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# Effects of Temperature Changes on the Spatial Distribution and Ecology of Ostracod (Crustacea) Species

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## ABSTRACT

To understand the possible effects of changes in ambient temperature on spatial distribution and ecology of ostracods, samples were randomly collected from 70 aquatic sites with 12 different habitat types from Hatay (Turkey) province during the summer season of 2012. 14 of 19 ostracod species were newly reported for the province. The first two axes of CCA explained 79.7% of the cumulative variance of the relationship between the 12 most common species and five environmental variables. Accordingly, water temperature and electrical conductivity were the most effective factors on species occurrences ($p<0.05$). Estimating ecological optimum and tolerance values of species revealed that *Herpetocypris chevreuxi* and *Cypridopsis vidua* displayed the lowest and highest tolerance values for water temperature, respectively. TWINSPAN results illustrated that ostracod species can be used to determine characteristics of habitat conditions. Indeed, the co-occurrence of *H. chevreuxi* with one or more cosmopolitan species is the indication of an increase in salinity and temperature values. Results suggested that temperature changes can cause critical alteration in shallow water bodies where species with lower ecological tolerances will eventually be negatively affected. Therefore, such species, which may be called "potential candidate species for local extinction" will either be eliminated from the habitats in short term or become extinct in long term.

**Keywords:** Ecology, Ostracoda, indicator species, local extinction, Turkey

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**Sıcaklık Değişimlerinin Ostrakod (Crustacea) Türlerinin Mekansal Dağılımı ve Ekolojisi Üzerine Etkisi**

**Öz:** Ortam sıcaklığındaki değişimlerin ostrakodların mekansal dağılımı ve ekolojisi üzerindeki olası etkilerini anlamak için, 2012 yazında Hatay (Türkiye) ilinden 12 farklı habitat türüne sahip 70 su sahasından rastgele örnekler toplanmıştır. Elde edilen 19 türden 14 tanesi Hatay için yeni kayıttır. CCA'nın ilk iki ekseni en yaygın 12 tür ile beş çevresel değişken arasındaki ilişkinin toplam varyansının %79,7'sini açıklamıştır. Buna göre, su sıcaklığı ve elektriksel iletkenlik türlerin oluşu üzerinde en etkili faktörlerdir ($p<0,05$). Türlerin ekolojik optimum ve tolerans değerlerine göre, *Herpetocypris chevreuxi* ve *Cypridopsis vidua* su sıcaklığı için sırasıyla en düşük ve en yüksek tolerans değerlerini göstermiştir. TWINSPAN sonuçları, ostrakod türlerinin habitat koşullarının özelliklerini belirlemek için kullanılabileceğini göstermiştir. Özellikle *H. chevreuxi*'nin bir veya daha fazla kozmopolit türle birlikte bulunması, tuzluluk ve sıcaklık değerlerinde bir artışın göstergesidir. Sonuçlar, özellikle sığ su kütlelerinde kritik değişikliğe neden olabilen sıcaklık değişiklikleri nedeniyle düşük ekolojik toleranslı türlerin olumsuz etkileneceğini düşündürmektedir. Bu nedenle, "yerel yok olma için potansiyel aday türler" olarak adlandırılabilecek bu türler ya kısa dönemde habitatlardan elenecek ya da uzun dönemde nesli tükenme tehlikesiyle karşı karşıya kalacaktır.

**Anahtar kelimeler:** Ekoloji, Ostracoda, gösterge tür, yerel yok olma, Türkiye

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## Introduction

Extinction is not one inevitable result that organisms must face. However, it is a fact that most (if not all) species are under the threat of global and/or local extinction (Black et al. 2001; Eisenhauer et al. 2019) due to climatic and anthropogenic factors. The loss of biodiversity is especially noticeable in freshwater ecosystems. Because, cumulative effects of climate change and human-induced factors (e.g., land-use change, destruction, overexploitation) cause changing in flow regime and chemical composition of freshwaters (Dudgeon et al. 2006; Ertürk 2012; Leigh 2013). Consequently, this situation leads to critical alteration in species composition in a habitat and/or geographic distribution of species (An et al. 2013; Finlayson et al. 2013). Because, when species are faced with changes, most (if not all) of them will not be able to develop fast responses enough to the new environmental conditions. While the species may have a chance to survive as they fit the new conditions by different adaptation abilities, the others, which have restricted ecological ranges, may either become more vulnerable or die out.

Invertebrate animals, playing an important role in the continuous function of ecosystems, are examples of facing threats of extinction or rapid decline in their numbers (Benateau et al. 2019). Indeed, examples of human effect coped with local climatic factors have been illustrated in aquatic habitats along with rapid loss of invertebrates. For example, levels of response to climate change conditions were found various among different benthic invertebrates and four ecoregions in 26 European streams and rivers (Jourdan et al. 2018). Of which, an abundance of sensitive Plecoptera was declined during warmer years while the abundance of Ephemeroptera was increased in northern regions. Besides, Jourdan et al. (2018) found a significant increase in the abundance of invasive species with an increasing number of harsh days induced by climatic changes.

Of invertebrates, Ostracods (Ostracoda: Crustacea) are one of the diverse and abundant taxonomic groups with about 65000 fossil and living species (Kempf 1980, 1997). There are about 2300 subjective non-marine species distributed worldwide (Meisch et al. 2019). They are also an important element in the food chain in shallow aquatic bodies (Mesquita-Joanes et al. 2012) and work as key species on production and community metabolism of micro- or mesocosm freshwater beds (Ruiz et al. 2013). Having with wide global distribution in a variety of aquatic habitats, ostracods are considered to provide supportive evidence for environmental changes because of their species-specific habitat preferences and different levels of ecological tolerance and optimum ranges.

Combining developing technology with historical and palaeoclimatological data can help to produce future climate change scenarios. Accordingly, different future climate estimation models showed that the climate of the world with an increase in temperature and a shift in precipitation patterns has already changed (IPCC 2007). In Turkey, mean air temperature is foreseen to increase between 1°C-2°C in 2016-2040 and 1.5°C-4°C in 2041–2070, while rainfall trends are less predictable with possible increases and decreases in average precipitation rates (Demircan et al. 2017). Ragab and Prudhomme (2002) projected that amount of precipitation will decrease, and temperature will increase by about 1.75-2.5°C by the year 2050 for the Mediterranean region. In potent climate fluctuations especially the precipitation changes, in some areas such as the Mediterranean region of Anatolia where our study area Hatay province is located, is one of the susceptible areas in Turkey (Karabulut 2009).

Aside from these, Hatay province was chosen as a study area since there has been no spatially extensive and comprehensive study asking the relationship between temperature changes and their effect on ostracod assemblages. Hence, this study aimed to (i) investigate correlation between the effects of ecological changes (e.g., temperature) and distribution of individual ostracod species, and (ii) estimate species ecological tolerance and optimum values along with determining their indicator values.

## Materials and Methods

Hatay province with a surface area of 5403 km² is bordered by Syria and the Mediterranean Sea on the south-eastern and western sites, respectively (Figure 1). Having with İskenderun and Antakya ports, it is one of the heavily industrialized districts on the Mediterranean coast. Besides, organized industrial zones located around the sea, freshwater, and terrestrial ecosystems have negative effects on natural sources in its environment. Because of its location in the southern part of Turkey, the city is under the influence of the Mediterranean climate characterized by very hot, long, and dry summers with cool rainy winters. Samples were randomly collected from 12 different inland water bodies (lake, dam, pond, pool, trough, ditch, irrigation canal, creek, stream, river, waterfall, and spring) in 70 sites located at about sea level (11 m) to 740 m a.s.l of elevations. Since July and August are the hottest months of the region, we thought that sampling between 31 July and 7 August 2012 might be better to show the utmost effect of the air temperature on water bodies. Thus, materials were collected with a plankton hand net (200 μm in mesh size) from each site and stored in 250 ml of a plastic container with 70% ethanol. Then, the material was filtered over four standard sieves (1.5, 1.0, 0.5, and 0.25 mm) and ostracods separated from sediment with fine needles under the Meiji-Techno stereo microscope in the laboratory. Species description was done based on soft body parts and carapace, which are dissected and preserved in Lactophenol – Orange G solution, under the Olympus CX-41 light microscope by using different taxonomic works (Broodbakker and Danielopol 1982; Karanovic 2006, 2012;

Meisch 1984, 1985, 2000). All forms of the species are preserved at the Limnology Laboratory of Bolu Abant İzzet Baysal University, Bolu, Turkey.

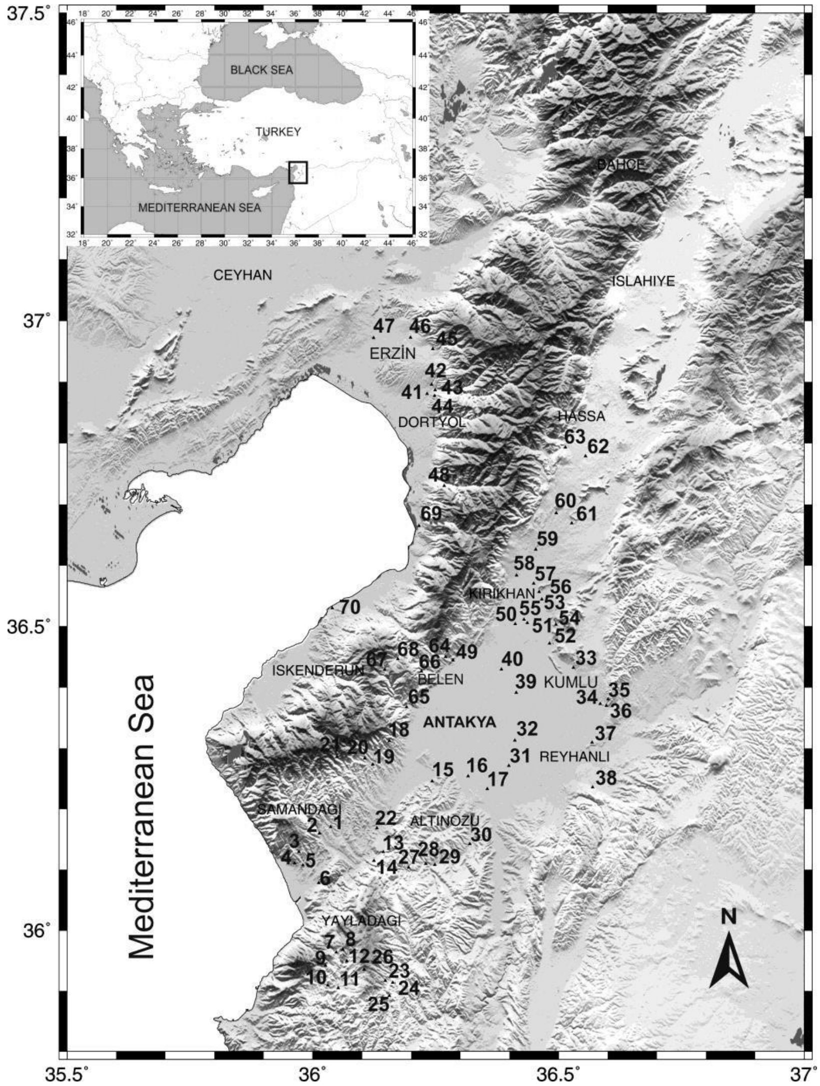


**Figure 1.** Total of 70 different sampling sites located in the Hatay province (Turkey)

During the sampling, we used a GPS 45 XL for recording the coordinate and elevation of each sampling site. While air temperature (Ta, °C) and moisture (Moi, %) were measured by Testo 410-2 model of anemometer, water temperature (Tw, °C), pH, dissolved oxygen (DO, mg $L^{-1}$), saturation (S, %), salinity (Sal, ppt), electrical conductivity (EC, µS $cm^{-1}$) and total dissolved solids (TDS, mg $L^{1}$) were measured by YSI Professional Plus Series *in situ*. The physicochemical and geographical data of stations along with distributions of the obtaining species were shown in the Appendix.

Shannon-Wiener (H') was calculated via Species Diversity and Richness, version 4 program (Seaby and Henderson 2006) to examine the species diversity within different habitat types. Canonical Correspondence Analysis (CCA) along with Monte Carlo permutation test (499 permutations) was used to determine the most effective environmental variable(s) on species (ter Braak 1986; ter Braak and Verdonschot 1995). Suitability of CCA was tested with a priori analysis of DCA (Detrended Correspondence Analyses). Length of DCA (>3) suggests possible linear correlation and suitability of the data for CCA. To reduce the influence of multicollinearity and arc-effect, rare species were automatically down-weighted, and the data was log-transformed by the program of Canoco 4. C2 program was used to calculate ecological tolerance and optimum values of individual ostracod species (Juggins 2003). In all statistical analyses, live adults occurred in at least three different samples were used while juveniles, damaged individuals, and sub-fossils were excluded from the analyses. We used Two Way Indicator Species Analysis (TWINSPAN) to estimate the indicator values of individual ostracod species among the habitats in the Community Analysis Package program (CAP 4.1.3) (Seaby and Henderson 2006). This method provides a clustering relationship among the habitats distinguished by species with positive or negative indicator values.

## Results

Total of 19 ostracod species [*Darwinula stevensoni* (Brady & Robertson 1870), *Neglecandona neglecta* (Sars, 1887), *Pseudocandona albicans* (Brady, 1864), *Cypridopsis vidua* (Müller, 1776), *Prionocypris zenkeri* (Chyzer & Toth, 1858), *Ilyocypris inermis* Kaufmann, 1900, *I. monstrifica* (Norman, 1862), *I. bradyi* Sars, 1890, *Heterocypris salina* (Brady, 1868), *H. incongruens* (Ramdohr, 1808), *Herpetocypris intermedia* Kaufmann, 1900, *H. chevreuxi* (Sars, 1896), *Psychrodromus olivaceus* (Brady & Norman, 1889), *P. fontinalis* (Wolf, 1920), *Potamocypris fallax* Fox, 1967, *P. variegata* (Brady & Norman, 1889), *Zonocypris costata* (Vávra, 1897), *Limnocythere* cf. *stationis* Vávra, 1891 and *Cyprideis torosa* (Jones, 1850)] were found 58 of 70 sites from the study area (Appendix). Additionally, carapaces of two marine ostracods (*Pokornyella* sp. and *Tenedocythere* sp.) were obtained from spring water (St. No. 14). Of the species, 14 species (*D. stevensoni, N. neglecta, P. albicans, C. vidua, P. zenkeri, I. inermis, I. monstrifica, H. intermedia, P. olivaceus, P. fontinalis, P. fallax, P. variegata, Z. costata, L.* cf. *stationis*) are new records for this area. Among the species, finding a bisexual population of *I. inermis* (Sarı et al. 2012) is important to extend the known geographical distribution of the species toward the southern parts of Turkey.

The distribution of habitat types along with a total number of species and numbers of individuals among the sampling sites at different elevational ranges were shown in Table 1. According to this, both abundance values and numbers of species were found to show a gradual decrease with increasing elevation. Besides, the majority of the stations (21 stations) with the highest habitat diversity (9 types) were found in the range of 101-200 m a.s.l. The highest species numbers (13 species) were observed at 0-100 m and 201-300 m, even though the numbers of stations were significantly different with 18 and 11 sites, respectively. On the other hand, the highest number of individuals (abundance) was calculated for 301-400 m with seven sites and 1616 individuals.

**Table 1.** Distribution of habitat types, the total number of species and individuals according to their grouped elevations with Shannon-Wiener index results for 12 different habitat types

| | 0-100 m | 101-200 m | 201-300 m | 301-400 m | 401-500 m | 501-600 m | 601-700 m | 701-800 m | No. Sta. | No. Spe. | H' | Var. H' | Exp. H' |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Spring** | | 5 | 1 | 2 | 1 | | 1 | | 10 | 7 | 1.758 | 0.029 | 5.802 |
| **Ditch** | | 1 | | | | | | | 1 | 0 | 0 | 0 | 1 |
| **Creek** | 4 | 4 | 7 | 1 | 1 | 2 | 1 | | 20 | 15 | 2.473 | 0.014 | 11.86 |
| **Stream** | 3 | 2 | 1 | 1 | | | 1 | | 8 | 11 | 2.282 | 0.031 | 9.8 |
| **River** | 2 | | | | | | | | 2 | 1 | 0 | 0 | 1 |
| **Lake** | 1 | 1 | | | | | | | 2 | 1 | 0 | 0 | 1 |
| **Dam** | | 1 | | | 1 | | | | 2 | 1 | 0 | 0 | 1 |
| **Pond** | 1 | 2 | | 1 | | 2 | | 1 | 7 | 4 | 1.386 | 0.093 | 5 |
| **Pool** | | | | | 1 | | | | 1 | 5 | 1.609 | 0.08 | 4 |
| **Waterfall** | | | 1 | | | | | | 1 | 2 | 0.693 | 0.125 | 2 |
| **Canal** | 6 | 4 | 1 | | | | | | 11 | 6 | 1.643 | 0.053 | 5.173 |
| **Trough** | 1 | 1 | | 1 | | 1 | 1 | | 5 | 4 | 1.255 | 0.051 | 3.51 |
| **No. Sta.** | 18 | 21 | 11 | 6 | 4 | 5 | 4 | 1 | 70 | | | | |
| **No. Hab.** | 7 | 9 | 5 | 5 | 4 | 3 | 4 | 1 | | | | | |
| **No. Spe.** | 13 | 10 | 13 | 7 | 8 | 6 | 6 | 2 | | | | | |
| **No. Ind.** | 415 | 328 | 535 | 1616 | 380 | 174 | 404 | 24 | | | | | |
| **All Sample Index** | | | | | | | | | | | | | 2.546 |
| **Jackknife Std Error** | | | | | | | | | | | | | 0.116 |

Abbreviations: No. Sta., number of stations; No. Hab., number of habitats; No. Spe.1, number of species; No. Ind., number of individual (abundance) for each of elevational ranges and habitat types; H', Shannon-Wiener Index value; Var. H', variance H'; Exp. H', expected H'

Among the habitat types, creeks displayed the highest species diversity (H'= 2.473) (Table 1). Following creeks, species diversity was found high in streams (H'= 2.282) and spring (H'= 1.758) waters.

The first two axes of CCA diagram explained about 79.7% of the relationship between cumulative percentage variance of species and environmental variables. Eventually, the most influential factors on species were water temperature

(*P*= 0.002, *F*= 4.327) and electrical conductivity (*P*= 0.014, *F*= 2.562) (Figure 2 a, b).

