Species composition and distribution of ostracods (Crustacea, Ostracoda) in some lakes and lagoons (Kocaeli and Sakarya, Turkey)

Selçuk Altınsaçlı, Songül Altınsaçlı & Ferda Perçin Paçal

Abstract
In the present study the community structure and diversity of ostracods were investigated seasonally in the water of the nine wetlands located in Sakarya and Kocaeli Province during September 2009-January 2010. As a result of the qualitative study, totally of 24 taxa belonging to 20 genera were recorded in nine wetlands. Among the ostracods species found at wetlands, Cosmopolitan species Darwinula stevensoni (8 wetlands) Cypria ophthalmica (8 wetlands) and Cypridopsis vidua (8 wetlands) were the most common species (88.8%) in nine wetlands, whereas, five species of ostracods (Candonopsis kingslei, Tommacypris lutaria, Potamocypris variegata, Sarscypridopsis aculeata and Pleosocypridopsis newtoni) were found only in one wetland. According to the Shannon-Weaver diversity index (H') the highest diversity values determined in the Lake Kanlıgöl (3.378) and Lake Kamış (3.38), whereas, the lowest values of the Shannon-Weaver diversity index (H') was determined in Dalyan Lagoon (0.86).

Keywords: Ostracoda, Lakes, Lagoons, Distribution, Ecology

1. Introduction
Ostracods are likely the common group of microbenthic fauna in aquatic ecosystems. Ostracods (Crustacea) are bivalved crustaceans with adults being typically 0.5 to 3.0 mm long. Ostracods are environmentally and geographically diverse, and are often abundant in almost all aquatic and in some terrestrial habitats [1, 2, 3, 4]. Ostracods have been accepted as ecological and palaeoecological indicators [2, 5, 6, 7, 8, 9, 10]. Many freshwater ostracods live among the macrophytes in the littoral and sublittoral zones of lakes for feed and shelter. The benthic ostracods play a role of converting phytoplankton to food for fish and other aquatic animals. Also ostracods are an important nutritional source for fish species. Freshwater ostracods (Crustacea, Ostracoda) are sensitive to environmental conditions, and are widely used as biological indicators for past and present environmental changes [2, 10]. Wetlands have been an important habitat for many species. Only about 1% of the world surface is occupied by the wetlands. Wetlands provides a habitat for about 20% of the world’s species [15]. 1.3 million ha. of its historic wetlands over the past 60 years has lost at least in Turkey, mostly due to human impacts [16, 17]. Eutrophication, altered surface and subsurface flows and exceedingly high sedimentation rates will be major threats to wetlands of Turkey [18]. Although it be neglected for state authorities, ongoing since long time uncontrolled and high population growth rate of the Turkey is major threat to future of wetlands. Preliminary researches on the Ostracoda species, which lives in the inland water of Turkey, were performed by Schäfer [19] and Hartmann [20]. Altınsaçlı and Griffiths [21] presented a checklist of the non-marine Ostracoda fauna from Turkey. There are publications containing floristic information about adjacent wetlands [22, 23, 24, 25, 26]. There are publications containing faunistic and floristic information about adjacent wetlands [23, 24, 25, 26, 27, 28, 29, 30, 31]. A compulsory condition determination must be made for recent ostracods studies, unfortunately, some recent studies published on the freshwater ostracods has been presented as a detailed ecological and faunistic studies although they only a preliminary and time limited studies. The aims of this study are to document ostracod species composition in the lakes and some lagoons of the Sakarya and Kocaeli Provinces, to evaluate ecological characteristics of...
ostracod species, to determine to microhabitat preferences of species and to contribute to the knowledge of ostracod diversity and ecology.

2. Material and Methods
2.1 Site description
Lake Saklıgöl: Lake Saklıgöl (41°07' 25.81"N 29°55' 19.27"E) is a karstic freshwater lake situated in the northwest part of Kandıra District (Kocaeli Province), at an altitude of 77 m a.s.l. (Fig. 1) [26]. It is a mesotrophic lake, with a mean depth of 1.5 m, maximum depth of 4 m and surface area of 3.9 ha. [26]. The lake is fed by underground water source and rain water falling into a depression with no surface inlet or outlet. The only outlet of the lake water is via discharge through a karst aquifer. The codes of abbreviated names for each species were coded beside species names and these codes were used in next sentences. Eleven macrophyte species were identified by Altınsaçlı et al. [26].

Lake Sarıcagelin: Lake Sarıcagelin (41°07' 58.17"N 30°00' 51.35" E) is a karstic freshwater lake situated in the Upper Cretaceous–Paleocene limestones in the northwestern part of Kandıra District (Kocaeli Province), at an altitude of 26 m a.s.l. (Fig. 1) [26]. The lake basin was formed by dissolved carbonated rocks. It is a mesotrophic lake, with a mean depth of 1 m, maximum depth of 3 m and surface area of 1.6 ha [26]. The lake is fed by an underground water source and by rain water falling into a depression with no surface inlet or outlet. The only outlet of the lake water is via discharge through a karst aquifer. Seven macrophyte species were identified by Altınsaçlı et al. [26].

Sarısu Lagoon: Sarısu Lagoon is located in the northwestern part of Kandıra District (Kocaeli Province) (41°08' 17.77"N 30°09' 01.14"E), at an altitude of 0 m (Fig. 1) [26]. Like many other lagoonal lakes, Lake Sarısu is situated on a sandy shore. This semi-enclosed water body is separated from the open sea by a sandy barrier [26]. Sarısu lagoon is formed in a depression behind the coastal dunes. It is a mesotrophic and oligomesaline lagoon, with a mean depth of 1 m, maximum depth of 2.8 m and surface area of 1.94 ha [26]. It is fed by the rain water, a small freshwater stream and Sarısu Creek [26]. Its only temporary outlet is in the east. Fifteen macrophyte species were identified by Altınsaçlı et al. [26].

