from the hypocrenon region to the metapotamon region of the rivers [24]. And, it is distributed in medium and high flow regions of the rivers [24]. It is known that it generally prefers beta-mesosaprobic regions and is also found in oligosaprobic and alpha-mesosaprobic regions [25] . When the data obtained in line with this information are compared with the previous studies where this species was found, it is observed that they are parallel and support each other. According to the ecological requirements of the detected Ephemeroptera species, it can be concluded that 35 stations sampled in the Black Sea Region have oligosaprobic, β- and α-mesosaprobic waters.

According to the research by Türkmen and Kazancı [10], Aksu Stream, İkizdere Stream and Fırtına Stream are common with the stations in this study. They noted that the abundance of Caenidae species is generally very low throughout the basin. However, in this study, Caenidae individuals were identified as the dominant species. It can be said that the general reason for this may be habitat change.

In conclusion, this study was carried out to determine the diversity of Ephemeroptera species in 35 stations in the Black Sea Region. A total of 34 taxa from the region (total zoobenthic members: 10266) were identified in this study. Some of the identified species are the first records on a provincial basis. The species *Baetis buceratus* is the first record for Trabzon (Solaklı Stream), Rize (Fırtına Stream) in Black Sea Region. The species *Baetis fuscatus* is the first record for Artvin (Orçi Stream and Karaosmaniye Stream), Samsun (Abdal Stream) from the region. The species *Baetis lutheri* is the first record for Samsun (Kabaceviz Waterfall and Abdal Stream); *Baetis niger* is the first record for Ordu (Kumru Stream); *Baetis rhodani* is the first record for Samsun (Kabaceviz Waterfall and Abdal Stream); *Baetis vardarensis* is the first record for Ordu (Kumru Stream); *Cloeon simile* is the first record for Rize (İkizdere Stream); *Cloeon dipterum* is the first record for Ordu (Terme Stream and Elekçi Stream) and Samsun (Sarımsaklı Stream) provinces; *Procloeon bifidum* is the first record for Rize (Çataklıhoca Stream) and Artvin (Orçi Stream) provinces; *Procloeon pennulatum* is the first record for Rize (Sümer Stream) and Giresun (Aksu Stream) province; *Caenis macrura* is the first record for Samsun (Kabaceviz Waterfall and Abdal Creek); *Caenis pseudorivulorum* is the first record for Rize (Sümer Creek) and Ordu (Kumru Creek) provinces; *Caenis robusta* is the first record for Samsun

(Yeşilırmak); *Serratella ignita* is the first for Samsun (Kabaceviz Waterfall and Abdal Creek; *Electrogena lateralis* is the first record for Artvin (Orçi Stream) and Rize (Fırtına Stream) provinces; *Electrogena quadrilineata* is the first record for Artvin (Karaosmaniye Stream and Hopa Stream), Samsun (Kabaceviz Waterfall) and Sinop (Akçay) provinces; *Epeorus znojkoi* is the first record for Artvin (Hopa Stream); *Rhithrogena beskidensis* is the first record for Artvin (Orçi Stream); *Isonychia ignota* is the first record for Ordu (Kumru Stream); *Potamanthus luteus* is the first record for Ordu (Kumru Stream and Bolaman Stream), Samsun (Abdal Stream) provinces in Black Sea Region.

Consequently, a total of 20 species identified in this study are the first records for 7 provinces in Black Sea Region and have contributed to the Ephemeroptera fauna of Türkiye.

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Ethical statement: This study does not require ethical approval.

Author contributions: Tuğba Demir performed the field studies, identified the Ephemeroptera species, evaluated the laboratory studies and analysis, Naime Arslan had designed the research project, performed field studies, improved the discussion and conclusion, Nesil Ertorun identified the Ephemeroptera species, evaluated the laboratory studies and analysis, and wrote the manuscript, Deniz Mercan performed the field studies, identified the Ephemeroptera species, evaluated the laboratory studies and analysis and wrote the manuscript. All authors give final approval of the version to be published.

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