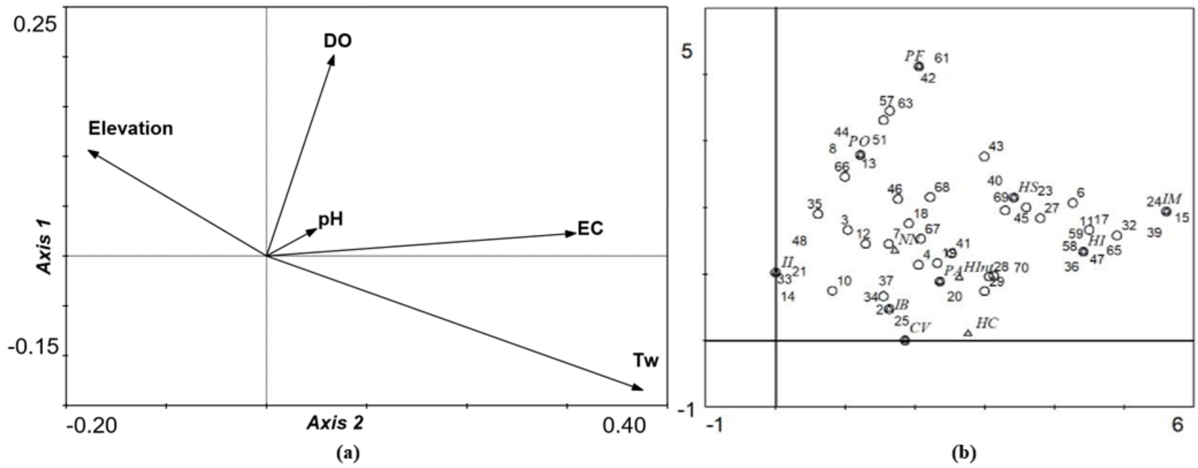


**Figure 2.** (a) The most effected environmental variable(s) on species according to CCA, (b) distribution of 12 species, occurred three or more times, with sampling sites
Abbreviations of environmental variables and species are shown in the Appendix.

According to the tolerance and optimum estimate values (Table 2) of the species, two species (*H. incongruens* and *H. salina*) displayed the highest tolerance values for dissolved oxygen and salinity (referring to electrical conductivity) while *C. vidua* and *P. albicans* showed the highest values for water temperature and pH, respectively. *H. chevreuxi* known as a pure freshwater species showed the lowest tolerance for water temperature ($t_k$= 1.29) and conductivity ($t_k$ = 75.85).

**Table 2.** Ecological tolerance ($t_k$) and optimum ($u_k$) values of 12 species which were occurred three or more times (pH, Tw, DO, EC, Sal.) with maximum, minimum, and average levels for five environmental variables.

| | | | pH | | Tw | | DO | | EC | | Sal. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Code** | **Count** | **N2** | $u_k$ | $t_k$ | $u_k$ | $t_k$ | $u_k$ | $t_k$ | $u_k$ | $t_k$ | $u_k$ | $t_k$ |
| **HC** | 3 | 1.3 | 7.42 | **0.39** | 22.54 | **1.29** | 3.04 | **2.69** | 804.96 | **75.85** | 0.41 | **0.09** |
| **PA** | 3 | 1.32 | 7.67 | **0.54** | 21.93 | **5.69** | 3.54 | **1.53** | 833.38 | **179.86** | 0.43 | **0.14** |
| **HInt** | 3 | 1.85 | 8.28 | **0.3** | 23.78 | **4.59** | 6.08 | **3.68** | 848.62 | **386.37** | 0.41 | **0.24** |
| **PO** | 17 | 3.35 | 7.95 | **0.41** | 16.95 | **3.3** | 7.51 | **2.48** | 452.04 | **237.05** | 0.25 | **0.13** |
| **PF** | 4 | 2.64 | 7.86 | **0.25** | 18.83 | **3.48** | 6.76 | **1.4** | 620.28 | **173.19** | 0.34 | **0.11** |
| **CN** | 6 | 1.74 | 7.74 | **0.49** | 20.39 | **2.74** | 4.81 | **3.06** | 719.29 | **165.61** | 0.38 | **0.13** |
| **HI** | 12 | 2.91 | 7.99 | **0.38** | 27.37 | **4.7** | 6.25 | **5.83** | 1512 | **534.34** | 0.72 | **0.29** |
| **HS** | 18 | 1.8 | 8.33 | **0.43** | 31.39 | **7.69** | 12.7 | **5.71** | 1624.8 | **560.26** | 0.7 | **0.29** |
| **CV** | 4 | 2.15 | 8.22 | **0.13** | 23.56 | **8.97** | 9.3 | **1.99** | 632.66 | **292.96** | 0.3 | **0.15** |
| **IB** | 11 | 2.77 | 7.66 | **0.35** | 18.34 | **3.18** | 6.49 | **1.26** | 506.97 | **172.02** | 0.26 | **0.08** |
| **II** | 11 | 3.97 | 7.98 | **0.35** | 22.3 | **6.58** | 8.72 | **1.75** | 614.77 | **240.31** | 0.3 | **0.11** |
| **IM** | 6 | 2.13 | 7.71 | **0.31** | 25.75 | **1.95** | 6.48 | **2.25** | 1161.1 | **1362.3** | 0.57 | **0.84** |
| | | **Mean** | 7.9 | **0.36** | 22.76 | **4.51** | 6.81 | **2.8** | 860.9 | **365.01** | 0.42 | **0.22** |
| | | **Max** | 8.33 | **0.54** | 31.39 | **8.97** | 12.7 | **5.83** | 1624.8 | **1362.3** | 0.72 | **0.84** |
| | | **Min** | 7.42 | **0.13** | 16.95 | **1.29** | 3.04 | **1.26** | 452.04 | **75.85** | 0.25 | **0.08** |
| | | **Std Error** | 0.28 | **0.11** | 4.063 | **2.34** | 2.61 | **1.56** | 379.54 | **347.8** | 0.16 | **0.21** |

Count and N2 imply numbers of species occurrence and Hill's coefficient (a measure of the effective number of occurrences), respectively. Abbreviations for species and environmental variables were given in the Appendix.

TWINSPAN results outlined that species (e.g., *H. chevreuxi*) with certain indicator values can be used to discriminate characteristics of habitats (Figure 3).

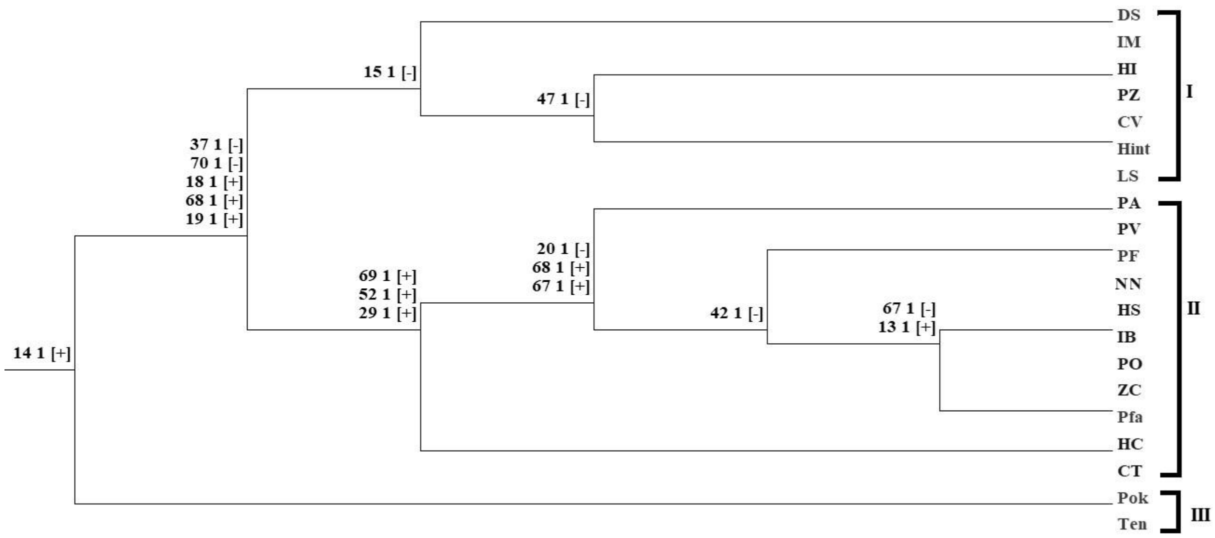


**Figure 3.** Twinspan dendrogram. Species are clustered into three groups (I-III) while habitats are shown in each node of division. Positive (+) and negative (-) values in parentheses represent the right and left sides of the branch. For abbreviations see Appendix.

## Discussion

Hartmann (1964) was the first to report five ostracod species [*Heterocypris incongruens*, *Heterocypris. salina*, *Ilyocypris bradyi*, *Herpetocypris chevreuxi* and *Potamocypris zschokkei* (Kaufmann, 1900)] from the province. Then after, Gülen (1985, 1988) found five more species in addition to *H. salina* [*Candonopsis kingsleii* (Brady & Robertson, 1870), *Eucypris virens* (Jurine, 1820), *Cypris pubera* Müller, 1776, *Tonnacypris lutaria* (Koch, 1838), *Cytherissa lacustris* (Sars, 1863)]. Most recently, Özuluğ and Kılıç (2002) listed one more species *Costa edwardsii* (Roemer, 1838), which is especially known with its preference of marine waters but can also be found in brackish waters (Meisch 2000). Four of these species (*H. incongruens, H. salina, I. bradyi* and *H. chevreuxi*) were also found during the present study. Combining the species with our 19 ostracods, total numbers of freshwater ostracods of Hatay province increased to 26.

Finding 15 of 19 species from the creeks corresponds to highest species richness (H'= 2.473) in these habitats. According to Connor and McCoy (1979) more species can be encountered with increasing sampling sites in wider areas. This suggests that there can be a positive correlation between the numbers of species and sampling sites. Thus, the fact that more species were encountered in creeks may be related to the high numbers of sampling efforts (20 out of 70 sites). On the other hand, numbers of samples alone cannot explain relatively high species diversity in different habitat types. For example, streams also had high diversity with 11 species, collected from only 8 different sites (Table 1). In such a case, we assume that habitat suitability may also play an important role in species diversity and distribution.

In general, the highest number of species was found at low elevations when the least number of species was found at high elevations. According to Rapoport's Rule (see e.g., Stevens 1992), numbers of species decrease with increasing elevation. The results of this study do not correspond to the assumption of the rule due to differences in the numbers of stations and habitat types that the greater part of the stations with more different sampling sites were already situated at low elevations. On the other hand, the situation can be explained with the "habitat diversity hypothesis" (Williams 1943) and then with ecological features that individual species showed. Some species (e.g., *H. incongruens*) with wide tolerance levels to different environmental variables exhibited a wide geographical distribution in a variety of habitats. These species so-called "cosmoecious species" (Külköylüoğlu 2013) usually display elevation free distribution. For example, during the present study, *H. salina* was reported from almost all elevations. In contrast, stenoecious species (e.g., *H. chevreuxi*) with a narrow tolerance levels to some of those environmental variables are of limited distributional ranges. This may imply that such these species do have advantages over other species. However, cosmoecious species concept does not include biological factors on species distribution that is probably effective with the arrival of species into a new area. As stated above, water temperature plays an important role for water quality and life in aquatic ecosystems (Morril et al. 2005). Besides, herein as illustrated in CCA diagram showed that water temperature was the most effective factor on species distribution ($p < 0.05$). In reality, changes in water temperature are relatively slower and narrower interval ranges than the air temperature due to physicochemical properties of water bodies (Odum and Barrett 2005). This is generally (and especially) true for deep waters. However, in the present study, ostracods were collected from shallow aquatic habitats which are more prone to the influence of changes in air temperature. This supports the idea of Preud'homme and Stefan (1992) that predictions can be better for shallow water bodies than a deeper one. In this way trends of water and air temperatures in each site were changed almost parallel to each other. Following such changes, most of the ostracod species must deal with the new conditions, to which that the species with high tolerances will have better adapted. For instance, when a freshwater habitat is altered to hypersaline waters due to increasing temperature gradients, *Cyprideis torosa* can survive approximately 30 days in dormant form (Meisch 2000), but stenoecious species can suffer from this change.

In this study, estimating ecological optimum and tolerance values of species revealed that *H. chevreuxi* displayed low tolerance values for water temperature ($t_k$= 1.29) and conductivity ($t_k$= 75.85) (Table 2). This species usually prefers stagnant waters in Turkey but there is not much ecological data about it. In a recent study, *H. chevreuxi* was found among those with low tolerance value for temperature and dissolved oxygen in the shallow waters of Bolu (Turkey) (Külköylüoğlu and Sarı 2012). If the current climatic scenarios are correct, one may consider that *H. chevreuxi* will possibly the first species put under the risk of local extinction in this region due to its low tolerance level for water temperature ($t_k$= 1.29). According to Meisch (2000), the species can be considered as pure freshwater species and its co-occurrence with one or more halophilic ostracods (e.g., *Heterocypris salina*) indicates an increase in salinity levels of that water body. Our results support this view that *H. chevreuxi* was found from five different sampling sites where the species was commonly found with one or more of those cosmopolitan species (e.g., *H. salina, H. incongruens, I. bradyi, C. vidua*) which are known to tolerate different levels of environmental variables, including high levels of salinity changes.

The first two clustering groups in TWINSPAN are separated from group III (Figure 3) with five sites where all sites (numbered as 18, 19, 37, 68, 70) were creeks. The species, *H. chevreuxi*, was only found in site 18 where the electrical conductivity value was over the freshwater range (EC 789 µS/cm). This may partially reinforce the idea that site 18 can be under the effect of increasing salinity. Six species (except *H. incongruens*) in group I have rare occurrences in creeks while species in group II have a wide distribution in several different habitat types characterized in freshwater ranges. Supporting evidence can be provided to generalize this result. Considering the dissolved oxygen level, a similar situation is applied to some of the species such as *I. bradyi* and *P. fontinalis* with low tolerance levels to dissolved oxygen as $t_k$= 1.26 and $t_k$= 1.4, respectively. One might reasonably think that since the two species have similar tolerance levels, they are in some sense ecologically equivalent. The same idea may be applied to other species with similar occurrences. Also, *C. vidua* showed a relatively low tolerance ($t_k$= 1.99) level for oxygen tolerance. Kiss (2007) explained that a low density of *C. vidua* was related to its low tolerance value for poorly oxygenated waters despite its high ecological tolerance levels. Unlike these species, the optimum and tolerance levels of cosmopolitan species such as *N. neglecta*, *H. incongruens,* and *H. salina* were generally higher than the mean values for 12 species (Table 2). Therefore, such species can be considered to tolerate fluctuations in temperature changes and other ecological factors as well.

In conclusion, inland waters, especially the shallow water bodies, are critical for species conservation, biogeochemical cycling, and hydrological management even though they occupy an only a small portion of the Earth (An et al. 2013; Zhang et al. 2020). However, because of current temperature changes elevated by human activities, ecological features of many aquatic habitats have been changed, causing a critical alteration in species composition and their geographic distribution (An et al. 2013; Finlayson et al. 2013). Additionally, it is, however, expected that some ostracod species with low tolerance levels to ecological changes can be affected by such temperature changes earlier than those with high tolerance levels. To make an assumption about which ostracod species can be disappearing in the future (or which will have more chance to survive) is important in terms of the determining of inland waters dynamics due to changes in the structure of biological communities which affect freshwater ecosystem processes negatively (Dudgeon et al. 2006). Nevertheless, long-term studies are required to use ostracods as an early warning sign of changes in shallow-water habitats.

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**Appendix.**
Some of the physicochemical and geographical data of stations and distribution of species. Abbreviations: St. No., station number; El., elevation (m); Tw, water temperature (°C); DO, dissolved oxygen (mg $L^{-1}$); S, saturation (%); EC, electrical conductivity (µS $cm^{-1}$); Sal., salinity (ppt); TDS, total dissolved solids (mg $L^{-1}$); Moi., moisture (%) NA, not available. Species codes: DS, *Darwinula stevensoni;* NN, *Neglecandona neglecta;* PA, *Pseudocandona albicans;* HI, *Heterocypris incongruens;* HS, *Heterocypris salina;* CV, *Cypridopsis vidua;* PZ, *Prionocypris zenkeri*; IB, *Ilyocypris bradyi*; II, *Ilyocypris inermis;* IM, *Ilyocypris monstrifica;* HC, *Herpetocypris chevreuxi;* HInt, *Herpetocypris intermedia;* PO, *Psychrodromus olivaceus;* PF, *Psychrodromus fontinalis;* Pfa, *Potamocypris fallax;* PV, *Potamocypris variegata;* ZC, *Zonocypris costata;* LS, *Limnocythere* cf. *stationis;* CT, *Cyprideis torosa; Pok.*sp., *Pokornyella* sp.*; Ten.sp.*, *Tenedocythere* sp. Note that species with italic represent sub-fossil (carapace or valves) forms.