Dalyan Lagoon: Dalyan Lagoon is located in the eastern part of the Karasu District (Adapazarı Province) (41°04' 58.60"N 30°47' 12.4"E), at an altitude of 4 m a.s.l. (Fig. 1) [26]. It is a mesotrophic lake, with a mean depth of 1 m, maximum depth of 1.5 m and surface area of 0.6 ha [26]. The lake fed by underground water and rain water, and has no inlet and no outlet. The lake is surrounded by little sand hills [26]. Sixteen macrophyte species were identified by Altınsaçlı et al. [26].

Lake Kanlıgöl: Lake Kanlıgöl is located in the northeast part of the Kaynarca District (Adapazarı Province) (41°09' 55.77"N 30°22' 39.6"E) at an altitude of 4 m a.s.l. (Fig. 1). It is an eutrophic lake, with a mean depth of 1 m, maximum depth of 1.5 m, and surface area of 20 ha. Seventeen macrophyte species (Phragmites australis (Cav.) Trin.ex Steud., Typha angustifolia L., Typha latifolia L., Salvinia natans (L.) All., Nasturtium officinale R. Br., Alisma plantago-aquatica L., Ceratophyllum demersum L., Myriophyllum spicatum L., Juncus effusus L., Juncus littoralis C.A. Mey., Juncus maritimus Lam., Iris pseudacorus L., Mentha aquatica L., Lemna minor L., Utricularia vulgaris L., Nymphaea alba L., Potamogeton crispus L.) were identified during present study in Lake Kamış by Altınsaçlı (unpublished data).

Lake Kamış: Lake Kamış is located in the northeast part of the Kaynarca District (Adapazarı Province) (41°10' 05.8"N 30°21' 29.5"E) at an altitude of 0 m a.s.l. (Fig. 1). It is an eutrophic lake, with a mean depth of 1 m, maximum depth of 2 m, and surface area of 92 ha. Twenty macrophyte species (Phragmites australis (Cav.) Trin.ex Steud., Sparganium erectum L., Typha latifolia L., Salvinia natans (L.) All., Nasturtium officinale R. Br., Alisma plantago-aquatica L., Ceratophyllum demersum L., Myriophyllum spicatum L., Juncus effusus L., Juncus littoralis C.A. Mey., Juncus maritimus Lam., Iris pseudacorus L., Mentha aquatica L., Lemna minor L., Utricularia vulgaris L., Potamogeton crispus L., Nymphaea alba L., Nuphar lutea (L.) Sm., Trapa natans L.) were identified during present study in Lake Kamış by Altınsaçlı (unpublished data). Excluding ostracods, other animal species found during this study in the wetlands are shown in Table 1.
Climate of Marmara bears common traits both of the Mediterranean climate (mild and rainy winters, warm and dry summer) and Black Sea climate (wet, humid, rainy in all season).

2.2 Sampling
Between September 2009 and August 2010, ostracods were collected from 9 wetland sites in at least two different aquatic habitats (littoral zone of lakes and lagoons) in two counties (Kaynarca and Karasu) of Sakarya and one county (Kandıra) of Kocaeli. Five physicochemical variables commonly used were measured monthly from September 2009 to August 2010: dissolved oxygen (DO), pH, water temperature (Tem.), electrical conductivity (EC) and salinity (Sal.). Table 2 presents values of each physicochemical parameter for each of the different wetlands. Two hundred milliliter of sediment (with submerged aquatic plants) were collected from a depth of 10 to 60 cm (ca. 1 m² of area) using a standard hand net (250 μm mesh size) and fixed in 4% formaldehyde in situ.
the laboratory, ostracods were separated from sediment using four standardized sieves: 2.0, 1.5, 0.5, and 0.25 mm mesh size. Samples were stored in 1:1 70% ethanol:glycerine and species were identified using both soft part and carapace-based characters using standard keys [2, 32, 33] with systematic nomenclature following and Meisch [2] and Hartmann & Puri [34]. Permanent and temporary soft part preparations were made with Canada balsam and lactophenol. Seasonal individual numbers of ostracod species are shown in Table 3.

2.3 Statistical Analyses

Sorensen’s Similarity Quotient (QS) [35], i.e. the species similarity based on the presence or absence of species, was used to determine the degree of similarity of ostracod species collected from the nine wetlands: QS = 2C/(A+B), where A and B are the number of species from each sample, and C is the number of common species. The (log2) Shannon-Weaver diversity index (H’) [36], was calculated for each sample based on number of individuals of each ostracod species found. Binary (presence–absence) data was used to show relationships among species using the Bray Curtis similarity coefficient and non-weighted pair group mean averages (here after UPGMA) analysis provided by the program Multivariate Statistical Package Version 3.1 [37]. We used numbers of individuals in Spearman Rank Correlation analysis along with two-tailed significance of bivariate correlations to determine the correlations among the species, environmental variables and both [38]. Significant results were determined at 0.01 and/or 0.05 critical levels.