| St. No | St. Name | Latitude N | Longitude E | El. | Tw | Ph | DO | S | EC | Sal. | TDS | Ta | Moi. | Species codes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Karamanlı Pond | 36° 10.109' | 036° 01.888' | NA | 29.5 | 8.49 | 6.01 | 76.7 | 592.0 | 0.26 | 0.351 | 30.8 | 56.5 | IB |
| 2 | Batı Ayaz Creek | 36° 09.606' | 036° 00.799' | NA | 28.4 | 8.69 | 7.32 | 98.3 | 496.9 | 0.22 | 0.300 | 34.7 | 63.3 | NN, IB, II, PO |
| 3 | Hıdır Bey Creek | 36° 07.767' | 035° 58.311' | 162 | 15.7 | 7.61 | 8.07 | 83.3 | 297.1 | 0.20 | 0.234 | 32.4 | 63.7 | HS, IB, PO |
| 4 | Irrigation Canal | 36° 06.910' | 035° 58.496' | 159 | 19.3 | 7.77 | 6.15 | 66.7 | 326.2 | 0.18 | 0.238 | 30.8 | 70.3 | |
| 5 | Small Ditch Water | 36° 06.598' | 035° 58.610' | 117 | 16.6 | 7.70 | 9.42 | 97.3 | 295.8 | 0.17 | 0.228 | 31.8 | 74.5 | HS, IM, *CT* |
| 6 | Asi River | 36° 04.710' | 036° 00.742' | 11 | 30.3 | 8.60 | 13.6 | 190.6 | 1076 | 0.48 | 0.637 | 36.9 | 57.2 | HS, IB, PO, *CT* |
| 7 | Leylekli Creek | 35° 57.818' | 036° 02.863' | 522 | 17.1 | 7.44 | 6.1 | 63.7 | 635 | 0.31 | 0.409 | 28.0 | 65.6 | PO |
| 8 | Through | 35° 57.237' | 036° 03.562' | 551 | 16.7 | 7.33 | 7.81 | 77.5 | 415.3 | 0.24 | 0.320 | 31.5 | 65.6 | LS |
| 9 | Leylekli Dam Lake | 35° 56.730' | 036° 03.536' | 490 | 29.4 | 8.55 | 5.24 | 68.9 | 439.7 | 0.19 | 0.262 | 34.4 | 57.8 | IB, II, PV |
| 10 | Devrent Creek | 35° 54.547' | 036° 01.833' | 426 | 20.0 | 7.28 | 2.71 | 32.1 | 630 | 0.34 | 0.448 | 30.4 | 61.4 | HI |
| 11 | Kureyşi Creek | 35° 54.268' | 036° 03.108' | 389 | 29.1 | 7.92 | 1.67 | 22.0 | 697 | 0.31 | 0.402 | 30.0 | 66.7 | NN, CV, IB, II, PO |
| 12 | Yayla Kastalı Through | 35° 56.730' | 036° 03.536' | 490 | 14.9 | 8.19 | 8.96 | 89.0 | 291.9 | 0.17 | 0.235 | 29.3 | 65.1 | PO, PFa |
| 13 | Harbiye Waterfall | 36° 07.755' | 036° 08.613' | 252 | 17.3 | 8.31 | 9.20 | 95.3 | 413 | 0.23 | 0.314 | 29.9 | 69.4 | II |
| 14 | Spring Water | 36° 06.901' | 036° 07.466' | 282 | 16.6 | 7.59 | 9.13 | 93.3 | 396 | 0.23 | 0.306 | 29.9 | 70.8 | IM, *Pok.*sp., *Ten.sp.* |
| 15 | Narlıca Creek | 36° 14.756' | 036° 14.581' | 149 | 25.3 | 7.60 | 7.10 | 86.4 | 684 | 0.33 | 0.442 | 31.5 | 65.3 | DS |
| 16 | Irrigation Canal | 36° 15.250' | 036° 18.965' | 115 | 30.8 | 7.67 | 1.77 | 2316 | 1217 | 0.54 | 0.708 | 33.0 | 58.2 | HI, HS, IM |
| 17 | Through | 36° 13.981' | 036° 21.320' | 91 | 25.4 | 7.74 | 4.67 | 58.0 | 1747 | 0.88 | 1.131 | 31.8 | 61.2 | NN, PA, HS, PO |
| 18 | Oğlakören Creek | 36° 16.970' | 036° 08.086' | 242 | 20.8 | 7.57 | 3.66 | 41.5 | 789 | 0.42 | 0.559 | 33.3 | 60.5 | HS, IB, HC, PO |
| 19 | Küçük Creek | 36° 16.748' | 036° 07.188' | 267 | 24.0 | 7.94 | 6.52 | 79.1 | 606 | 0.29 | 0.396 | 32.3 | 61.1 | PA, *PZ, HC* |

(Appendix continued)

| St. No | St. Name | Latitude N | Longitude E | El. | Tw | Ph | DO | S | EC | Sal. | TDS | Ta | Moi. | Species codes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | Karlısu Central Irrigation Pond | 36º 17.026' | 036º 06.366' | 358 | 30.0 | 8.70 | 5.67 | 75.3 | 580 | 0.26 | 0.344 | 32.0 | 49.2 | II |
| 21 | Kisecik Creek | 36º 17.152' | 036º 02.940' | 658 | 23.4 | 8.43 | 6.20 | 73.5 | 574 | 0.29 | 0.383 | 35.5 | 49.7 | |
| 22 | Asi River | 36º 10.117' | 036º 07.827' | 59 | 28.9 | 8.14 | 7.33 | 93.4 | 1221 | 0.56 | 0.741 | 33.3 | 53 | HS |
| 23 | Görentaş Through | 35º 55.036' | 036º 08.859' | 605 | 23.6 | 7.95 | 6.85 | 83.0 | 679 | 0.34 | 0.455 | 33.4 | 38.1 | IM |
| 24 | Görentaş Pond | 35º 54.807' | 036º 09.743' | 524 | 28.3 | 8.55 | 8.25 | 99.4 | 401.8 | 0.18 | 0.245 | 37.3 | 33.3 | CV, *IB* |
| 25 | Güveçci Pond | 35º 53.508' | 036º 09.337' | 529 | 30.7 | 8.76 | 8.73 | 117.7 | 555 | 0.24 | 0.325 | 35.3 | 50.0 | *HI*, *IB* |
| 26 | Yalaz Pond | 35º 56.135' | 036º 06.287' | 740 | 28.3 | 8.38 | 6.23 | 80.1 | 361.1 | 0.16 | 0.221 | 37.0 | 26.4 | HI, HS |
| 27 | Kozkalesi Through | 36º 06.221' | 036º 11.700' | 374 | 34.5 | 8.49 | 15.03 | 217 | 1941 | 0.81 | 1.066 | 35.1 | 26.5 | HS, HC |
| 28 | Kuseyri Creek | 36º 06.607' | 036º 13.785' | 252 | 22.3 | 7.35 | 2.53 | 29.5 | 831 | 0.43 | 0.572 | 33.6 | 41.9 | HS, HC |
| 29 | Tokaçlı Creek | 36º 06.507' | 036º 14.913' | 231 | 24.8 | 7.69 | 5.23 | 67.0 | 818 | 0.40 | 0.533 | 34.0 | 51.9 | *CT* |
| 30 | Yarseli Dam Lake | 36º 08.554' | 036º 19.148' | 177 | 29.6 | 8.08 | 6.86 | 91.2 | 855 | 0.38 | 0.513 | 35.0 | 49.5 | |
| 31 | Irrigation Canal | 36º 16.271' | 036º 23.918' | 93 | 28.4 | 7.78 | 3.72 | 48.1 | 1209 | 0.66 | 0.741 | 34.3 | 50 | HI, IM |
| 32 | Afrin Irrigation Canal | 36º 18.764' | 036º 24.655' | 109 | 27.2 | 8.19 | 3.41 | 44.5 | 963 | 0.45 | 0.598 | 34.6 | 46.9 | II |
| 33 | Akpınar Creek | 36º 25.939' | 036º 31.810' | 92 | 22.2 | 7.68 | 6.71 | 72.2 | 682 | 0.35 | 0.468 | 31.8 | 52.5 | IB |
| 34 | Spring Water | 36º 22.664' | 036º 35.671' | 114 | 29.5 | 7.56 | 4.29 | 56.4 | 804 | 0.36 | 0.481 | NA | 51.6 | II, PO |
| 35 | Spring Water | 36º 22.574' | 036º 35.675' | 114 | 24.4 | 7.22 | 2.89 | 34.6 | 727 | 0.36 | 0.474 | 37.3 | 51.6 | HI |
| 36 | Spring Water | 36º 22.433' | 036º 35.753' | 111 | 34.8 | 6.84 | 1.44 | 21.9 | 2743 | 1.40 | 1.781 | 40.3 | 49.2 | HI, CV, IB, II, LS |
| 37 | Afrin Stream | 36º 18.259' | 036º 32.796' | 85 | 28.4 | 8.22 | 9.96 | 128 | 815 | 0.37 | 0.494 | 41.3 | 33.6 | |
| 38 | Yenişehir Lake | 36º 14.173' | 036º 34.165' | 177 | 29.8 | 8.11 | 6.92 | 94.4 | 622 | 0.27 | 0.370 | 35.2 | 39.8 | IM, *PZ* |
| 39 | Murat Paşa Irrigation Canal | 36º 23.497' | 036º 24.828' | 98 | 33.1 | 8.01 | 7.40 | 107.8 | 9205 | 4.36 | 5.187 | 37.5 | 40.5 | HS |
| 40 | Comba Irrigation Canal | 36º 25.794' | 036º 23.026' | 76 | 32.1 | 8.16 | 4.39 | 59.7 | 1418 | 0.64 | 0.851 | 35.3 | 37.7 | CT, HS, IB |
| 41 | Deli Stream | 36º 52.846' | 036º 13.957' | 98 | 19.6 | 8.41 | 8.77 | 97.2 | 520 | 0.28 | 0.377 | 32.2 | 59.4 | |
| 42 | Spring Water | 36º 53.218' | 036º 14.947' | 132 | NA | NA | NA | NA | NA | NA | NA | 31.3 | 59.6 | HS, PF |

(Appendix continued)

| St. No | St. Name | Latitude N | Longitude E | El. | Tw | Ph | DO | S | EC | Sal. | TDS | Ta | Moi. | Species codes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 43 | Spring Water | 36º 53.218' | 036º 14.947' | NA | 19.9 | 7.91 | 77.8 | 7.22 | 797 | 0.44 | 0.572 | NA | NA | PO |
| 44 | Sulu Creek | 36º 52.654' | 036º 14.841' | 207 | 22.5 | 8.48 | 7.71 | 89 | 561 | 0.29 | NA | 32.2 | 56.9 | HS, HI, *IB* |
| 45 | Irrigation Canal | 36º 57.232' | 036º 14.669' | 295 | 23.3 | 8.47 | 9.07 | 108.6 | 1133 | 0.58 | 0.767 | 37.1 | 46.3 | NN, HS, II, PO |
| 46 | Acısu Spring Water | 36º 57.564' | 036º 15.878' | 391 | 19.4 | 7.85 | 104.7 | 9.36 | 1115 | 0.62 | 0.812 | 32.0 | 61.2 | HI, PZ, *II* |
| 47 | İssos Creek | 36º 58.325' | 036º 07.425' | 62 | 32.2 | 8.44 | 5.11 | 71.3 | 674 | 0.25 | 0.383 | 37.9 | 61.2 | II |
| 48 | Virgin Mary Spring Water | 36º 43.852' | 036º 16.043' | 601 | 16.0 | 8.14 | 9.42 | 95.8 | 501 | 0.30 | 0.396 | 30.4 | 71.2 | |
| 49 | Creek | 36º 26.668' | 036º 17.119' | 298 | 26.3 | 8.46 | 7.98 | 99.3 | 419.6 | NA | 0.266 | 35.9 | 50.1 | |
| 50 | Karasu Stream | 36º 30.265' | 036º 24.717' | 181 | 25.2 | 8.11 | 6.16 | 73.6 | 796 | 0.39 | 0.513 | 34.4 | 45.1 | PO |
| 51 | Irrigation Canal | 36º 30.361' | 036º 26.209' | 131 | 27.6 | 8.04 | 4.06 | 55.3 | 670 | 0.31 | 0.416 | 36.5 | 40.4 | |
| 52 | Irrigation Canal | 36º 28.350' | 036º 28.881' | 91 | 29.4 | 7.74 | 2.28 | 30.9 | 769 | 0.34 | 0.461 | 38.1 | 48.4 | CT |
| 53 | Irrigation Canal | 36º 32.698' | 036º 27.946' | 88 | 25.8 | 8.16 | 5.68 | 70.7 | 617 | 0.29 | 0.396 | 41.2 | 44.4 | |
| 54 | Gülbaşı Lake | 36º 30.193' | 036º 29.667' | 89 | 30.0 | 7.85 | 123.3 | 9.19 | 787 | 0.35 | 0.469 | 40.2 | 27.8 | |
| 55 | Irrigation Canal | 36º 30.713' | 036º 25.767' | 92 | 30.4 | 8.24 | 6.53 | 88.9 | 635 | 0.28 | 0.377 | 40.1 | 50.1 | II |
| 56 | Creek | 36º 33.420' | 036º 27.629' | 87 | 26.9 | 8.07 | 5.93 | 74.7 | 614 | 0.29 | 0.383 | 38.8 | 44.1 | PO, PF |
| 57 | Çamsarı Pond | 36º 34.236' | 036º 26.957' | 94 | 26.5 | 8.22 | 6.86 | 73.5 | 649 | 0.30 | 0.409 | 42.3 | 38.8 | HI |
| 58 | Güzelce Through | 36º 35.023' | 036º 24.879' | 107 | 24.9 | 8.14 | 151 | 12.42 | 594 | 0.29 | 0.390 | 41.9 | 38.8 | HI |
| 59 | Irrigation Canal | 36º 37.586' | 036º 27.233' | 142 | 19.8 | 7.90 | 8.98 | 98.9 | 598 | 0.32 | 0.435 | 37.6 | 38.4 | |
| 60 | Karapınar Creek | 36º 41.147' | 036º 29.728' | 216 | 26.8 | 8.13 | 109.1 | 8.79 | 450.6 | 0.21 | 0.292 | 38.9 | 36.9 | PF |
| 61 | Stream | 36º 40.173' | 036º 31.623' | 202 | 19.9 | 8.29 | 8.04 | 89.6 | 345.3 | 0.18 | 0.248 | 47.9 | 24.8 | DS |
| 62 | Höpüren Stream | 36º 46.743' | 036º 33.292' | 336 | 26.0 | 8.21 | 8.28 | 104.6 | 663 | 0.31 | 0.422 | 39.3 | 24.8 | PO, PF, II |
| 63 | İncesu Spring Water | 36º 47.598' | 036º 30.837' | 427 | 16.3 | 7.67 | 55.2 | 5.15 | 484.6 | 0.28 | 0.378 | 36.2 | 33.5 | |
| 64 | Çakallı-Topboğazı Pond | 36º 27.003' | 036º 16.203 | 180 | 26.8 | 8.47 | 7.66 | 96.3 | 417.7 | 0.19 | 0.262 | 30.5 | 61.5 | HI |
| 65 | Serinyol Creek | 36º 22.080' | 036º 11.426' | 177 | 24.7 | 7.86 | 5.36 | 67 | 765 | 0.37 | 0.500 | 32.0 | 49.1 | II, PO |

(Appendix continued)

| St. No | St. Name | Latitude N | Longitude E | El. | Tw | Ph | DO | S | EC | Sal. | TDS | Ta | Moi. | Species codes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 66 | Bakras Spring Water | 36º 25.598' | 036º 13.259' | 361 | 22.2 | 8.66 | 8.06 | 92.1 | 844 | 0.44 | 0.578 | 35.0 | 41.2 | NN, HS, IB, HInt, PO |
| 67 | Fengin Stream | 36º 25.769' | 036º 08.786' | 679 | 21.7 | 8.40 | 7.57 | 87 | 608 | 0.30 | 0.403 | 31.9 | 47.9 | NN, HS, PO, ZC |
| 68 | Benli Creek | 36º 26.805' | 036º 10.358' | 591 | 22.7 | 8.44 | 8.29 | 97.1 | 755 | 0.39 | 0.513 | 31.5 | 39.8 | HS, HInt |
| 69 | Sarıseki Stream | 36º 39.912' | 036º 12.960' | 40 | 28.3 | 7.68 | 6.27 | 82.3 | 1555 | 0.73 | 0.949 | 33.5 | 47.5 | PA, HI, CV, HInt |
| 70 | Büyükdere Creek | 36º 31.837' | 036º 02.383' | 23 | 28.5 | 8.13 | 1.56 | 19.2 | 1335 | 0.62 | 0.812 | 39.3 | 44.4 | |

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# The Comparative Gut Content Analysis of Some Chironomidae Larvae Living in the Freshwaters at Northern Thrace Region of Turkey

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**A B S T R A C T**

The roles of larval chironomids in the food chain of both the lotic and the lentic ecosystems are very important. On the one hand, chironomid larvae feeding on algae, diatoms, rotting organic matter, plant, and animal residues also play an important role in these systems as a source of food for other carnivores and omnivorous organisms. In this study, the gut contents of *Cryptochironomus defectus* (Kieffer, 1913), *Cladotanytarsus mancus* (Walker, 1856), *Polypedilum scalaenum* (Schrank, 1803), *Tanypus kraatzi* (Kieffer, 1912) collected from the freshwater ecosystems located in the northern parts of the Thrace region of Turkey were analyzed to compare their feeding habits. As a result of the analysis, it was determined that while plant fragments were dominant in *C. defectus* species in the gut content (44.3%), algae were dominant for *C. mancus* (44.7%), *P. scalaenum* (63.5%), *T. kraatzi* (65%). According to the results of the Shannon-Wiener (H') index species, diversity of the *P. scalaenum* was found to be the highest among the larvae (H'= 1.345). Also, according to the Bray-Curtis similarity index, the most similar types of gut contents were *P. scalaenum* and *C. defectus* (38%). This low rate indicated that the species have different food preferences.

**Keywords:** Chironomidae, gut content, food chain, Turkish Thrace

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## Türkiye'nin Kuzey Trakya Bölgesi'ndeki Tatlı Sularda Yaşayan Bazı Chironomidae Larvalarının Karşılaştırmalı Mide İçerik Analizi

**Öz:** Gerek lotik gerekse lentik ekosistemlerin besin zincirinde larval chironomidlerin rolü oldukça büyüktür. Ayrıca, algler, diyatomlar, çürüyen organik madde, bitki ve hayvan kalıntıları ile beslenen chironomid larvaları, bu sistemlerde diğer karnivor ve omnivor organizmalar için bir besin kaynağı olarak da önemli bir rol oynamaktadır. Bu çalışmada, Trakya Bölgesi'nin kuzey bölgelerinde bulunan tatlı su ekosistemlerinden toplanan *Cryptochironomus defectus* (Kieffer, 1913), *Cladotanytarsus mancus* (Walker, 1856), *Polypedilum scalaenum* (Schrank, 1803), *Tanypus kraatzi* (Kieffer, 1912) türlerinin mide içerikleri, bu türlerin beslenme alışkanlıklarını karşılaştırmak için analiz edildi. Analiz sonucunda *C. defectus*'un mide içeriğinde (%44,3) bitki parçalarının baskın olduğu, *C. mancus* (%44,7), *P. scalaenum* (%63,5), *T kraatzi* (%65) için alglerin baskın olduğu belirlendi. Shannon-Wiener (H ') indeksi sonuçlarına göre, *P. scalaenum'*un mide içeriğinin çeşitliliğinin larvalar arasında en yüksek olduğu bulundu (H' = 1,345). Ayrıca, Bray-Curtis benzerlik endeksine göre, mide içeriği en benzer *P. scalaenum* ve *C. defectus* olduğu saptandı (%38). Bu düşük oran, türlerin farklı besin tercihlerine sahip olduğunu gösterdi.

**Anahtar kelimeler:** Chironomidae, mide içeriği, besin zinciri, Türkiye Trakya'sı

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## Introduction

Gut content analysis of chironomid larvae provides significant data on their ecological and biological structure, importance in the food chain, habitat use, and modes of feed (Armitage et al. 1995; Manko 2016). In an aquatic ecosystem, chironomid larvae have an important place since they are the most abundant organisms and have an important role in the food chain by being the food of fish, other aquatic invertebrates and by feeding on algae, detritus, associated microorganisms, fungi, woody debris, macrophytes, other aquatic invertebrates (Armitage et al. 1995; Epler 2001; Butakka et al. 2016). Therefore, it can be said that chironomid larvae are an important connection point of the food web in an aquatic ecosystem by being a bridge between producers and consumers (Silva et al. 2008). The gut content studies of chironomid larvae provide important insights into the modes of feeding and according to based on larval feeding modes chironomids can be grouped into collector-gatherers, collector-filterers, scrapers, shredders, engulfers, and piercers (Armitage et al. 1995). But it is important to know that most chironomid larvae are not limited to a single mode of feeding and it is based on larval size, food size and quality, sediment composition (Armitage et al. 1995; Kornijo´w et al. 2019). The other factor on the chironomids feeding is swallowing food non-selectively and selectively in accordance with food availability, type, and size (Armatige et al. 1995). Studies of chironomid feeding show that the diet of chironomids constitutes of detritus and associated microorganisms, macrophytes, invertebrates, and especially algae (Baker and Mclachlan 1979; Armitage et al. 1995; Sanseverino and Nessimian 2008; Butakka et al. 2016; Öterler et al. 2018; Kornijo´w et al. 2019).

In this study, it was aimed to analyze the gut contents of the four species (*Cryptochironomus defectus, Cladotanytarsus mancus, Polypedilum scalaenum,* and *Tanypus kraatzi*) collected from freshwater resources at the Northern Thrace Region of Turkey and make comparisons about the feeding modes and feeding similarities of the species.

## Materials and Methods

### Sampling

The Thrace Region is the European Part of Turkey and was surrounded by Bulgaria, Greece, and the Black Sea (Figure 1). The material of the study was collected at ten different freshwater resources located in the northern parts of the Thrace region between June 2012 and August 2012. The locality names, habitat features, and coordinates were given in Table 1. The sediment samples were taken by a hand mud scoop net and the obtained material was washed through mesh nets then preserved in 250 cc plastic bottles containing 70% ethanol. In the laboratory, chironomid larvae were selected from the sediment using a binocular stereomicroscope.

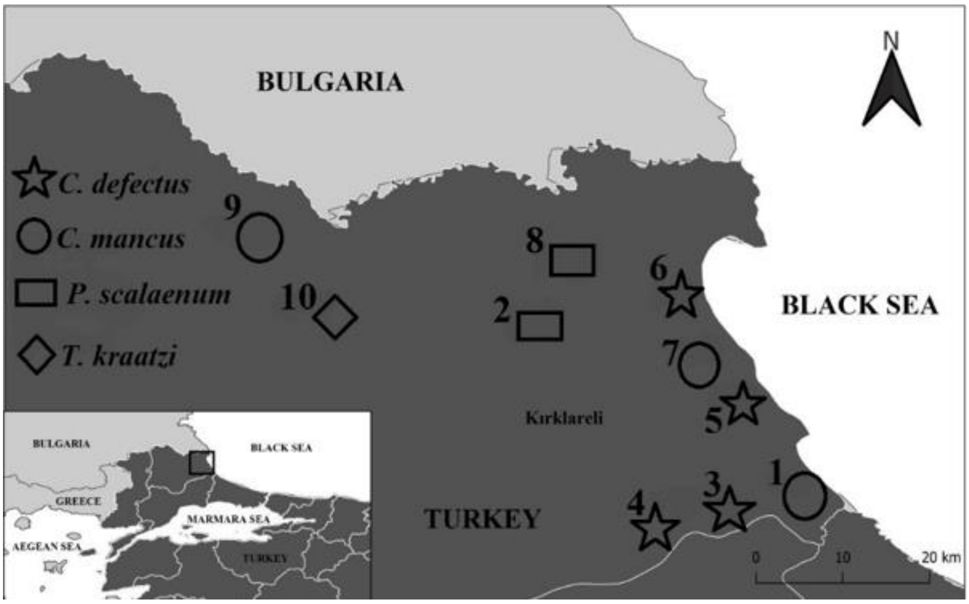


**Figure 1.** Locations of sampling sites of the chironomid larvae.

### Analyses

For the larval identification, Saether (1980), Fittkau and Roback (1983), Pinder and Reiss (1983), Epler (2001), and Vallenduuk and Morozova (2005) were followed. The fourth instar stage of the samples was selected among the material for the gut content analysis. Ten specimens for each species were used to analyze the gut contents. Each chosen specimen was placed into petri dishes containing 1 ml of 70% ethanol and dissected to reveal the gut contents by using a needle under a binocular stereo-microscope. The diffused material in the petri dish was infused into a Sedgewick-Rafter count chamber with a 1 ml volume. All of the organic and inorganic materials in the gut contents were counted. Algal bio-volume was estimated from the abundancedata and measurements of specific cell volumes by approximating geometric shapes of the cells (Hillebrand et al. 1999; Sun and Liu 2003). Identifications were performed at 1000x magnification under immersion oil, and identification of the taxa was based on the literature (Huber-Pestalozzi 1982; John et al. 2002; Krammer and Lange-Bertalot 1986-2004; Round et al. 1990;

Komárek and Anagnostidis 2005; Hindak 2008; Kristiansen and Preisig 2011). All of the determined species were confirmed using AlgaeBase, an electronic database of algae information hosted by the National University of Ireland (Guiry and Guiry 2020).

**Table 1.** The features of the locations where the larvae were collected.

| Locations | Locality Name | Habitat | Coordinates |
|---|---|---|---|
| Loc.1 | Kazandere Brook | Stream | 41°37′57″N, 28°05′12″E |
| Loc.2 | Kömürköy Brook | Stream | 41°40′18″N, 26°33′40″E |
| Loc.3 | Kazandere Dam Lake | Lake | 41°37′49″N, 28°05′14″E |
| Loc.4 | Pabuçdere/Kıyıköy | Stream | 41°39′55″N, 27°57′30″E |
| Loc.5 | Pabuçdere/Hamidiye | Stream | 41°39′55″N, 27°57′30″E |
| Loc.6 | Saka Brook | Stream | 41°48′42″N, 27°57′02″E |
| Loc.7 | Saka Lake | Lake | 41°48′00″N, 27°59′40″E |
| Loc.8 | Pedina Lake | Lake | 41°50′01″N, 27°56′05″E |
| Loc.9 | Dereköy Brook | Stream | 41°55′48″N, 27°22′14″E |
| Loc.10 | Armağan Village | Pond | 41°52′31″N, 27°25′43″E |

### Data Analysis

Shannon-Wiener index was used for the evaluation of the species diversity of the larval gut contents. The Bray-Curtis and Correspondence index analyses were used to determine the similarities of the gut contents of the species. Analyses were carried out with the XLSTAT-ADA statistical package program (Addinsoft 2015) and Graphpad PRISM software, trial version (Intuitive Software for Science, San Diego, CA).

## Results

Four species were determined in the studied area (*Cryptochironomus defectus*, *Cladotanytarsus mancus*, *Polypedilum scalaenum*, *Tanypus kraatzi)*. While a total of 81 algal species were determined in the gut contents of the larvae, it was observed that the other food fragments belonged to plants, animals, and fungi. The analyses showed that the gut contents of the larvae consisted of algae (52.7%) followed by plant fragments (27.8%), animal fragments (10.2%), and fungi spores (9.3%) (Figure 2). These proportional data belonged to only approximately 50-70% of the alimentary tract of larvae. Because the data in our study included gut content data other than detritus. It is known that detrital components (non-living organic and inorganic matter, microorganisms, bacteria), constitute about 50% of the gut contents and some larvae could complete the larval stage on the detrital components (Rodina 1971).

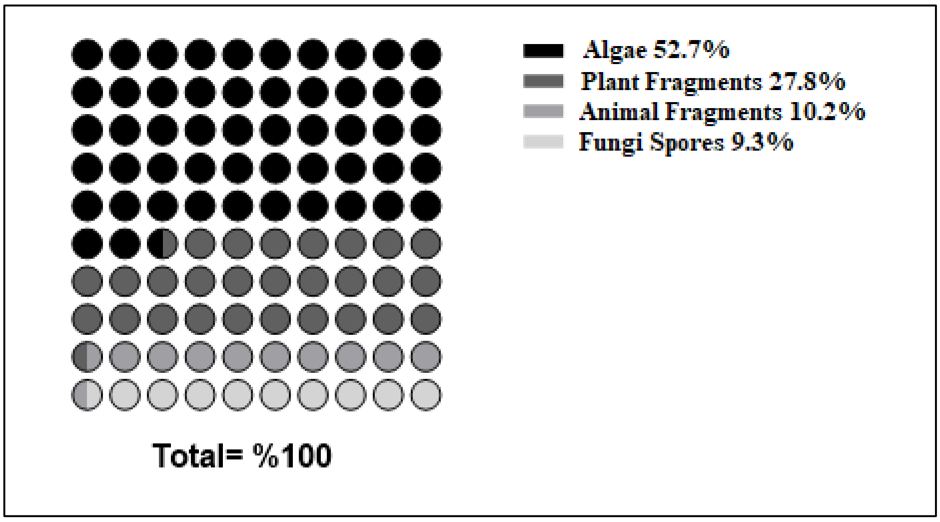


**Figure 2.** The composition of food items observed in gut contents of the chironomid larvae.

The results of the analyses showed that plant fragments were the dominant diet of the gut content of *C. defectus* (44.3%) followed by algae (37.3%), fungi spores (12.7%), and animal fragments (5.7%). Algae were the dominant diet of the gut content of *P. scalaenum* (63.5%) followed by fungi spores (19%), plant fragments (16.5%), and animal fragments (1%). In the gut content of *C. mancus,* algae were dominant (44.7%) and were followed by plant fragments (32%), animal fragments (18.7%), and fungi spores (4.6%). The gut content of *T. kraatzi* consisted of algae (65%), plant fragments (18.5%), animal fragments (15.5%), and fungi spores (1%) (Figure 3).

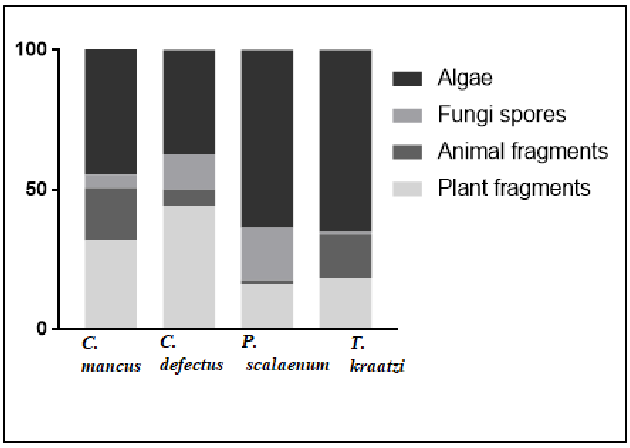


**Figure 3.** The gut contents of the determined chironomid larvae.

A total of 81 taxa belonging to 5 algal divisions were found in the gut contents of the four chironomid larvae (Table 2). They were Bacillariophyta (with 57 taxa), Euglenophyta (with 1 taxon), Chlorophyta (with 9 taxa), Cyanophyta (with 7 taxa), and Charophyta (with 7 taxa). Based on the data of the algal composition of the larvae, diatoms were dominant for all species (Figure 4). However, euglenoids were found only on the gut content of *T. kraatzi* (Figure 4). Several gut content studies reporting benthic algae as the basic food source for chironomids showed that diatoms especially constitute most of the diet (Tarkowska-Kukuryk 2013; Butakka et al. 2016; Kornijo´w et al. 2019). Members of the subfamily Chironominae, known as non-predatory fed primarily on algae especially diatoms, and in this study the algal diet of *C. defectus*, *C. mancus* and *P. scalaenum* (members of subfamily Chironominae) consisted of mostly diatoms (Figure 4). However, the diatom preference is not restricted to taxa considered to be non-predators. Although subfamily Tanypodinae is known as a predator, as determined in our study members of *Tanypus* genus can preference diatoms as a major food source (Armitage et al. 1995; Galizzi et al. 2012).

**Table 2.** The composition of gut contents of chironomid larvae.

| | *C. mancus* | *C. defectus* | *P. scalaenum* | *T. kraatzi* |
|---|---|---|---|---|
| Kingdom: Chromista | | | | |
| Phylum: Bacillariophyta | | | | |
| Class: Coscinodiscophyceae | | | | |
| *Melosira varians* C.Agardh 1827 | | + | | |
| Class: Mediophyceae | | | | |
| *Cyclotella meneghiniana* Kützing 1844 | + | + | + | + |
| *Stephanodiscus hantzschii* Grunow 1880 | | | + | |
| Class: Bacillariophyceae | | | | |
| *Lemnicola exigua* Grunow 1880 | | + | | |
| *Planothidium lanceolatum* (Brébisson ex Kützing) Lange-Bertalot 1999 | + | | + | |
| *Achnanthes armillaris* (O.F.Müller) Guiry 2019 | | | + | |
| *Achnanthidium minutissimum* (Kützing) Czarnecki 1994 | + | | + | + |
| *Achnanthidium* sp. | | + | | |
| *Amphora ovalis* (Kützing) Kützing 1844 | | + | | |
| *Caloneis* sp. | | | | + |
| *Caloneis amphisbaena* (Bory) Cleve 1894 | | | | + |
| *Cocconeis* sp. | | | | + |
| *Cocconeis placentula* Ehrenberg 1838 | + | + | + | |
| *Craticula* sp. | | | + | |
| *Craticula cuspidata* (Kutzing) D.G.Mann 1990 | | | | + |
| *Cymbella* sp. | | | + | |
| *Cymbella affinis* Kützing; 1844 | | | + | + |
| *Cymbella cistula* (Ehrenberg) O.Kirchner 1878 | + | | | + |

**Table 2.** Continued.

| | *C. mancus* | *C. defectus* | *P. scalaenum* | *T. kraatzi* |
|---|---|---|---|---|
| *Cymbella excisa* Kützing 1844 | + | | | |
| *Brebissonia lanceolata* (C.Agardh) Mahoney & Reimer, 1986 | | | | + |
| *Cymbopleura naviculiformis* (Auerswald ex Heiberg) Krammer 2003 | + | + | | |
| *Denticula* sp. | + | | | |
| *Denticula elegans* Kützing 1844 | | + | | |
| *Diatoma vulgaris* Bory 1824 | | | + | |
| *Encyonema minutum* Cholnoky) D.B.Czarnecki 1994 | | | + | |
| *Encyonema silesiacum* (Bleisch) D.G.Mann in Round, R.M.Crawford & D.G.Mann 1990 | + | | | |
| *Epithemia* sp. | | + | | |
| *Epithemia sorex* Kützing 1844 | | | | + |
| *Epithemia turgida* Kützing 1844 | + | + | | |
| *Epithemia adnata* (Kützing) Brébisson 1838 | + | | | |
| *Fragilaria capucina* (Kützing) Lange-Bertalot 1980 | | | | + |
| *Ulnaria ulna* (Nitzsch) Compère; 2001 | + | + | + | + |
| *Gomphonema* sp. | | | | + |
| *Gomphonema acuminatum* Ehrenberg 1832 | | | | + |
| *Gomphonema gracile* Ehrenberg 1838 | + | | | |
| *Gomphonema parvulum* (Kützing) Kützing 1849 | + | + | + | + |
| *Gomphonema truncatum* Ehrenberg 1832 | | | | + |
| *Hannaea* sp. | | + | | |
| *Hannaea arcus* (Ehrenberg) R.M.Patrick 1966 | + | | | |
| *Meridion circulare* (Greville) C.Agardh 1831 | | + | + | + |
| *Navicula* sp. | + | + | + | + |
| *Hippodonta capitata* (Ehrenberg) Lange-Bertalot, Metzeltin & Witkowski 1996 | + | + | + | + |
| *Navicula cryptocephala* Kützing 1844 | | | + | + |
| *Navicula lanceolata* Ehrenberg 1838 | | | + | |
| *Navicula tripunctata* (O.F.Müller) Bory 1822 | + | | | + |
| *Navicula viridula* (Kützing) Ehrenberg 1836 | + | + | | |
| *Neidium affine* (Ehrenberg) Pfitzer 1871 | | + | | + |
| *Nitzschia* sp. | + | + | + | + |
| *Nitzschia denticula* Grunow 1880 | | | | + |
| *Nitzschia palea* (Kützing) W.Smith 1856 | + | + | | |
| *Nitzschia recta* Hantzsch ex Rabenhorst 1862 | + | | | + |
| *Nitzschia sigmoidea* (Nitzsch) W.Smith 1853 | | | | + |
| *Pinnularia* sp. | | | + | + |
| *Pinnularia viridis* (Nitzsch) Ehrenberg 1843 | | | | + |
| *Rhoicosphenia curvata* (Kützing) Grunow 1860 | | | + | |
| *Surirella brebissonii* Krammer and Lange-Bert. 1987 | + | | | |
| *Tabellaria flocculosa* (Roth) Kützing 1844 | | + | | |

**Table 2.** Continued.

| | *C. mancus* | *C. defectus* | *P. scalaenum* | *T. kraatzi* |
|---|---|---|---|---|
| Kingdom: Plantae | | | | |
| Phylum: Chlorophyta | | | | |
| Class: Chlorophyceae | | | | |
| *Tetraëdron minimum* (A.Braun) Hansgirg 1889 | | | + | |
| *Desmodesmus opoliensis* (P.G.Richter) E.Hegewald 2000 | | | + | |
| *Tetradesmus dimorphus* (Turpin) M.J.Wynne 2016 | | + | | |
| *Tetradesmus lagerheimii* M.J.Wynne & Guiry 2016 | + | | | |
| *Desmodesmus intermedius* (Chodat) E.Hegewald 2000 | + | | | |
| *Scenedesmus quadricauda* (Turpin) Brébisson in Brébisson & Godey 1835 | | | + | |
| *Kirchneriella lunaris* (Kirchner) Möbius 1894 | + | | | |
| *Chlamydomonas* sp. | + | | | |
| Class: Trebouxiophyceae | | | | |
| *Oocystis* sp. | | | | + |
| Phylum: Charophyta | | | | |
| Class: Zygnematophyceae | | | | |
| *Closterium littorale* F.Gay 1884 | | | | + |
| *Closterium lunula* Ehrenberg & Hemprich ex Ralfs 1848 | | | | + |
| *Closterium* sp. | | | | + |
| *Cosmarium* sp. | | | | + |
| *Spirogyra* sp. | | | | + |
| Class: Ulvophyceae | | | | |
| *Cladophora glomerata* (Linnaeus) Kützing 1843 | | | | + |
| *Cladophora* sp. | + | | + | + |
| Kingdom: Protozoa | | | | |
| Phylum: Euglenozoa | | | | |
| Class: Euglenophyceae | | | | |
| *Trachelomonas volvocina* (Ehrenberg) Ehrenberg 1834 | | | | + |
| Kingdom: Eubacteria | | | | |
| Phylum: Cyanobacteria | | | | |
| Class: Cyanophyceae | | | | |
| *Anabaena* sp. | + | | | |
| *Chroococcus* sp. | | + | | |
| *Chroococcus minimus* (Keissler) Lemmermann 1904 | + | | | |
| *Kamptonema formosum* (Bory de Saint-Vincent ex Gomont, 1892) Strunecky et al., 2014 | | + | | |
| *Leptolyngbya boryana* (Gomont) Anagnostidis & Komárek 1988 | | + | | |
| *Lyngbya majuscula* Harvey ex Gomont 1892 | | | + | |
| *Oscillatoria princeps* Vaucher ex Gomont 1892 | + | + | + | |
| Plant Fragments | + | + | + | + |

**Table 2.** Continued.

| | *C. mancus* | *C. defectus* | *P. scalaenum* | *T. kraatzi* |
|---|---|---|---|---|
| Animal Fragments | + | + | + | + |
| Fungi Spores | + | + | + | + |
| Fungi Hyphal | | + | + | |
| Pollen | + | + | + | + |
| Protozoan | + | | | + |

According to the Shannon-Wiener index results, *P. scalaenum* has the richest diversity (H'= 1.345) followed by *C. defectus* (H'= 1.303), *C. mancus* (H'= 1.063), and *T. kraatzi* (H'= 0.834) (Figure 5). According to the Bray-Curtis similarity index, while the most similar types of gut contents were *P. scalaenum* and *C. defectus* (38%), *T. kraatzi* had different gut content from the other species (Figure 6). These results were supported by Correspondence analysis (Figure 7).