3. Results

8147 individuals belonging to 20 genera and 24 taxa (Darwinula stevensoni (Brady & Robertson, 1870), Cypria ophthalmica (Jurine, 1820), Physocyrpa krapełinii G.W. Müller, 1903, Illyocypres bipectata (Koch, 1838), Illyocypres bradyi Sars, 1890, Notodromas monacha (O.F. Müller, 1776), Cardona neglecta Sars, 1887, Pseudocandona compressa (Koch, 1838), Pseudocandona marchica (Hartwig, 1899), Pseudocandona rostrata (Brady & Norman, 1889), Fabaeformiscandona fabaeformis (Fischer, 1851), Cardonopsis kingsleii (Brady & Robertson, 1870), Eucypris virrens (Jurine, 1820), Tomnacypres gutata (Koch, 1838), Heterocypris incongruens (Ramdohr, 1808), Heterocypris salina (Brady, 1868), Cypridopsis vidua (O.F. Müller, 1776), Potamocypris variegata (Brady & Norman, 1889), Sarscypridopsis aculeata (Costa, 1847), Plesiocypridopsis newtoni (Brady & Robertson, 1870), Cyprideis torosa (Jones, 1850), Loxoconchae (Loxocapsia) immundulata (Stepanaitis, 1958), Limnocthyere inopinata (Baird, 1843), Metacypris cordata Brady & Robertson 1870) were collected from the nine sampled sites (See Table 3). Individual numbers of 24 ostracod species collected from nine wetlands are shown in Table 3. The values of eight physicochemical variables measured in ten wetlands from September 2009 (Sept. 2009) to August 2010 (Aug.2010) (Table 2).

Table 2: Physicochemical variables measured in the wetlands during September 2009 to August 2010. Abbreviations (Tem.= Water temperature (°C), DO = Dissolved oxygen (mg/L), pH, Sal.= Salinity (%), EC= Electrical Conductivity (µS/cm))
Table 3: List and total individual numbers of ostracod taxa collected in the wetlands during September 2009 to August 2010.

<table>
<thead>
<tr>
<th>Species</th>
<th>Lake Saklıgöl</th>
<th>Lake Sancagelin</th>
<th>Lake Kanlıgöl</th>
<th>Lake Akçagöl</th>
<th>Lake Kamyş</th>
<th>Lake Akçagöl</th>
<th>Total individual number</th>
<th>Percent Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daphnia stevensoni</td>
<td>176</td>
<td>189</td>
<td>200</td>
<td>196</td>
<td>186</td>
<td>197</td>
<td>980</td>
<td>11.4</td>
</tr>
<tr>
<td>Cypris ophthalmica</td>
<td>262</td>
<td>296</td>
<td>306</td>
<td>296</td>
<td>300</td>
<td>306</td>
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<td>15.9</td>
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<tr>
<td>Physocypris kraepelini</td>
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<td>34</td>
<td>34</td>
<td>34</td>
<td>34</td>
<td>34</td>
<td>166</td>
<td>1.9</td>
</tr>
<tr>
<td>Illyocypris biplicata</td>
<td>87</td>
<td>88</td>
<td>86</td>
<td>84</td>
<td>83</td>
<td>87</td>
<td>430</td>
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<td>Illyocypris bradyi</td>
<td>72</td>
<td>73</td>
<td>73</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>216</td>
<td>2.5</td>
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<tr>
<td>Nisakrothamnus minornebrae</td>
<td>8</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>58</td>
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<tr>
<td>Candona neglecta</td>
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<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>42</td>
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</tr>
<tr>
<td>Candona compressa</td>
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<td>30</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>159</td>
<td>1.9</td>
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<td>Pseudocandona majorica</td>
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<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>71</td>
<td>0.9</td>
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<tr>
<td>Pseudocandona rostrata</td>
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<td>62</td>
<td>62</td>
<td>62</td>
<td>333</td>
<td>4.1</td>
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<tr>
<td>Canthocandina kingslei</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td>216</td>
<td>2.5</td>
</tr>
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<td>Loxocandina uranica</td>
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<td>31</td>
<td>31</td>
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<td>31</td>
<td>107</td>
<td>1.2</td>
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<tr>
<td>Euocypris virens</td>
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<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>107</td>
<td>1.2</td>
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<tr>
<td>Heterocypris incongruens</td>
<td>197</td>
<td>187</td>
<td>197</td>
<td>197</td>
<td>197</td>
<td>197</td>
<td>980</td>
<td>11.4</td>
</tr>
<tr>
<td>Heterocypris salina</td>
<td>271</td>
<td>271</td>
<td>271</td>
<td>271</td>
<td>271</td>
<td>271</td>
<td>1399</td>
<td>16.3</td>
</tr>
<tr>
<td>Cypridopsis vidua</td>
<td>203</td>
<td>203</td>
<td>203</td>
<td>203</td>
<td>203</td>
<td>203</td>
<td>1191</td>
<td>14.6</td>
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<tr>
<td>Potamoocypris variegata</td>
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<td>17</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td>88</td>
<td>1.1</td>
</tr>
<tr>
<td>Sarscypris aculeata</td>
<td>56</td>
<td>56</td>
<td>56</td>
<td>56</td>
<td>56</td>
<td>56</td>
<td>336</td>
<td>4.1</td>
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<td>Pleocypris platystomus</td>
<td>48</td>
<td>48</td>
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<td>48</td>
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<td>48</td>
<td>264</td>
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<td>265</td>
<td>265</td>
<td>265</td>
<td>265</td>
<td>1399</td>
<td>16.3</td>
</tr>
<tr>
<td>Loxoconcha immodulata</td>
<td>47</td>
<td>47</td>
<td>47</td>
<td>47</td>
<td>47</td>
<td>47</td>
<td>199</td>
<td>2.4</td>
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<tr>
<td>Limnothrone inopinata</td>
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<td>117</td>
<td>117</td>
<td>117</td>
<td>117</td>
<td>117</td>
<td>776</td>
<td>9.5</td>
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<tr>
<td>Metacypris cordata</td>
<td>7</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>7</td>
<td>8</td>
<td>41</td>
<td>0.5</td>
</tr>
<tr>
<td>Total individual number of ostracods in wetlands</td>
<td>1100</td>
<td>984</td>
<td>886</td>
<td>721</td>
<td>1137</td>
<td>343</td>
<td>1093</td>
<td>1386</td>
</tr>
</tbody>
</table>