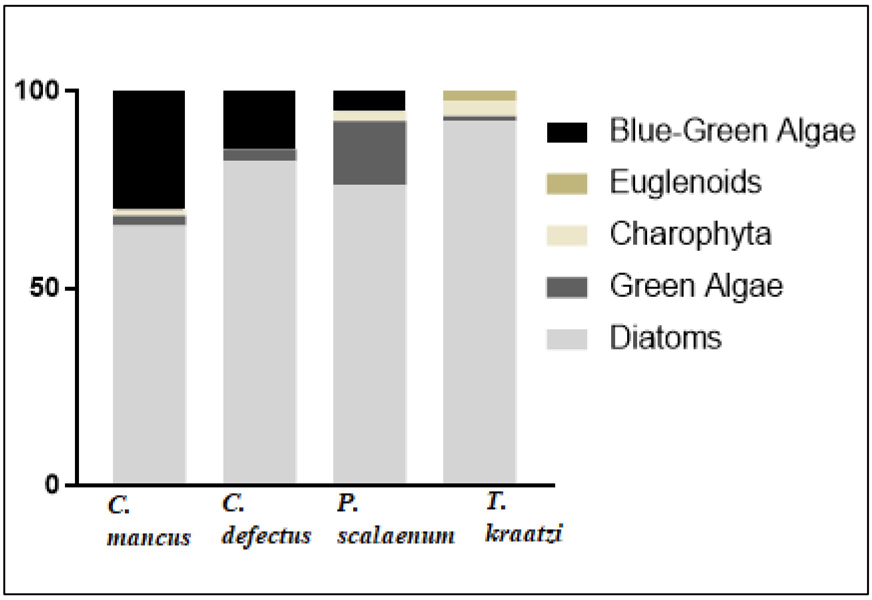


**Figure 4.** The algal composition of the gut contents of the determined chironomid larvae.

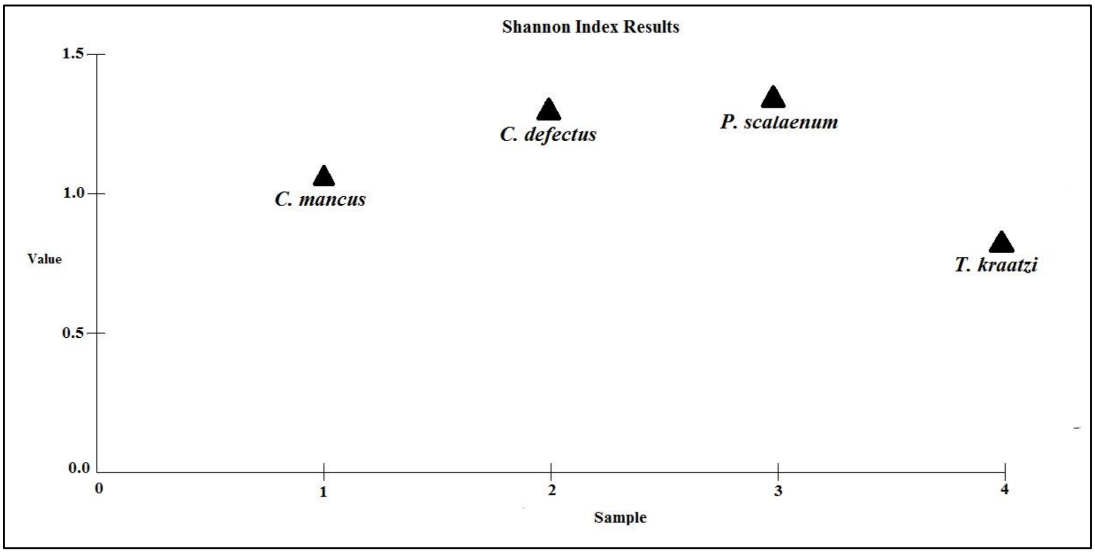


**Figure 5.** Species diversity (values of the Shannon-Wiener Diversity Index) of gut contents of the chironomid larvae.

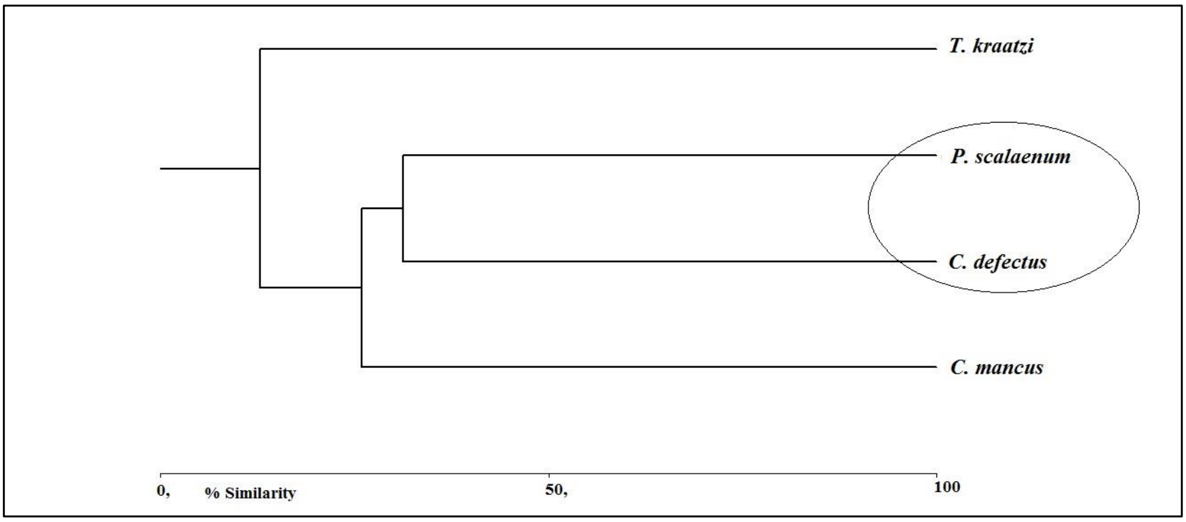


**Figure 6.** The gut contents similarity (based on the Bray-Curtis Similarity Index) of the chironomid larvae.

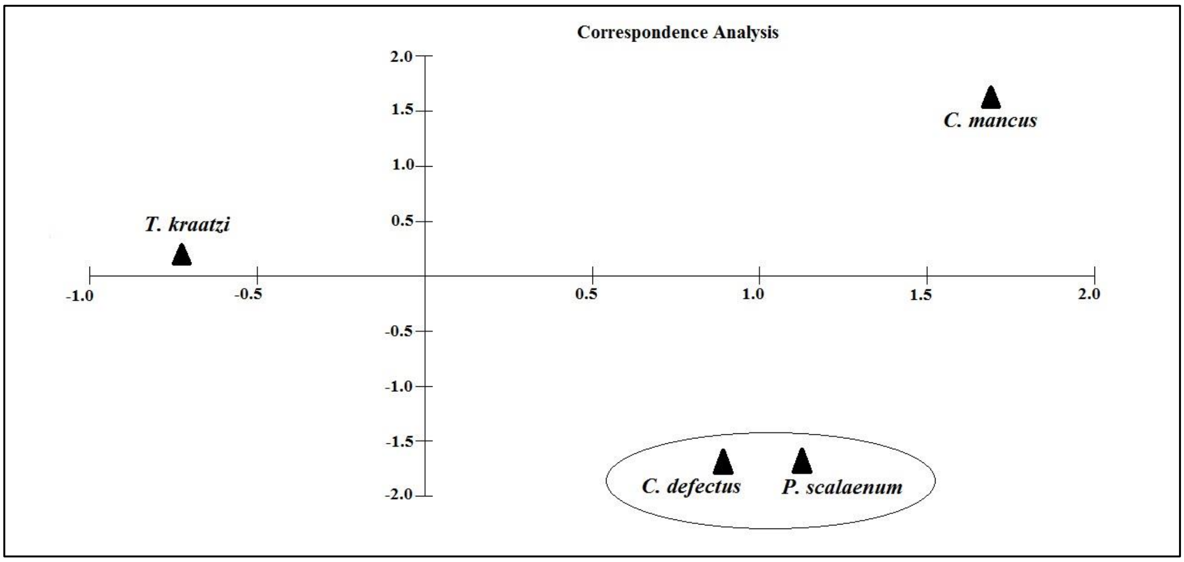


**Figure 7.** Correspondence analysis of the gut contents of the chironomid larvae.

## Discussion

In this study, it was compared to the gut content of *C. defectus*, *C. mancus*, *P. scalaenum*, and *T. kraatzi* collected from the freshwater ecosystems in the Northern Thrace Region of Turkey. The main food component of the alimentary tract of Chironomidae larvae is detritus (Berg 1995; Dukowska et al. 1999; Kornijo´w et al. 2019). But in our study, the data included gut content data other than detritus. As a result of our gut content study, Algae was the dominant component as in other studies (Tarkowska-Kukuryk 2013; Butakka et al. 2016; Kornijo´w et al. 2019). According to Kornijo´w et al. (2019) food of animal origin is a less involved component than plant fragment as in our study. According to the algal composition of the gut contents of the determined chironomid species, diatoms were dominant as in the many other studies (Cattaneo 1983; Tokeshi 1986; Tarkowska-Kukuryk 2013). Although *Tanypus* genus is known as a predator, members of *Tanypus* genus can preference diatoms as a major food source (Armitage et al. 1995; Galizzi et al. 2012) and is probably the result of larval size, food size, and quality, sediment composition (Armitage et al. 1995). Also, diatoms are rich in protein and essential fatty acids and this situation makes them preferred and high-quality food for growing larvae (Tarkowska-Kukuryk 2013).

According to the Bray-Curtis similarity index results, the most similar types of gut contents were *P. scalaenum* and *C. defectus*. It could say that *T. kraatzi* had different gut content among the other three species. The members of the subfamily Tanypodinae (including *T. kraatzi*) generally feed on other organisms as predators and so the results made thought us that the food spectrum of *C. defectus*, *C. mancus*, and *P. scalaenum* (subfamily Chironominae) was broader than *T. kraatzi*.

Gut content studies result in attention to the importance of chironomid larvae and their energy flow role in aquatic ecosystems. Gut content studies provide important insights into the trophic level and food sources of aquatic ecosystems. It is known that many chironomids are grazer on epiphytes and macrophytes and because of the high abundance of chironomids the plant food sources of an aquatic ecosystem could reduce. Thanks to the gut content studies it will be possible to know where it must suppress chironomid populations. We think that the studies examining the gut content of chironomid larvae could provide a good data set to speculate on the structure of an aquatic ecosystem.

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# Zooplankton Diversity of a Sub-Tropical Small Urban Wetland of Meghalaya, Northeast India with Remarks on Spatial Variations

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## ABSTRACT

Limnological survey of a small urban wetland of Meghalaya state of northeast India (NEI), undertaken at the littoral and semi-limnetic stations, reveals one of the biodiverse zooplankton assemblages (148 species belonging to 72 genera and 30 families) known from any lentic environ of the Indian sub-region. The speciose nature, peak constellation/sample of 83 zooplankton species, and diverse Rotifera (90 species) are hypothesized to environmental heterogeneity of this urban wetland in contrast to the general pattern of reduced richness expected in highly modified urban aquatic environments. The soft and de-mineralized waters are characterized by low zooplankton abundance. This study records high species diversity and evenness, and low dominance attributed to low and equitable abundance depicts 'generalist' nature of all species. Rotifera > Cladocera and Chydoridae > Lecanidae > Lepadellidae > Daphniidae are important at both stations, and Testudinellidae, Trichocercidae, and Macrothricidae are notable at the littoral station. Individual abiotic factors exert limited and differential spatial influence on various taxa, while the CCA registers a high cumulative influence of 10 abiotic factors on the littoral (87.37%) and semi-limnetic (75.81%) zooplankton assemblages. The spatial variations of composition, richness, similarities, abundance, diversity indices, and of the influence of individual abiotic factors are hypothesized to habitat heterogeneity amongst the sampled stations.

**Keywords:** Abundance, diversity indices, habitat diversity, salient features, trophic status

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## Introduction

The smaller water bodies (wetlands and ponds < 10 ha in surface area) form over 90% of the standing waters of our biosphere and ~ 30% of the global lentic biotopes by surface area (Downing et al. 2006). Seekell et al. (2013) and Verpoorter et al. (2014) suggested even higher conservative estimates as high-resolution satellite imagery inventories omit water bodies smaller than 0.2 ha in size, although even the very smallest of these have important roles in ecosystem processes (Holgerson and Raymond 2016). The small urban biotopes are recognized as keystone systems for the conservation of biodiversity (Céréghino et al. 2008, 2014; Vad et al. 2017; Oertli 2018) despite vulnerability to severe threats of extinction and habitat degradation (Moss et al. 2011). Mullins and Doyle (2019) remarked that limnology will benefit from a renewed focus on these water bodies as they provide valuable ecological services and are likely important hot spots of carbon transformations and carbon sequestration (Downing et al. 2008; Céréghino et al. 2014). The small wetlands are important for maintaining regional biodiversity in urban landscapes that have been highly modified but may not follow the general pattern of reduced taxonomic richness expected in highly modified urban terrestrial or aquatic environments (Hill et al. 2017).

The small wetlands and ponds form an integral part of the rural and urban landscape of India. These environs have attracted relatively more attention since the inception of the Indian limnology and have resulted in the proliferation of 'ad-hoc' and 'routine' reports on zooplankton assemblages due to incomplete species lists, unidentified species, limited sampling, and inadequate data analysis (Sharma and Sharma 2019a, 2019b). The selected Indian studies with variable and limited extant of useful information are from small wetlands of Bihar (Kumar et al. 2011; Pandey et al. 2013), Jammu & Kashmir (Jyoti et al. 2009), Haryana (Tyor et al. 2014; Chopra and Jakhar 2016), Karnataka (Majagi 2014), Telangana (Karuthapandi et al. 2016), Uttarakhand (Kumar et al. 2012) and West Bengal (Datta 2011; Halder Mallick and Chakraborty 2015; Patra et al. 2015; Adhikari et al. 2017; Saha et al. 2017; Midya et al. 2018). Amongst other wetlands, some useful studies are from the floodplains of Bihar (Sanjer and Sharma 1995), Kashmir (Khan 1987; Ahangar et al. 2012; Slathia and Dutta 2013) and West Bengal (Khan 2002, 2003; Ganesan and Khan 2008), while the notable zooplankton diversity works are restricted to the floodplain wetlands of Assam (Sharma and Hussain 2001; Sharma and Sharma 2008, 2012; Sharma 2011a; Sharma and Hatimuria 2017; Sharma and Noroh 2020) and Manipur (Sharma 2011b; Sharma and Sharma 2011) states of NEI. On the other hand, some notable studies from small wetlands of NEI are yet limited to surveys from Meghalaya (Sharma and Wanswet 2006), Arunachal Pradesh (Saikia et al. 2017), and Assam (Deka and Goswami 2015). Also, Sharma et al. (2016), Sharma and Kensibo (2017), and Sharma and Sharma (2019a, 2019b, 2019c) highlighted small wetlands of NEI to be one of the Rotifera biodiversity hot-spots of the Indian sub-region. The literature from India thus reflects the overall paucity of extensive investigations till date on various aspects of zooplankton diversity of small wetlands of India and NEI in general and urban wetlands in particular.

The present study, a follow-up of our survey of the rotifer assemblage (Sharma et al. 2016), endeavors to undertake detailed analyses of zooplankton diversity of a small urban wetland of Meghalaya state of NEI; it assumes biodiversity and limnology interest in light of the stated lacunae. Our study deals with the spatio-temporal variations of richness, species composition, community similarities, abundance, species diversity, equitability and dominance, and individual and cumulative influence of abiotic factors on zooplankton assemblages. The results are discussed vis-a-vis zooplankton diversity of India and of small freshwater environs in particular.

## Materials and Methods

We undertook a limnological survey of a small urban perennial wetland (~ 1.5 ha area; maximum depth: 4 meters) located at the campus of North-Eastern Hill University (NEHU wetland), Shillong - the capital of Meghalaya state of NEI (Figure 1, A-B). Water and qualitative and quantitative plankton and semi-plankton samples were collected monthly from the littoral (25°35'33.6"N; 91°53'46.6"E) and the semi-limnetic (25°36'30.3"N; 91°54'01.2"E) stations during August 2014-July 2015 from this wetland which lacked limnetic features. The littoral station showed growth of *Myriophyllum verticillatum*, *Nelumbo nucifera*, and *Hydrilla verticillata* and the semi-limnetic station indicated *Hydrilla verticillata*, *Ipomoea aquatica*, *Nymphoides indica*, and *Spirogyra* sp.