During the present study, five cosmopolitan species (D. stevensoni, C. ophthalmica, H. salina, S. aculeata, C. vidua) were found. Five cosmopolitan species are significant contribution to species diversity. All of the species during the present study had been determined from Turkey, and within the geographical region and sub-regions located of Turkey [2]. The results from the species-clustering analysis (UPGMA) revealed three major clustering groups (Fig 2). The first group consisted in brackish (oligosaline) lagoon (Dalyan Lagoon). Second group comprised from slightly brackish (oligosaline)-freshwater coastal lakes and lagoons located in the Black Sea coastline (mentioned lagoons are fed by freshwater of rainwater and creeks) Three major clustering groups are includes karstic freshwater lakes (Lake Sancagelin and Lake Saklıgöl).

![Fig 2: An analysis of Unweighted Pair-Group Mean Averages (UPGMA) shows the clustering relationships of ostracod fauna among wetlands.](image)

Results of Sorensen’s Similarity Coefficient analysis results are shown in table 4.
Table 4: Percent similarities among the wetlands, calculated using the estimates of the Sorenson Index. (* The highest similarity scores).

<table>
<thead>
<tr>
<th>Name of Wetlands</th>
<th>Lake Saklıgöl</th>
<th>Sarsu Lagoon</th>
<th>Lake Sarıçagelin</th>
<th>Dalyan Lagoon</th>
<th>Lake Küçükboğaz</th>
<th>Lake Akçagöl</th>
<th>Lake Kanlıgöl</th>
<th>Lake Kamış</th>
<th>Lake Akgöl</th>
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<tbody>
<tr>
<td>Lake Saklıgöl</td>
<td>100</td>
<td>62.5</td>
<td>66.6*</td>
<td>0</td>
<td>44.4</td>
<td>40</td>
<td>40</td>
<td>38</td>
<td>50</td>
</tr>
<tr>
<td>Sarsu Lagoon</td>
<td>62.5</td>
<td>100</td>
<td>55.5</td>
<td>30.7*</td>
<td>66.6*</td>
<td>66.6</td>
<td>53.8</td>
<td>51.8</td>
<td>72.7*</td>
</tr>
<tr>
<td>Lake Sarıçagelin</td>
<td>66.6*</td>
<td>55.5</td>
<td>100</td>
<td>0</td>
<td>30</td>
<td>35.2</td>
<td>45.4</td>
<td>43.4</td>
<td>55.5</td>
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<tr>
<td>Dalyan Lagoon</td>
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<tr>
<td>Lake Küçükboğaz</td>
<td>44.4</td>
<td>66.6</td>
<td>30</td>
<td>26.6</td>
<td>100</td>
<td>52.1</td>
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<td>55.1</td>
<td>41.6</td>
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<td>66.6</td>
<td>33.2</td>
<td>16.6</td>
<td>52.1</td>
<td>100</td>
<td>72</td>
<td>57.2*</td>
<td>66.6</td>
</tr>
<tr>
<td>Lake Kanlıgöl</td>
<td>40</td>
<td>53.8</td>
<td>45.4</td>
<td>0</td>
<td>50</td>
<td>72*</td>
<td>100</td>
<td>96.7*</td>
<td>61.5</td>
</tr>
<tr>
<td>Lake Kamış</td>
<td>38</td>
<td>51.8</td>
<td>43.4</td>
<td>0</td>
<td>55.1</td>
<td>69.2</td>
<td>96.7*</td>
<td>100</td>
<td>66.6</td>
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<tr>
<td>Lake Akgöl</td>
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<td>72.7*</td>
<td>55.5</td>
<td>0</td>
<td>41.6</td>
<td>66.6</td>
<td>61.5</td>
<td>66.6</td>
<td>100</td>
</tr>
</tbody>
</table>

According to the results of the Sorenson Similarity Index, the greatest similarity (96.7%) was found between Lake Kanlıgöl and Lake Kamış while the lowest similarity (0%) occurred between Dalyan Lagoon and other lakes (see Table 4). Species diversity values of the wetlands according to Shannon Wiener diversity index are shown in Fig 3. Higher values of Shannon’s index (H’) indicate of greater species diversity.

Fig 3: Shannon-Weaver similarity index (H’) values of the wetlands in Sakarya and Kocaeli Provinces.

According to the Shannon-Weaver diversity index (H’) values (Fig 3) suggested high diversity values for the Kanlıgöl (3.37) and Lake Kamış (3.38), whereas values of the Shannon-Weaver diversity index (H’) were the lowest for Dalyan Lagoon (0.86) (Fig 3). Seasonal Shannon-Weaver diversity index (H’) values of the wetlands are shown in Fig 4.

Fig 4: Seasonal Shannon-Weaver diversity index (H’) values of the wetlands during September 2009 to August 2010
In the present study, the lowest (1.61) and the highest (2.26) Shannon Wiener index (H) values recorded during winter and spring, respectively at Lake Saklıgöl. The lowest winter (0.81) and the highest (3.14) Shannon Wiener index (H) values recorded during winter and summer, respectively at Sarsu Lagoon. The lowest (0.97) and the highest (2.81) Shannon Wiener index (H) values recorded during winter and autumn, respectively at Lake Sancagelin. The lowest (0.86) and the highest (0.98) Shannon Wiener index (H) values recorded during autumn and winter, respectively at Dalıy Lagoon. The lowest (3.33) and the highest (3.53) Shannon Wiener index (H) values recorded during winter and early spring, respectively at Lake Küçükboğaz. The lowest (0.0) and the highest (3.02) Shannon Wiener index (H) values record during winter and early autumn, respectively at Lake Akçagöl. The lowest (1.6) and the highest (3.63) Shannon Wiener index (H) values recorded during winter and summer, respectively at Lake Kanlıgöl. The lowest (3.08) and the highest (3.79) Shannon Wiener index (H) values recorded during winter and summer, respectively at Lake Kamış. The lowest (0.0) and the highest (3.18) Shannon Wiener index (H) values recorded during late autumn and winter and summer, respectively at Lake Akğöl. In terms of species diversity has the lowest to Shannon-Weaver diversity indices in the late autumn and winter months in nine wetlands.

All ostracods species were significantly positive correlated with each other in Lake Saklıgöl. The most strong positive correlation was observed between C. vidua and I. bradyi (r = 0.910, P < 0.01). Except dissolved oxygen, the positive correlation was observed between all other environmental variables. The most positive correlation was observed between salinity and electrical conductivity (r = 0.939) while strong negative correlation was observed between salinity and dissolved oxygen (r = -0.902).

All ostracods species were significantly positive correlated with each other in Lake Küçükboğaz. The most strong positive correlation was observed between H. salina and C. neglecta (r = 0.975, P < 0.01). Except dissolved oxygen, the positive correlation was observed between all other environmental variables. The most positive correlation was observed between electrical conductivity and dissolved oxygen (r = 0.848, P < 0.01) while weak negative correlation was observed between temperature and dissolved oxygen (r = -0.132).

All ostracods species were significantly positive correlated with each other in Lake Akgöl. The most strong positive correlation was observed between D. stevensoni and C. neglecta (r = 0.991, P < 0.01). The most weak positive correlation was observed between N. monacha and L. immundula (r = 0.441). The most positive correlation was observed between temperature and conductivity (r = 0.798, P < 0.01) while weak negative correlation was observed between pH and dissolved oxygen (r = -0.340).

All ostracods species were significantly positive correlated with each other in Sarsu Lagoon. The most strong positive correlation was observed between L. inopinata and P. compressa (r = 0.992, P < 0.01). The most weak positive correlation was observed between P. marchica and H. salina (r = 0.651, P < 0.05). The positive correlation was observed between all environmental variables in Sarsu Lagoon. The most positive correlation was observed between salinity and conductivity (r = 0.991, P < 0.01) while weak positive correlation was observed between electrical conductivity (r = -0.135).

All ostracods species were significantly positive correlated with each other in Lake Saricagelin. The most strong positive correlation was observed between C. ophthalmica and D. stevensoni (r = 0.993, P < 0.01). The most weak positive correlation was observed between C. ophthalmica and L. inopinata (r = 0.848, P < 0.01). The most positive correlation was observed between pH and temperature (r = 0.494) while weak positive correlation was observed between pH and dissolved oxygen (r = -0.057). The most negative correlation was observed between electrical conductivity and pH (r = -0.380) while weak negative correlation was observed between electrical conductivity and dissolved oxygen (r = -0.152).

Two ostracods species were positive correlated in Dalıy Lagoon. The most strong positive correlation was observed between C. torosa and H. salina (r = 0.910, P < 0.01). The positive correlation was observed between all environmental variables in Dalıy Lagoon. The most positive correlation was observed between salinity and electrical conductivity (r = 0.982, P < 0.01) while weak positive correlation was observed between temperature and dissolved oxygen (r = 0.067).

All ostracods species were strongly positive correlated with each other ostracod in species in Lake Kamış. The most strong positive correlation was observed between F. fabaeformis and I. bradyi (r = 0.993, P < 0.01). The positive correlation was observed between all environmental variables in Lake Kamış. The most positive correlation was observed between temperature and electrical conductivity (r = 0.822, P < 0.01) while weak positive correlation was observed between temperature and dissolved oxygen (r = 0.127).

All ostracods species were strongly positive correlated with each other ostracod in species in Lake Kanlıgöl. The most strong positive correlation was observed between H. incongruens and C. vidua (r = 0.975, P < 0.01). The positive correlation was observed between all environmental variables in Lake Kamış. The most positive correlation was observed between pH and electrical conductivity (r = 0.703, P < 0.01) while weak positive correlation was observed between electrical conductivity and dissolved oxygen (r = 0.159).

All ostracods species were strongly positive correlated with each other ostracod in species in Lake Akğöl. The most strong positive correlation was observed between C. neglecta and I. biplicata (r = 0.987, P < 0.01). The most positive correlation was observed between electrical conductivity and salinity (r = 0.754, P < 0.01) while weak positive correlation was observed between electrical conductivity and temperature (r = 0.271) in Lake Akğöl. The most negative correlation was observed between temperature and dissolved oxygen (r = -0.802, P < 0.01) while weak negative correlation was observed between electrical conductivity and dissolved oxygen (r = -0.361).