Water samples collected from the two stations were examined for 13 abiotic parameters each. Water temperature was recorded using a centigrade thermometer; pH and specific conductivity were recorded with the field probes; dissolved oxygen was estimated by the modified Winkler's method, and other abiotic factors namely total alkalinity, total hardness, calcium, magnesium, chloride, dissolved organic matter, total dissolved solids, phosphate, and nitrate were analyzed following APHA (1992). The qualitative plankton and semi-plankton samples, collected from each sampling station by towing nylobolt plankton net (mesh size: 40 µm), were preserved in 5% formalin. All samples were screened with a Wild stereoscopic binocular microscope, zooplankton taxa were isolated and mounted in polyvinyl alcohol-lactophenol mixture, and were observed with Leica (DM 1000) stereoscopic microscope. Zooplankton species were identified following Michael and Sharma (1988), Sharma (1998, 2016), Sharma and Sharma (1999a, 1999b, 2000, 2008), and Sharma et al. (2016). The community similarities were calculated vide Sørensen's index and the hierarchical cluster analysis was done using SPSS (version 20). Monthly quantitative samples were obtained from the two stations by filtering 25 L of water each through nylobolt plankton net and were preserved in 5% formalin. Quantitative enumeration of zooplankton and constituent taxa was done by using a Sedgewick-Rafter counting cell. The abundance of various taxa was expressed as n/l as well as ranges and mean ± S.D. Species diversity (Shannon Weiner's index), dominance (Berger-Parker's index) and evenness ($E_1$ index) were calculated vide Ludwig and Reynolds (1988) and Magurran (1988). Two-way analysis of variance (ANOVA) was used to ascertain significance of spatio-temporal variations of abiotic and biotic parameters between the sampled stations and months. Pearson's correlation coefficients for the two stations ($r_1$ and $r_2$, respectively) were calculated between abiotic and biotic factors; p values were calculated *vide* http://vassarstats.net/tabs.html and their significance was ascertained after applying Bonferroni corrections. The canonical correspondence analysis was done using XLSTAT (version 2015) to record the cumulative influence of 10 abiotic factors (for logistic limitations of the study period): water temperature, pH, specific conductivity, dissolved oxygen, total alkalinity, total hardness, chloride, dissolved organic matter, total dissolved solids and phosphate on zooplankton assemblages.

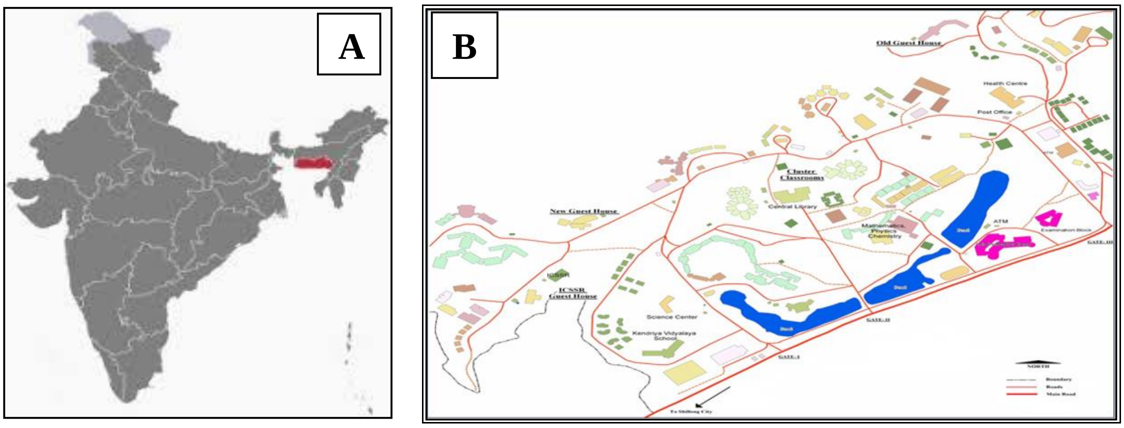


**Figure 1.** A, map of India showing the state of Meghalaya (red color); B, campus map of North-Eastern Hill University, Shillong showing NEHU urban wetland (blue color).

## Results

Water temperature ranged between 12.0-22.5°C, pH between 6.02-6.99, specific conductivity between 31.0-51.0 µS/cm, dissolved oxygen between 5.6-7.6 mg/l, total alkalinity between 18.0-30.0 mg/l, total hardness between 20.0-32.0 mg/l; calcium between 8.4-27.3 mg/l, magnesium between 2.7-19.5 mg/l, chloride between 23.9-37.9 mg/l, dissolved organic matter between 0.038-0.180 mg/l and total dissolved solids between 0.068-0.160 mg/l during the study period (Table 1). In addition, phosphate and nitrate varied between 0.209-1.055 mg/l and 0.356-1.214 mg/l, respectively (Table 1).

**Table 1.** Variations of abiotic parameters.

| **Parameters↓ Sampling stations→** | **Littoral station** | | **Semi-limnetic station** | |
|---|---|---|---|---|
| | **RANGE** | **MEAN±SD** | **RANGE** | **MEAN±SD** |
| Water temperature (° C) | 12.0-22.5 | 17.4±3.2 | 12.0-22.5 | 17.4±3.2 |
| pH | 6.02-6.97 | 6.43±0.29 | 6.40-6.99 | 6.59±0.19 |
| Specific Conductivity.(µS/cm) | 31.0-50.0 | 34.8±5.4 | 32.0-51.0 | 37.4±5.4 |
| Dissolved oxygen (mg/l) | 5.6-7.6 | 6.7±0.5 | 5.6-7.2 | 6.3±0.5 |
| Total Alkalinity (mg/l) | 18.0-28.0 | 22.7±3.3 | 20.0-30.0 | 24.0±3.5 |
| Total Hardness (mg/l) | 20.0-32.0 | 24.8±3.6 | 22.0-32.0 | 26.3±3.4 |
| Calcium (mg/l) | 8.4-23.1 | 14.3±4.6 | 8.4-27.3 | 14.3±6.1 |
| Magnesium (mg/l) | 7.0-17.5 | 10.5-3.1 | 2.7-19.5 | 11.9±4.6 |
| Chloride (mg/l) | 24.9-36.9 | 32.2±3.6 | 23.9-37.9 | 32.5±4.1 |
| Dissolved organic matter (mg/l) | 0.038-0.169 | 0.103±0.038 | 0.038-0.180 | 0.105±0.042 |
| Total dissolved solids (mg/l) | 0.068-0.128 | 0.106±0.015 | 0.072-0.160 | 0.107±0.028 |
| Phosphate (mg/l) | 0.251-1.055 | 0.717±0.250 | 0.209-1.035 | 0.748±0.247 |
| Nitrate (mg/l) | 0.356-1.214 | 0.780±0.319 | 0.503-1.128 | 0.832±0.253 |

**Table 2.** Composition of zooplankton.

| **Groups↓ Taxa →** | **Species** | **Genera** | **Families** |
|---|---|---|---|
| Rotifera | 90 | 29 | 15 |
| Cladocera | 36 | 28 | 6 |
| Rhizopoda | 10 | 6 | 5 |
| Copepoda | 7 | 4 | 2 |
| Ostracoda | 5 | 5 | 2 |
| **Zooplankton** | **148** | **72** | **30** |

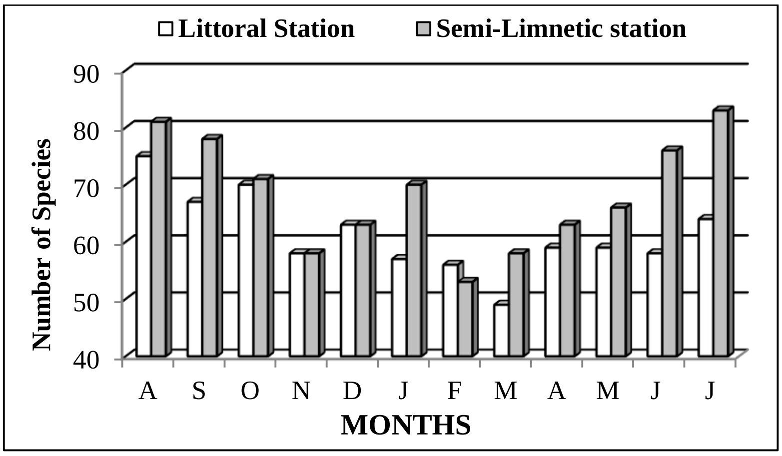


**Figure 2.** Monthly variations of zooplankton richness.

We observed 148 zooplankton species belonging to 72 genera and 30 families (Table 2-3) with 148 and 122 species from the two sampling stations, respectively. Rotifera, Cladocera, Rhizopoda, Copepoda, and Ostracoda indicate 90, 36, 10, 7, and 5 species, respectively. The monthly zooplankton richness varied between 49-75(61±7) and 53-83(68±9) species (Figure 2), registered 47.2-74.5 % and 55.7-84.0 % similarities (Table 3) and record notable differences in monthly groupings *vide* the hierarchical cluster analysis (Figures 3-4). Rotifera and Cladocera (Table 3) record richness between 16-35 and 24-46 species; and 19-25 and 18-28 species and community similarities ranging between 19.0-60.9 and 37.3-79.5 %, and 58.5-94.7 and 71.4-89.5% at the littoral and semi-limnetic stations, respectively.

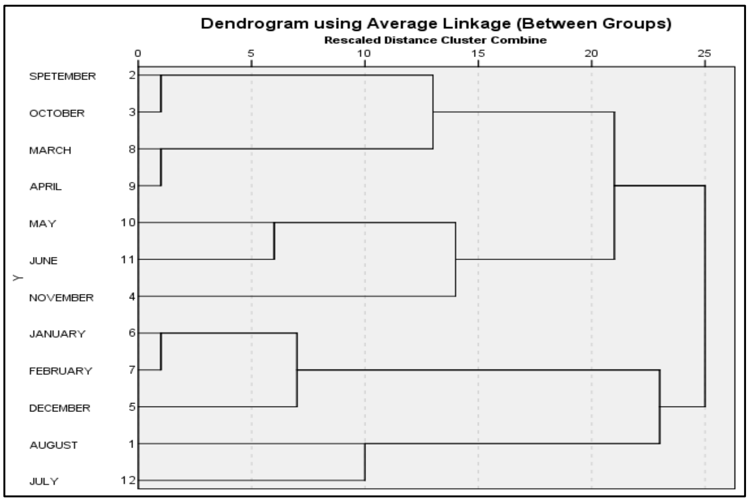


**Figure 3.** Hierarchical cluster analysis of zooplankton assemblages (Littoral station).

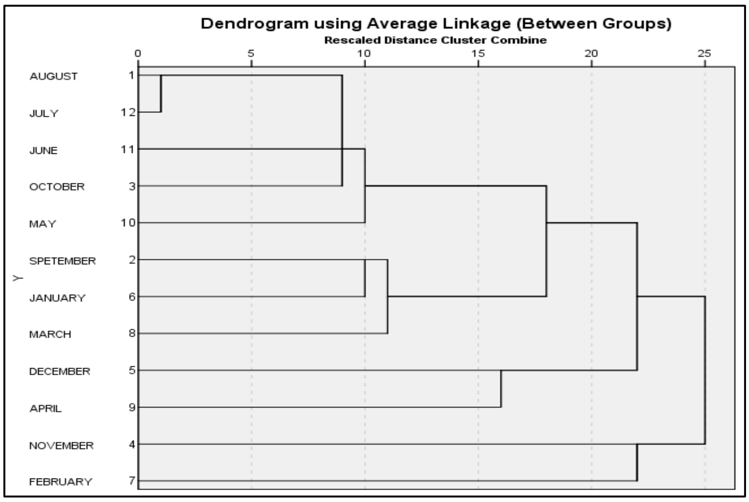


**Figure 4.** Hierarchical cluster analysis of zooplankton assemblages (Semi-limnetic station).

The monthly variations in zooplankton abundance and diversity indices are indicated in Table 3. The abundance ranged between 208 -308 n/l and 197-245 n/l (Figure 5), species diversity (Figure 6), evenness and dominance of zooplankton ranged between 3.469-4.195 and 3.934-4.452, 0.858-0.974 and 0.877-0.995, and 0.030-0.093 and 0.027-0.046 at the littoral and semi-limnetic stations, respectively (Table 3). Rotifera (64-142 n/l; 71-129 n/l) and Cladocera (82-107n/l; 70-84 n/I) comprised between 42.9±11.3, 44.2±4.6%, and 40.0±5.2, 38.4±4.3% of zooplankton abundance (Figures 7-8); Rhizopoda and Copepoda abundance varied between 20±4 n/l, 19±4 n/l; 21±3, 13±2 n/l (Table 3); and Ostracoda (8±1, 4±2 n/l) recorded poor abundance at the two stations, respectively.

**Table 3.** Zooplankton richness, abundance, and diversity indices.

| Groups↓ Stations→ | Littoral Station | | Semi-limnetic Station | |
|---|---|---|---|---|
| **Richness** | | | | |
| Zooplankton (total richness) | 148 species | | 122 species | |
| Zooplankton (monthly)<br>Community similarity | 49-75 species 61±7 species<br>47.2-74.5 % | | 53-83 species 68± 9 species<br>55.7-84.0 % | |
| Rotifera (monthly)<br>Community similarity | 16-35 species 25±7 species<br>19.0-60.9 % | | 24-46 species 35±7 species<br>37.3-79.5% | |
| Cladocera (monthly)<br>Community similarity | 19-25 species 22±2 species<br>58.5-94.7% | | 18-28 species 22±3 species<br>71.4-89.5% % | |
| **Abundance and diversity** | | | | |
| Zooplankton (n/l) | 208-308 | 247±26 | 197-245 | 213±23 |
| Species diversity | 3.469-4.195 | 3.842±0.192 | 3.934-4.452 | 4.135±0.142 |
| Evenness | 0.858-0.974 | 0.943±0.046 | 0.877-0.995 | 0.974±0.030 |
| Dominance | 0.030-0.093 | 0.058±0.010 | 0.027-0.046 | 0.057±0.017 |
| **Different Groups** | | | | |
| Rotifera (n/l) | 64-142 | 98±7 | 71-129 | 81 ±7 |
| % composition | 29.9-73.9 | 42.9±11.3 | 38.6-52.9 | 44.2±4.6 |
| Cladocera (n/l) | 82-107 | 58±18 | 70-84 | 66±17 |
| % composition | 14.6-37.9 | 40.0±5.2 | 19.0-52.2 | 38.4±4.3 |
| Rhizopoda (n/l) | 15-28 | 20±4 | 15-28 | 19±4 |
| % composition | 5.1-9.6 | 8.1±1.1 | 6.3-11.8 | 9.0±1.3 |
| Copepoda (n/l) | 12-25 | 21±3 | 9-18 | 13±2 |
| % composition | 5.0-11.3 | 8.0±1.9 | 4.6-8.2 | 6.3±1.0 |
| Ostracoda (n/l) | 6-11 | 8±1 | 1-7 | 4±2 |
| **Different Families (n/l)** | | | | |
| Chydoridae | 49-68 | 59±6 | 34-64 | 52±7 |
| Lecanidae | 20-51 | 39±9 | 22-53 | 37±9 |
| Lepadellidae | 7-27 | 16±7 | 12-28 | 21±5 |
| Daphniidae | 11-18 | 14±2 | 7-15 | 12±2 |
| Testudinellidae | 9-24 | 16±5 | 0-12 | 6±3 |
| Trichocercidae | 0-17 | 10±5 | 3-14 | 8±3 |
| Macrothricidae | 8-14 | 11±2 | 4-8 | 6±1 |

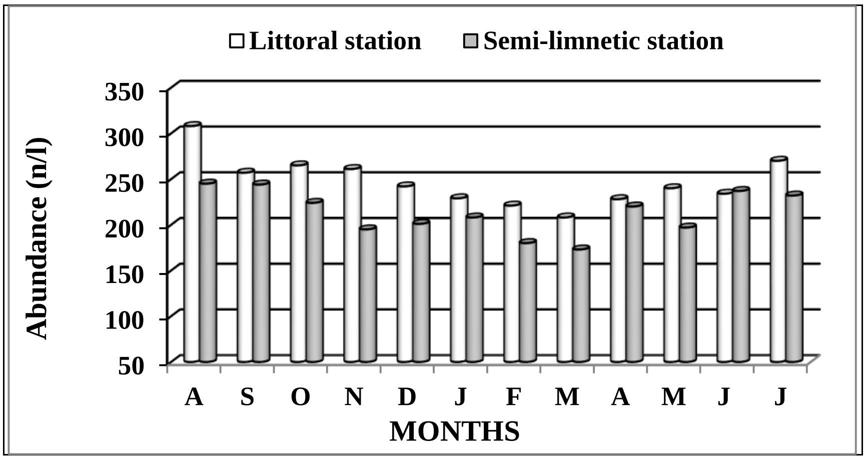


**Figure 5.** Monthly variations of zooplankton abundance.

The significance of various abiotic and biotic factors (vide ANOVA) between the littoral and semi-limnetic stations and months are indicated in Table 4.