4. Discussion

Faunistic studies on ostracods were performed in wetlands that with regard to similar climate, conditions and geographical characteristics [24, 27, 28, 29, 30, 31, 39].

In another study, a total of 19 ostracod species (Ilyocypris bradyi, I. gibba (Ramdohr, 1808), C. neglecta, Pseudocandona compressa, P. marchica, Eucypris mareotica (Fischer, 1855), Cypris pubera O.F. Müller, 1776, H. incongruens, C. vidua, Cypridopsis parva G.W. Müller, 1900 Syn.: Cypridopsis vidua, Cypridopsis newtoni Brady & Robertson, 1870 Syn.: P. newtoni (Brady & Robertson, 1870), C. ophthalmica, Physocypris kliei Schäfer, 1934 Syn.: Physocypris kraepelini, Cyprideis sorbyana (Jones, 1857) Blake, 1933, L. immundula, Tyrrhenocythere annicerca (Sars, 1887), Leptocythere rara (Mueller, 1894) Ruggieri, 1953, D. stevensoni, C. torosa) were recorded in Lake Terkos (Durusu)...
by Altınsaç & Yılmaz [27].

Ten ostracod species (C. ophthalmica, E. virens, C. parva, C. vidua, P. newtoni, Potamocypris unicaudata Schäfer, 1943, P. variegata, P. villosa (Jurine, 1820), P. zschokkei (Kaufmann, 1900), L. inopinata) were determined in the Omerli Dam [29]. One ostracod species (M. cordata) was determined by Altınsaç et al. [39].

A total of 24 ostracod species were determined in the Lake Hamam, Lake Pedina, Mert Lagoon, Eirkli Lagoon, and Saka Lagoon by Altınsaç [30]. Thirteen ostracod species (C. neglecta, Pseudocandona hartwigi (G.W. Müller, 1900), P. marchica, Candonopsis kingsleii, P. kraepelini, I. biplicata, E. virens, H. incongruens, Cyprinotus inaequalisv Bronstein, 1928) Syn.: Heterocypris salina, C. vidua) were determined in the Lake Hamam [30].

Fourteen species (C. neglecta, P. marchica, C. kingsleii, P. kraepelini, I. biplicata, Ilyocypris monacha (Norman, 1862), Cypris bipinosa Lucas, 1849, E. virens, Psychodromus olivaceus (Brady & Norman, 1889), H. incongruens, H. salina, C. vidua, C. torosa, C. difusa) were determined in the Mert Lagoon. Ten species (C. neglecta, F. fabaeformis, P. compressa, C. kingsleii, P. marchica, P. kraepelini, I. biplicata, Eucypris inflata Sars, 1903 Syn.: Eucypris mareotica (Fischer, 1855), H. incongruens, C. vidua) were determined in the Lake Pedina [30].

Lagoon. Four species (C. neglecta, E. inflata, H. salina, C. vidua) were determined in the Saka Lagoon by Altınsaç [30].


In another studies performed in adjacent area on ostracods was carried out in and Sakarya River Basin and Lake Sapanca [29, 38]. Sixteen ostracod species (I. biplicata, I. gibba, I. bradyi, Ilyocypris decipiens Masi, 1905, C. neglecta, C. ophthalmica, E. virens, Prionocypris zenkeri (Chyzer & Toth, 1858), H. incongruens, C. inaequalisv Herpetocypris chevreuxi (Sars, 1896), P. olivaceus, C. vidua, Potamocypris villosa (Jurine, 1820), Potamocypris zschokkei (Kaufmann, 1900), T. donetziensis) were determined in Sakarya River and its arms by Gülen & Altınsaç [23]. Twenty five ostracod species (I. gibba, I. biplicata, I. decipiens, C. neglecta, P. marchica, Cryptocandona vavraei Kaufmann, 1900, C. vidua, F. fabaeformis, Candonopsis angulata G.W. Müller, 1900, C. kingsleii, C. ophthalmica, P. marchica, C. neglecta, P. kraepelini, H. salina, H. incongruens, H. chevreuxi, P. olivaceus, C. vidua, D. stevensoni, T. donetziensis, L. immodulata) were determined in Lake Sapanca by Altınsaç [28]. Concurrent studies were performed in different adjacent wetlands during present study. Seven ostracod species (D. stevensoni, C. ophthalmica, C. neglecta, P. marchica, F. fabaeformis, H. salina, C. vidua) were determined in unnamed shallow wetland (41° 03′ 42.4″ N 30° 46′ 42.4″ E) close by Karasu village. Nine ostracod species (D. stevensoni, C. ophthalmica, I. biplicata, C. neglecta, F. fabaeformis, H. salina, C. vidua, L. inopinata, C. torosa) were determined in Sarısu Creek (41° 07′ 54″ N 30° 09′ 17.2″ E). Ten ostracod species (D. stevensoni, C. ophthalmica, I. biplicata, C. neglecta, P. compressa, P. marchica, F. fabaeformis, H. salina, C. vidua, L. inopinata) were determined in Lake Sülüklük (41° 03′ 42.4″ N 30° 46′ 42.4″ E). Many quarries naturally fill with water after abandonment and become lakes to. Such a lake was formed close by Sarısu Creek. Four ostracod species (C. ophthalmica, H. incongruens, C. vidua, I. biplicata) were determined in this lake (41° 08′ 01.7″ N 30° 09′ 14.2″ E).