**Table 4.** ANOVA indicating the significance of abiotic and biotic factors

| Parameters | Stations | Months |
|---|---|---|
| **Abiotic factors** | | |
| Water temperature | - | $F_{11,23}$ = 7.981, P = 8.32E-05 |
| pH | $F_{1,23}$ = 5.789, P = 0.034 | $F_{11,23}$ = 3.572, P = 0.022 |
| Specific conductivity | $F_{1,23}$ = 14.978, P = 0.003 | $F_{11,23}$ = 19.526, P = 1.12E-05 |
| Dissolved oxygen | $F_{1,23}$ = 3.667, P= 0.081 | - |
| Total Alkalinity | $F_{1,23}$ = 5.49, P = 0.039 | $F_{11,23}$ = 11.125, P = 0.0002 |
| Total Hardness | $F_{1,23}$ = 11.879, P= 0.005 | $F_{11,23}$ = 20.307, P= 9.9E-06 |
| Calcium | - | $F_{11,23}$ = 20.047, P = 1.06E-05 |
| Magnesium | - | $F_{11,23}$ = 6.920, P = 0.002 |
| Chloride | - | $F_{11,23}$ = 35.850, P = 5.26E-07 |
| Dissolved organic matter | - | $F_{11,23}$ = 63.170, P = 2.6E-08 |
| Total dissolved solids | - | $F_{11,23}$ = 3.622, P = 0.021 |
| Phosphate | - | $F_{11,23}$ = 21.024, P = 8.3E-06 |
| Nitrate | - | $F_{11,23}$ = 35.140, P = 5.84E-07 |
| **Richness** | | |
| Zooplankton | $F_{1,23}$ = 11.724, P= 0.005 | $F_{11,23}$ = 4.611, P= 0.008 |
| Rotifera | $F_{1,23}$ = 68.075, P = 4.87E-06 | $F_{11,23}$ = 11.095, P= 0.0002 |
| Cladocera | - | - |
| **Abundance and diversity indices** | | |
| Zooplankton | $F_{1,23}$ = 31.866, P= 0.0001 | $F_{11,23}$ = 5.010, P= 0.006 |
| Rotifera | - | $F_{11,23}$ = 4.642, P= 0.008 |
| Copepoda | $F_{1,23}$ = 40.753, P= 5.2E-05 | - |
| Cladocera | $F_{1,23}$ = 40.745, P= 5.2E-05 | - |
| Zooplankton species diversity | $F_{1,23}$ = 15.380, P= 0.002 | - |
| Zooplankton evenness | - | - |
| Zooplankton dominance | - | - |
| **Important families** | | |
| Chydoridae | $F_{1,23}$ = 9.580, P= 0.010 | - |
| Lecanidae | - | $F_{11,23}$ = 3.664, P= 0.020 |
| Lepadellidae | - | $F_{11,23}$ = 3.664, P= 0.020 |
| Daphniidae | $F_{1,23}$ = 13.569, P= 0.004 | $F_{11,23}$ = 3.978, P= 0.015 |
| Testudinellidae | $F_{1,23}$ = 44.929, P= 3.36E-05 | |
| Trichocercidae | - | $F_{11,23}$ = 5.045, P= 0.006 |
| Macrothricidae | $F_{1,23}$ = 59..055, P= 9.55E-06 | - |

(-) indicates insignificant variations.

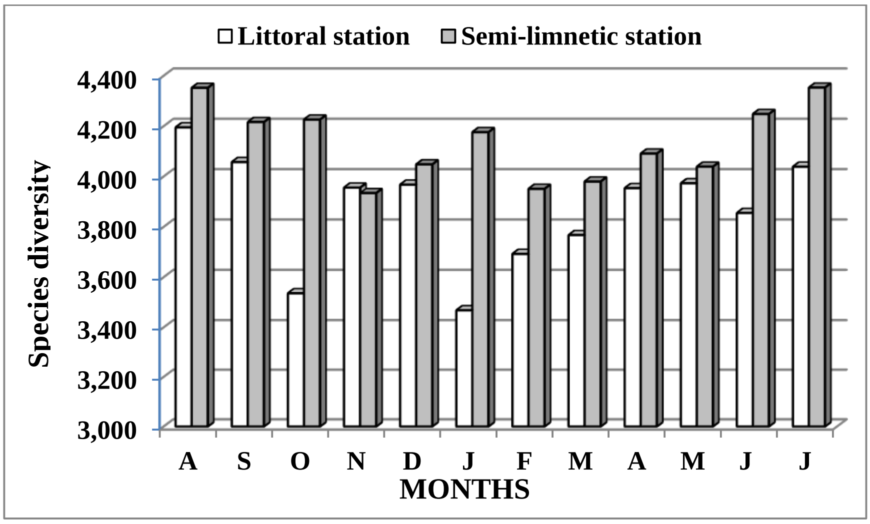


**Figure 6.** Monthly variations of zooplankton species diversity.

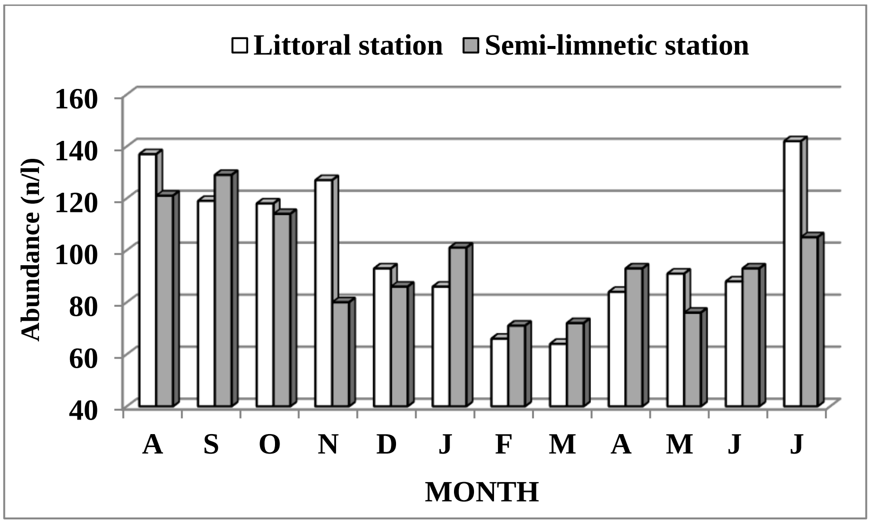


**Figure 7.** Monthly variations of the abundance of Rotifera.

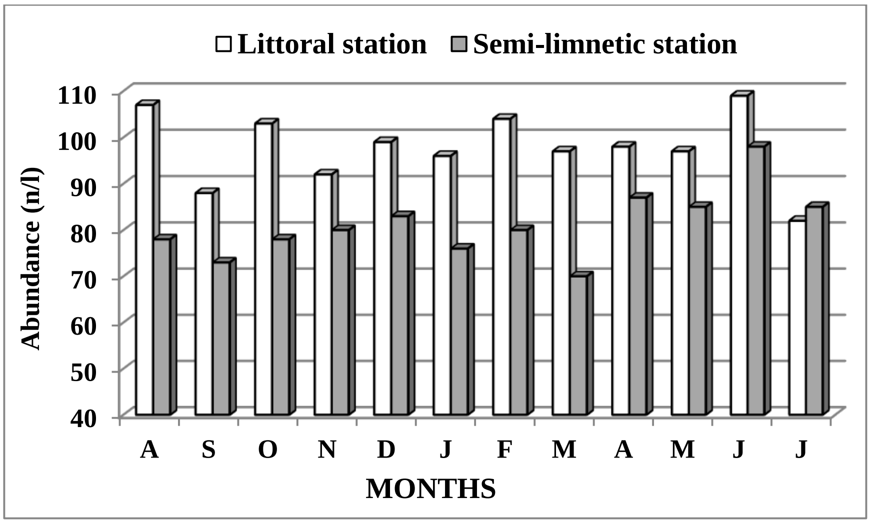


**Figure 8.** Monthly variations of the abundance of Cladocera.

Chydoridae (59±6 and 52±7 n/l), Lecanidae (39±9 and 37±9 n/l), Lepadellidae (16±7 and 21±5 n/l) and Daphniidae (14±2 and 12±2 n/l) deserved attention at the two stations, respectively. Testudinellidae (16±5 n/l), Trichocercidae (10±5 n/l), and Macrothricidae (11±2 n/l) recorded importance at Station 1, while Sidiidae and Brachionidae deserved limited importance.

Zooplankton ($r_1$ = 0.729, p = 0.0168) and Rotifera ($r_1$ = 0.874, p = 0.0009) richness, and abundance of zooplankton ($r_1$ = 0.789, p = 0.0067), Rotifera ($r_1$ = 0.813, p = 0.0042), Lecanidae ($r_1$ = 0.622, p = 0.0548) and Trichocercidae ($r_1$ = 0.762, p = 0.0104) are positively correlated with water temperature at the littoral station. In addition, zooplankton ($r_1$ = -0.856, p = 0.0016) and Rotifera ($r_1$ = -0.757, p = 0.0112) richness, and abundance of zooplankton ($r_1$ =- 0.786, p = 0.007), Rotifera ($r_1$ = - 0.668, p = 0.0348) and Lecanidae ($r_1$ = -0.808, p = 0.0047) are inversely correlated with total dissolved solids; zooplankton ($r_1$ = -0.860, p = 0.0014) and Rotifera ($r_1$ = -0.719, p = 0.0191) richness, and abundance of zooplankton ($r_1$ = - 0.849, p = 0.0019) and Rotifera ($r_1$ = - 0.664, p = 0.0363) are inversely influenced by dissolved organic matter, while Lecanidae abundance ($r_1$ = - 0.668, p = 0.034) is inversely correlated with specific conductivity at the littoral station. Zooplankton ($r_2$ = 0.838, p = 0.0025) and Rotifera ($r_2$ = 0.755, p = 0.026) richness, and abundance of zooplankton ($r_2$ = 0.837, p = 0.0032), Rotifera ($r_2$ = 0.771, p = 0.009), Rhizopoda ($r_2$ = 0.701, p = 0.024) and Lecanidae ($r_2$= 0.694, p = 0.026) is positively correlated with water temperature, and Rotifer density ($r_2$ = -0.743, p = 0.0138) is inversely correlated with dissolved organic matter at the semi-limnetic station.

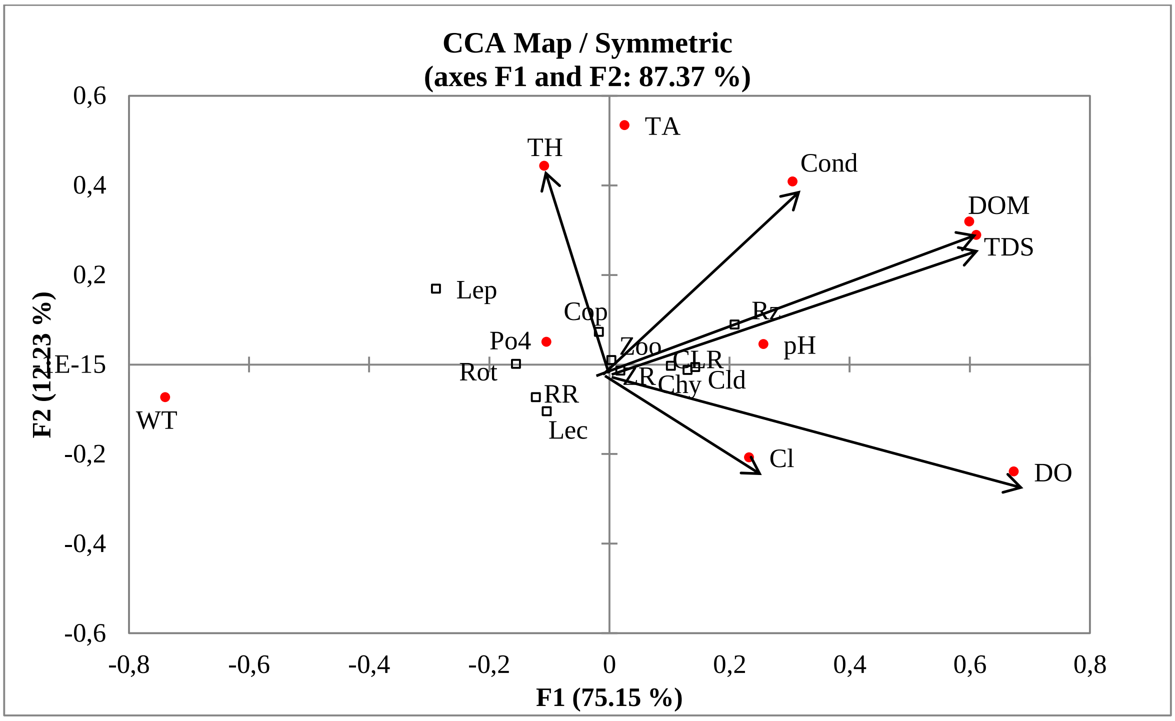


**Figure 9.** CCA coordination biplot of zooplankton and abiotic factors (Littoral station).
Abbreviations: Abiotic factors: Cl (Chloride), Cond (specific conductivity), DOM (dissolved organic matter), DO (dissolved oxygen), Po4 (phosphate), TA (total alkalinity), TDS (total dissolved solids), TH (total hardness), pH (hydrogen-ion concentration), Wt (water temperature). Biotic factors: Chy (Chydoridae abundance), Cld (Cladocera abundance), ClR (Cladocera richness abundance), Cop (Copepoda abundance), Lec (Lecanidae abundance), Lep (Lepadellidae abundance), Rot (Rotifera abundance), RR (Rotifera richness), Rz (Rhizopoda abundance), Zoo (Zooplankton abundance), ZR (Zooplankton richness).

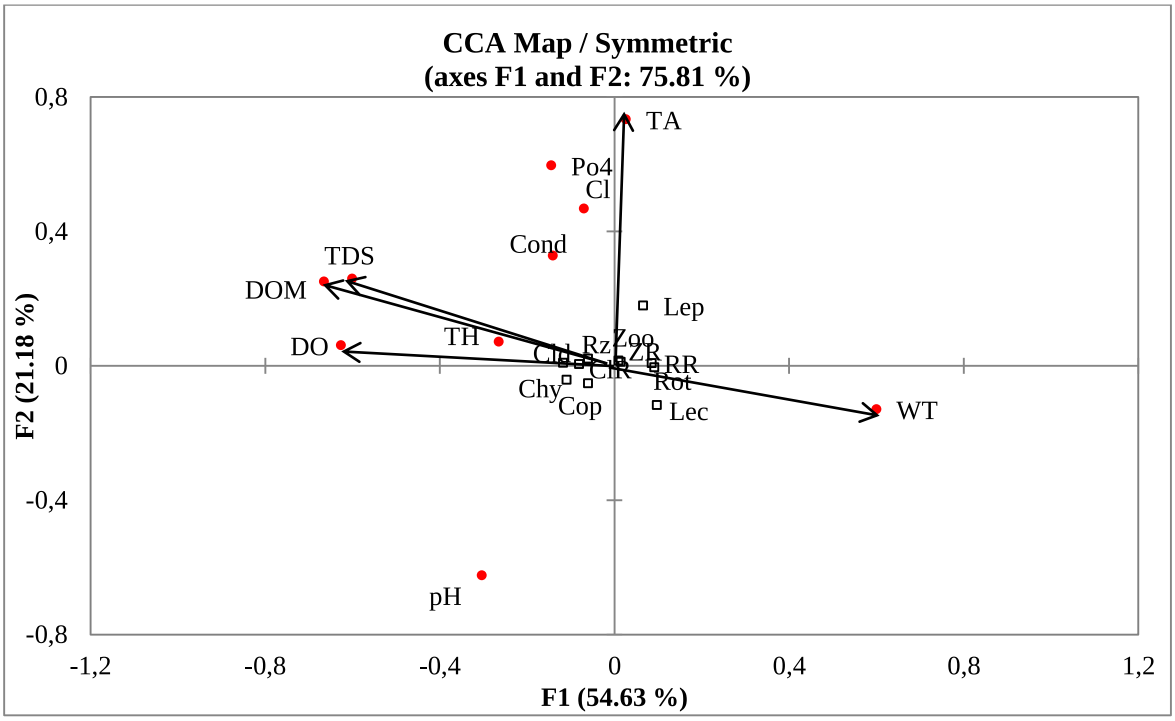


**Figure 10.** CCA coordination biplot of zooplankton and abiotic factors (Semi-limnetic station)
Abbreviations: Abiotic factors: Cl (Chloride), Cond (specific conductivity), DOM (dissolved organic matter), DO (dissolved oxygen), Po4 (phosphate), TA (total alkalinity), TDS (total dissolved solids), TH (total hardness), pH (hydrogen-ion concentration), Wt (water temperature). Biotic factors: Chy (Chydoridae abundance), Cld (Cladocera abundance), ClR (Cladocera richness), Cop (Copepoda abundance), Lec (Lecanidae abundance), Lep (Lepadellidae abundance), Rot (Rotifera abundance), RR (Rotifera richness), Rz (Rhizopoda abundance), Zoo (Zooplankton abundance), ZR (Zooplankton richness).

The canonical correspondence analysis (CCA) with 10 abiotic factors registered cumulative influence of 87.37% and 75.81% on zooplankton assemblages at the littoral and semi-limnetic stations, respectively (Figs. 9-10).

## Discussion

The sub-tropical NEHU wetland is characterized by soft, slightly acidic-circum neutral, calcium poor waters with low nutrients, chloride indicating a certain influence of human impact, and total alkalinity attributed to bicarbonate ions. The low specific conductivity is attributed to the leached nature of the soil and weathered condition of rocks due to heavy rainfall in NEI (Sharma 1995; Sharma and Sharma 2020) and lowered buffering capacity of de-mineralized waters (Steinitz-Kannan et al. 1983). ANOVA depicts significant variations of pH, specific conductivity, dissolved oxygen, total alkalinity, and total hardness between stations and months; water temperature and dissolved oxygen indicated significant variations between stations; and calcium, magnesium, chloride, dissolved organic matter, total dissolved solids, phosphate, and nitrate recorded significant monthly variations between the sampling stations. The spatial variations of abiotic factors are hypothesized to the habitat heterogeneity of the two stations.

Our report of 148 species, belonging to 72 genera and 30 families, reveals one of the biodiverse zooplankton assemblages known from any individual lentic environ of the Indian sub-region. This salient feature is hypothesized to the overall environmental heterogeneity of NEHU urban wetland. The biodiversity significance is in contrast to the general pattern of reduced taxonomic richness hypothesized to be expected in highly modified urban aquatic environs (Hill et al. 2017). We thus categorize this urban wetland as 'keystone' system of Meghalaya state of NEI for the conservation of aquatic biodiversity in light of the remarks of Céréghino et al. (2014), Vad et al. (2017), and Oertli (2018). The rich and diverse nature of zooplankton is in contrast to the reports from the floodplain wetlands of Assam (Sharma and Sharma 2008; Sharma and Hatimuria 2017), Bihar (Sanjer and Sharma 1995), Manipur (Sharma 2011a), and West Bengal (Khan 2002, 2003; Ganesan and Khan 2008; Datta 2011; Patra et al. 2011). The richness is distinctly higher than the reports from small water bodies of Arunachal Pradesh (Saikia et al. 2017), Bihar (Kumar et al. 2011, 2015; Singh et al. 2012; Pandey et al. 2013), Chhattisgarh (Mishra et al. 2014), Meghalaya (Sharma and Wanswett 2006), and West Bengal (Halder Mallick and Chakraborty 2015; Patra et al. 2015; Saha et al. 2017; Middya 2017; Midya et al. 2018) from India; and elsewhere from Bangladesh (Islam and Chowdhury 2013), Bhutan (Sharma and Bhattarai 2005) and Myanmar (Twin and Aung 2019). Zooplankton richness is notably higher than the reports from the lakes and reservoirs of Himachal (Jindal and Prajapat 2005; Thakur et al. 2013; Jindal and Thakur 2014), Karnataka (Hulyal and Kaliwal 2008; Kudari and Kanamadi 2008; Majagi and Vijaykumar 2009; Majagi 2014; Anita et al. 2019), Jammu & Kashmir (Khan 1987; Ahangar et al. 2012; Slathia and Dutta 2013; Sharma and Sharma 2019), Meghalaya (Sharma 1995; Sharma and Lyngdoh 2004; Sharma and Sharma 2020), Mizoram (Sharma and Pachuau 2013), Telangana (Karuthapandi et al. 2016) and Uttarakhand (Sharma and Pant 1985; Mishra et al. 2010; Malik and Panwar, 2016; Sharma and Kumari 2018; Singh and Sharma 2020) states of India. The reports of 148 and 122 species with 90.4% community similarity affirm high zooplankton homogeneity amongst the stations.