Eight ostracod species (D. stevensoni, C. ophthalmica, I. biplicata, C. neglecta, F. fabaeformis, H. salina, C. vidua, L. inopinata, C. torosa) were determined in Seyrek Creek (41° 07′ 58.1″ N 30° 05′ 56.4″ E). Eight ostracod species (D. stevensoni, C. ophthalmica, I. biplicata, C. neglecta, F. fabaeformis, H. salina, C. vidua, L. inopinata) were determined in Bağırganlı Creek (41° 07′ 54″ N 30° 01′ 07.7″ E). Five ostracod species (C. ophthalmica, I. biplicata, H. salina, C. vidua, L. inopinata) were determined in Karacaköy Creek (41° 09′ 21.0″ N 29° 46′ 41.2″ E). Tyrrhenocythere donetziensis was determined in Sakaryabaşı Spring pond (39° 21′ 16.7″ N 31° 03′ 21.3″ E). Twenty-six ostracod species (D. stevensoni, C. neglecta, F. fabaeformis, P. marchica, C. kingsleii, P. kraepelini, C. ophthalmica, C. pubera, N. monacha, I. biplicata, D. sinensis, E. inflata, L. lilljeborgi, E. virens, P. zsenkeri, T. lutaria, P. olivaceus, H. incongruens, H. salina, C. vidua, P. villosa, P. newtoni, L. inopinata, C. torosa, L. inopinata, T. donetziensis) were determined in Mollarık Ponds (Mollaköy, Arefiye, Sakarya). Three ostracod species (C. torosa, H. salina, Loxoconcha elliptica Brady, 1868) were determined in Hersek Lagoon (40° 43′ 02.6″ N 29° 31′ 02.1″ E) as Mischke et al [40]. This survey includes freshwater (0 ppt), oligosaline (<0.5 ppt) and mesosaline (<5 ppt) wetlands (Fig 1). Some ostracod species can grow and reproduce normally in freshwater and low brackish water. Salinity is an effective barrier to freshwater ostracods. Results showed salinity levels were below 0.5 % at Saklıgöl, Sancagelin, Kamas, Kanlıgöl, Akgăöl, Akgăöl and Saklıgöl Lakes (see Table 1). According to classification of Brackish [41], Sarısu Lagoon is mesosaline (average salinity values 2.5 %) wetlands. Dalyan Lagoon is mesosaline (average salinity values 6 %). Sarısu lagoon is fed by the rain water, several small freshwater streams and Sarısu
Creek in the all seasons. Its only temporary outlet is in the east. The closed outlet of lagoon opens with a dipper dredger by the local administration in summer months. Thus, waters of lagoon flow to the Black Sea. For this reason, the lagoon may become much more saline during in the summer months than the spring and winter months. Eleven ostracod species (D. stevensoni, C. ophthalmica, I. biplicata, C. neglecta, P. compressa, P. marchica, F. fabaeformis, H. salina, C. vidua, C. torosa, L. inopinata) were found in Sarsu Lagoon. Four of these species (F. fabaeformis, H. salina, C. vidua, C. torosa) were determined in oligo-mesosaline water of Lake Bafa [42].

Two ostracod species (H. salina, C. torosa) were found in Dalyan Lagoon. C. torosa is accompanies to the H. salina in the coastal lagoons. H. salina and C. torosa can be found different levels of the salinity and alkalinity. Except C. torosa and H. salina, the all other ostracods were found in lower salinity levels waters of Sarsu Lagoon due to excessive freshwater input to lagoon. Also, except C. torosa, S. aculeata and H. salina, all ostracod species were found in the freshwaters of the Lake Küçükboğaz.

Major sections of determined ostracod species in this present study are tolerant of harsh conditions such as salinity, pollution, eutrophication, low oxygenation and high pH levels. The present studies were performed three brackish water habitats (Dalyan Lagoon, Sarsu Lagoon and Lake Küçükboğaz) and other six freshwater habitats. Brackish water conditions have been determined in only a small section of the Lake Küçükboğaz that it connects to the Black Sea, because, input of freshwater into the lake are higher from input of brackish water. Therefore, a large part of the lake shows typical freshwater characteristics with regard to floristic and faunistic composition.

Air temperature and precipitation are considered two external environmental factors determining of water temperatures, water levels and ion concentrations in seasonal scales. Therefore, temperature is generally main factor controlling life cycles of ostracods species. According to results of this study, individual numbers of ostracod species usually reached peak numbers in warm seasons and only occasionally in late autumn.

Substrate types are effect to absence of preference of ostracod species. Lakes Sarıcagelin, Saklıgöl and Akçağöl lakes are formed in karst depression. Material were collected from sandy substrate of Lake Saklıgöl, muddy sandy substrate of Lake Sarıcagelin, muddy-sandy substrate of Lake Akçağöl, sandy and sandy muddy of Sarsu Lagoon, sandy substrate of Dalyan Lagoon, sandy and sandy muddy substrate of Lake Küçükboğaz, sandy muddy substrate of Lake Kamış and muddy-sandy substrate of Akçagöl. All species have been found suitable substrates for their lives in present study such as thoroughly described in the publication cited [2].

The ostracod C. vidua prefers periphyton growing on Chara fragilis Desvaux to other feeding substrates [43]. Also, this species were found in periphyton of Chara vulgaris Linnaeus 1753 (Lake Saklıgöl, Sarsu Lagoon, Karacaköy Creek and Lake Sarısu) and Nitellopsis obtusa (N.A.Desvaux) J. Groves 1919 (Lake Sarıcagelin).

C. vidua, C. neglecta, C. ophthalmica, P. kraepelini, D. stevensoni, L. inopinata, H. incongruens and H. salina are eurytypic taxa. Also, their occurrences were reported in nutrient-rich, eutrophic and polluted waters [21, 31]. C. torosa is a typically euryhaline species [2]. Smooth forms of C. torosa seen at salinities >5‰ [2]. Therefore, the smooth specimens (Cyprideis torosa forma litoralis) and noded specimens (Cyprideis torosa forma torosa) of C. torosa were determined in Dalyan Lagoon, whereas, only noded specimens of C. torosa were determined Lake Küçükboğaz and Sarısu Lagoon. C. torosa were determined coastal lagoons [31] and inland saline water [44].

P. kraepelini were found in many aquatic ecosystems of Turkey [30, 31]. Except Dalyan lagoon, C. ophthalmica was found in other eight wetlands. H. salina can tolerate salinities up to 20‰ [2]. Cosmopolitan species tolerant to brackish water conditions and eutrophication [2]. Dalyan lagoon is fed with rain water, and water losses due vaporization, therefore lagoon has to harsh conditions for inhabitant organism. Hence, salinity tolerant species H. salina and C. torosa can survive in harsh conditions such as Dalyan Lagoon.

Brackish waters are preferred by S. aculeata and H. salina [2]. In spite of that, these two species can live in pure freshwaters [2]. Also, H. salina and S. aculeata were found in both freshwater and brackish water in present study. I. biplicata has been synonymized with Ilyocypris gibba [2].

We were determined non noded form (Ilyocypris forma biplicata) of I. biplicata. The most dominant species were C. ophthalmica in Lake Saklıgöl (262 specimens, 23.8 %) and Kanlıgöl (169 specimens, 16 %). The most dominant species were C. vidua in Lake Küçükboğaz (166 specimens, 14.5 %), Lake Akçağöl (80 specimens, 23.3 %), Lake kamış (186 specimens, 12.2 %) and Lake Akgöl (139 specimens, 21.2 %). The most dominant species were C. torosa in Sarısu Lagoon (265 specimens, 33.6 %) and Dalyan Lagoon (450 specimens, 62.4 %).

The most common genus was Pseudocandona (P. compressa, P. marchica, P. rostrata) at the nine wetlands. Among all samples, C. vidua dominated the ostracods by a relative abundance of 14.61% (1191 individual), followed by C. ophthalmica (12.9 %, 1052 individual) and D. stevensoni (11.4 %, 900 individual). These wetlands must be carefully monitored for protection of ecological balance due to determining of cosmopolitan or ecological plasticity wide range ostracod species in present study. Cosmopolitan species C. vidua has tolerance to low oxygenated waters [2]. D. stevensoni is cosmopolitan and ubiquitous [45].

Loxoconcha immodulata (Stepańskiys, 1958) reported in the Lake Poyrazlar [24], Lake Terkos [27], Black Sea [46], Lake Taşkışığı and Büyük Akgöl [31], Aral Sea [47], Lake Sapanc [28, 48] and Mollaköy Ponds (Mollaköy, Arifiye, Sakarya) during in these studies. These results show that L. inopinata are common species in brackish and freshwater habitats located in the Pontocaspian region (Caspian Sea, Azov Sea, Black Sea and Aral Sea ).

N. monacha lives in both permanent and temporary water bodies, and prefers shallow water with rich vegetation such as ponds and littoral of lakes [49]. N. monacha has a Holarctic distribution [2]. N. monacha prefers dense submerged emergent macrophytes belt for habitat [50] as well as lakes Kamış and Kanlıgöl.

D. stevensoni is considered with a cosmopolitan species [51, 52]. Euryhaline benthic ostracod D. stevensoni was reported in the coastal lagoons [53, 54, 55].

L. inopinata and H. incongruens are typical inhabitants of still water bodies. L. inopinata can tolerate high alkalinites [56] as in lakes Sarıcagelin and Saklıgöl.

C. neglecta has worldwide geographical distribution and wide tolerance to environmental conditions [2]. Also, accuracy of above mentioned information about of C. neglecta are confirm due to known presence of C. neglecta in very different kinds habitats of Turkey [21, 31].
Result of this study showed that these 24 species have been previously reported alive from different wetlands such as lagoons, lakes, ponds, swamp, hot springs, creeks, rivers and dams of the world and Turkey where in different levels of ecological variables and in similar habitats by many researchers.

This study has shown that, the presence, absence, distribution and composition of the ostracod species in nine wetlands related to the structure of substrates, changes of physical and chemical variables, macrophyte composition and geomorphological origin of wetlands and levels of salinity.

5. Conclusions
Finally, we are summarized our findings on Ostracoda fauna of nine wetlands as follows:
1. We collected 8147 ostracod specimens from the nine wetlands and identified them into 24 species.
2. Five cosmopolitan ostracod species (D. stenonsoni, C. opththalmica, H. salina, S. aculeata, C. vidua) of the total 24 were found in nine wetlands. At least five cosmopolitan species from nine wetlands had an important contribution to local diversity.
3. All ostracods species were significantly positive correlated with each other. 
4. Sampling wetlands according to ostracod species assemblage were clustered into three groups (1. Lagoon, 2. Coastal lakes and lagoons, 3. Typical Karstic lakes).
5. The ostracod abundance and diversity increases in warm period from late spring and early autumn
6. We found the highest diversity in May mean diversity of 3.79 in lake Kamış.

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