The diverse Rotifera (90 species belonging to 29 genera and 15 families) merit biodiversity interest as ~56.0, ~38.0, and ~23.0% of the species of this taxon known till date from Meghalaya and NEI (Sharma and Sharma 2019c) and India (Sharma and Sharma 2017a), respectively. The salient features of poor Brachionidae richness and lack of *Brachionus* spp. noted in our collections are attributed to slightly acidic - circum neutral waters concurrent with the reports of Sharma and Pachuau (2013), Sharma et al. (2016), and Sharma and Sharma (2020), while Brachionidae paucity concurs with the report from Arunachal Pradesh (Saikia et al. 2017). Lecanidae > Lepadellidae collectively comprise ~57.0% of the rotifer richness and affirm the littoral-periphytic character of the taxon vides Sharma and Sharma (2017a, 2019c). Additional details of Rotifera diversity vis-à-vis new reports (Sharma 2016), species composition, and elements of biogeographic interest are dealt with separately by Sharma et al. (2016). Cladocera, the second speciose group, indicated 36 species belonging to 28 genera and 6 families; it depicts diverse nature in comparison with our conservative estimate of the occurrence of 60–65 species from the tropical and subtropical waters of the Indian subcontinent (Sharma and Michael 1987; Sharma and Sharma 2017b). High richness (~ 69%) of the Chydoridae affirms the littoral periphytic nature of cladoceran assemblages (Sharma and Sharma 2017b).

Higher monthly zooplankton richness at the semi-limnetic > the littoral station is hypothesized to greater habitat diversity of the former region, while ANOVA indicates significant richness variations between stations and months. The zooplankton richness follows oscillating monthly variations at the two stations, while peak consortium/sample of 83 species in monsoon (July 2015) and high assemblage of 81 (August 2014) species, noted at the semi-limnetic station, are attributed to the possibility of co-existence of many species due to high amount of niche overlap as hypothesized by MacArthur (1965). We categorize these assemblages as 'Zooplankton paradox' vs. small urban wetland; such consortia are hypothesized to the intriguing possibility of the co-existence of a number of species in a relatively unstructured environment of small wetlands (Sharma and Sharma 2019a). Peak monsoon richness at the two stations is affirmed by a positive correlation with water temperature; the latter concurs with the results of Thakur et al. (2013). Further, monsoon peaks concur with the reports from Holmari beel of Assam (Sharma and Hatimuria 2017), Karnataka (Majagi 2014), Meghalaya (Sharma and Wanswett 2006), North Bengal (Datta 2011), and Telangana (Karuthapandi et al. 2016) but deviate from the reports of the post-monsoon peak by Ganesan and Khan (2008) and winter peak by Sharma and Sharma (2020). Zooplankton register 47.2-74.5 % and 55.7-84.0 % community similarities at the littoral and semi-limnetic stations, respectively; ~ 92% instances record 51-70% similarities at the former station, while similarity matrix record 61-80% similarities in ~84% instances at semi-limnetic station. The hierarchical cluster analysis indicates closer affinities between September-October, March-April, and January-February assemblages while August collection indicates peak species divergence at the littoral station. High affinity is noted only between July-August and maximum divergence is noted during November > February > December collections at the semi-limnetic station. The heterogeneity in monthly richness, affirmed both by community similarities and the differential cluster groupings, is hypothesized to habitat heterogeneity of the two stations. The rotifers contribute to zooplankton richness ($r_1$=0.908, p=0.0003; $r_2$=0.915, p =0.0002) at the two stations, respectively, and register significant variations between stations and months (vide ANOVA). The report of 46 species in September 2014 (semi-limnetic station) vs. this urban wetland is categorized as 'Rotifera paradox' analogous to the reports of Sharma and Sharma (2019a, 2019b). The community similarities reflect greater rotifer heterogeneity at the former station. Cladocera contributed to zooplankton richness ($r_2$=0.915, p =0.0002) at the semi-limnetic station and higher similarities affirm lower heterogeneity of Cladocera at the two stations.

Our results highlight low zooplankton abundance with the littoral > semi-limnetic station except in June 2015; ANOVA registers significant variations of abundance between stations and months. The low densities are attributed to soft and de-mineralized waters of NEHU wetland in particular; these remarks correspond with the reports from identical aquatic environs of NEI (Sharma 1995, 2011a; Sharma and Wanswett 2006; Sharma and Sharma 2012, 2020; Sharma and Pachuau 2013; Sharma and Noroh 2020) as well as from Bhutan (Sharma and Bhattarai 2005). The zooplankton follow oscillating monthly variations with higher abundance during warmer months and peak densities during monsoon (August 2014) at both the stations, these are affirmed by positive correlation with water temperature ($r_1$ = 0.789, p = 0.0067; $r_2$ = 0.837, p = 0.0025). The latter concurs with the results of Patra et al (2011), Thakur et al. (2013), and Singh and Sharma (2020) but differ from the inverse correlation indicated by Pandey et al. (2013) and Slathia and Dutta (2013). Further, monsoon peaks concur with the reports from Arunachal Pradesh (Saikia et al. 2017), Assam (Deka and Goswami 2015), Uttarakhand (Thakur et al. 2013), and Myanmar (Twin and Aung 2019) but differ summer peaks listed from wetlands of Bihar (Pandey et al. 2013), Kashmir (Slathia and Dutta 2013), Karnataka (Majagi 2014; Anita et al. 2019) and from winter peaks known from Himachal Pradesh (Sharma and Kumari 2018), Meghalaya (Sharma and Wanswett 2006), Uttarakhand (Malik and Panwar 2016; Singh and Sharma 2020) and West Bengal (Halder Mallick and Chakraborty 2015; Patra et al. 2015). Low and equitable abundance categorizes 'generalist' nature of zooplankton species concurrent with the reports from Himachal Pradesh (Jindal and Prajapat 2005; Jindal and Thakur 2014), NEI (Sharma 1995; Sharma and Lyngskor 2003; Sharma 2011a, 2011b, Sharma and Sharma 2011, 2020; Sharma and Noroh 2020) and Uttarakhand (Malik and Panwar 2016; Singh and Sharma 2020). Rotifera (42.9±11.3, 44.2±4.6%) ≥ Cladocera (40.0±5.2, 38.4±4.3%) contribute to zooplankton abundance at the two stations, respectively but with different spatio-temporal patterns.

Rotifera, an important group, contributes to zooplankton density variations at the littoral ($r_1$=0.915, p =0.0002) and semi-limnetic ($r_2$=0.825, p=0.003) stations. The importance of Rotifera concurs with the reports of Khan (1987, 2003), Sanjer and Sharma (1995), Jindal and Prajapat (2005), Jyoti et al (2009), Patra et al. (2011), Sharma (2011a, 2011b), Sharma and Sharma (2011, 2012, 2019c) Pandey et al. (2013), Deka and Goswami (2015), Halder Mallick and Chakraborty (2015), Malik and Panwar (2016), Sharma and Kumari (2018) and Sharma and Noroh (2020). Higher rotifer abundance during warmer months is affirmed by a positive correlation with water temperature; the latter concurs with the results of Thakur et al. (2013), Malik and Panwar (2016), and Sharma and Sharma (2020). Peak Rotifera densities during monsoon at the two stations concur with the report from Maghuri beel of Assam (Sharma and Noroh 2020) and the reports of Jyoti et al. (2009), Karuthapandi et al. (2016), Saikia et al. (2017) but differ from summer (Sanjer and Sharma 1995; Patra et al. 2011; Pandey et al. 2013; Sharma and Kumari 2018), winter peaks (Sharma and Hussain 2001; Sharma 2011a; Sharma and Sharma 2011, 2012) from different states of India. Lecanidae ($r_1$=0.813, p=0.004; $r_1$=0.805, p=0.005) and Lepadellidae ($r_1$=0.827, p=0.003; $r_1$=0.884, p=0.0007), respectively contribute to zooplankton and Rotifera abundance at the littoral station; Lecanidae contributes to zooplankton ($r_2$=0.705, p=0.023) and Rotifera ($r_2$=0.814, p=0.004) the semi-limnetic station; and Trichocercidae ($r_1$=0.811, p=0.004) and Brachionidae ($r_1$=0.744, p=0.0136) contribute to Rotifera at the littoral station. Lecanidae comprise between 40.0±6.8 and 39.3±6.3% of Rotifera, while the five Eurotatoria families collectively form notable fractions of zooplankton (35.5±7.1, 37.6±4.1%) and Rotifera (87.2±6.7, 84.9±3.3%) at the two stations, respectively. ANOVA registers significant monthly variations of Rotifera, Lecanidae, Lepadellidae, and Trichocercidae abundance between the stations. Lecanidae and Lepadellidae importance concur with the reports from NEI (Sharma 2011a; Sharma and Sharma 2001, 2008).

Cladocera, another important group, indicates significant density variations between stations (vide ANOVA) and records higher abundance that the reports from Assam (Sharma and Hussain 2001; Deka and Goswami 2015; Sharma and Hatimuria 2017), Kashmir (Khan 1987), Meghalaya (Sharma and Lyngdoh 2004) and Mizoram (Sharma and Pachuau 2013), while it broadly concurs with the report of Sharma and Noroh (2020). The cladocerans follow oscillating monthly variations with peaks during pre-monsoon (June 2015) at both the stations; the latter concur with the reports of Sharma (2011a), Deka and Goswami (2015), Sharma and Noroh (2020), Malik and Panwar (2016), Saikia et al. (2017) and Singh and Sharma (2020). Cladocera is notable for the importance of the Chydoridae (60.3±4.5, 52.7±8.8%) at the two stations, respectively concurrent with the reports of Sharma (2011a, 2011b) and Sharma and Sharma (2008, 2011, 2012); ANOVA indicates significant variations of Chydoridae between the stations. Daphniidae deserved attention at the two stations; Macrothricidae is important at the limnetic station, while Sidiidae deserved limited importance. The four families comprise a significant fraction of Cladocera (95.1±1.9, 78.8±8.7%) and zooplankton (38.0±4.6, 31.3±4.4%) abundance at the two stations, respectively.

Copepoda and Rhizopoda, two sub-dominant groups, indicate low abundance and limited spatial variations at the two stations. Copepoda > Rhizopoda abundance pattern is noted during September 2014-January 2015 and again in July 2015 at the littoral station, while Rhizopoda > Copepoda abundance is recorded throughout the study at the limnetic station, except January 2015. Copepoda indicates low abundance at the two stations with significant variations between stations (vide ANOVA). The sub-dominance of copepods concur with the reports from Assam (Sharma and Sharma 2012; Deka and Goswami 2015; Sharma and Noroh 2020), Himachal Pradesh (Jindal and Prajapat 2005), Jammu & Kashmir (Jyoti et al. 2009; Sharma and Sharma 2020), Manipur (Sharma 2011a) and Uttarakhand (Malik and Panwar 2016; Singh and Sharma 2020). Monsoon maxima of this group at the two stations concur with the findings of Jindal and Thakur (2014) but deviate from pre-monsoon peaks vides the reports of Ganesan and Khan (2008) and Sharma and Sharma (2020). Copepoda abundance, largely influenced by Cyclopidae, is attributed to the prevalence of stable environmental conditions for these 'k-strategists' as suggested by Allen (1976). Rhizopoda abundance broadly concurs with the report of Sharma and Noroh (2020), it is higher than the results of Sharma and Pachuau (2013) and Sharma and Hatimuria (2017) but differs from the poor abundance reported by Sharma and Sharma (2020). The rhizopods record maxima during monsoon at the two stations. Ostracoda forms an insignificant fraction of zooplankton.

Zooplankton are characterized by high species diversity at the semi-limnetic station > the littoral station; the former station recorded higher diversity throughout the study, except in November 2014; ANOVA depicts significant diversity variations between stations. The limnetic station recorded H´ values > 4.0 during 9 months, while the semi-limnetic station indicated H´ values > 4.0 during 7 months. High zooplankton species diversity of this urban wetland, coupled with low densities of individual species, is hypothesized to fine niche portioning in combination with micro-and macro- habitat heterogeneity as hypothesized by (Segers 2008). The diversity is directly influenced by richness of zooplankton ($r_2$ = 0.964, p < 0.0001), Rotifera ($r_2$ = 0.875, p = 0.0009) and Cladocera ($r_2$=0.700, p=0.024), and abundance of zooplankton ($r_2$ = 0.962, p < 0.0001), Rotifera ($r_2$ = 0.827, p = 0.003) and Lecanidae ($r_2$ = 0.722, p = 0.018) at the semi-limnetic station, while so such relationship is noted at the littoral station. Shannon Weiner diversity index is a suitable option for assessing the health of aquatic biotopes (Wilhm and Dorris 1968). Mean annual diversity values indicate a relatively more clean water nature of the semi-limnetic region while in general NEHU wetland is characterized by a very clean – clean water nature. Low dominance noted at the two sampling stations, shared by a large number of 'generalist' species (Osborne et al. 1976), is hypothesized to the fact that the habitat of this urban wetland has resources for utilization by all species providing a low amount of niche overlap as hypothesized by MacArthur (1965). Low densities and equitable abundance of zooplankton species affirm higher evenness and reiterate that zooplankton are 'generalist' vis-à-vis the general environment of this wetland.

This study depicts the differential spatial influence of individual abiotic parameters on the richness and abundance of zooplankton. Our results affirm the importance of water temperature with a positive influence on zooplankton and Rotifera richness and abundance of zooplankton, Rotifera, and Lecanidae at the two stations, respectively; positive influence on the abundance of Trichocercidae density at the littoral station and Rhizopoda at the semi-limnetic station. Besides, dissolved organic matter indicates importance with inverse correlations on zooplankton and Rotifera richness, and abundance of zooplankton, Rotifera and Lecanidae, and zooplankton richness and abundance is inversely correlated with total dissolved solids; Lecanidae abundance is positively correlated with specific conductivity at the former station. Rotifera density is inversely correlated with dissolved organic matter at the semi-limnetic station. The limited and differential influence of individual abiotic factors affirms the reports of Sharma and Hussain (2001), Sharma (2011a), Sharma and Sharma (2011, 2012), Sharma and Noroh (2020), and Sharma and Sharma (2020).

The canonical correspondence analysis depicts high but the differential cumulative influence of 10 abiotic factors on zooplankton assemblages at the littoral (87.37%) and semi-limnetic (75.81%) stations, respectively; it broadly concurs with the report of Sharma and Sharma (2020). Also, the former broadly concurs with 84.8% cumulative variance reported from a subtropical reservoir of Mizoram (Sharma and Pachuau 2013), while our results record higher cumulative influence in contrast to the reports from the floodplain wetlands of NEI (Sharma 2011a; Sharma and Sharma 2012; Sharma and Hatimuria,2017; Sharma and Noroh 2020). CCA coordination biplot at the littoral station indicates ~ 75% and ~12% influence of abiotic factors along axis 1 and 2, respectively with the influence of water temperature on Rotifera abundance; dissolved oxygen on richness and abundance of Cladocera, and abundance of Chydoridae; dissolved oxygen and chloride on zooplankton richness; conductivity on zooplankton abundance; dissolved organic matter and total dissolved solids on Rhizopoda density; and total hardness on Copeopoda abundance. The semi-limnetic station indicates ~ 54% and ~21% influence of abiotic factors along axis 1 and 2, respectively with the influence of water temperature on Rotifera richness and abundance; DOM and TDS on Cladocera and Rhizopoda abundance; dissolved oxygen on zooplankton and Cladocera richness; total alkalinity on zooplankton abundance. Our results thus highlight the importance of cumulative influence over the individual influence of abiotic factors, while the impact of biotic factors vs. zooplankton-macrophytic associations in this urban wetland needs to be assessed.

To sum up, the biodiversity significance of zooplankton of NEHU wetland and its importance as 'keystone' system of NEI vs. lentic environs of the Indian sub-region is hypothesized to overall environmental heterogeneity of this urban wetland. Peak consortia indicating 'zooplankton' and 'Rotifera paradox' hypothesized to the possibility of co-existence of several species due to high amount of niche overlap in the relatively unstructured environment of the small wetland; low zooplankton abundance attributed to 'soft' and de-mineralized waters; and the differential spatial patterns of richness, abundance and diversity indices hypothesized to habitat heterogeneity of the sampled stations are noteworthy. High species diversity, and low dominance, and high equitability attributed to 'generalist' species are notable features; the former depicts the 'very clean – clean water nature' of this wetland. The importance of high cumulative influence vis-à-vis limited spatial influence of individual abiotic factors is noteworthy. This study is an important contribution to zooplankton diversity of small water bodies of the Indian sub-region, and highlights need for the future-focused studies on zooplankton diversity to avoid the proliferation of 'ad-hoc' and 'routine' reports.

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# Socio-Economic and Cost Benefits of Catfish (*Clarias gariepinus*) Marketing in Obio-Akpor Local Government Area, Rivers State, Nigeria

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**A B S T R A C T**

This study aims to analyze the cost-benefit of catfish marketing in Obio- Akpor Local Government Area of Rivers State. A random sampling technique was adopted in sampling 60 catfish marketers in 5 catfish markets for the study. Data were collected with a structured questionnaire and were analyzed using descriptive statistics and regression models. Results showed that all respondents were female within the active working-age of 31-50 years. Married catfish marketers were 33.3%, and 80% had formal education. The profitability of catfish marketing indicated a total mean total variable cost (TVC), ₦68,119.17, the total mean total fixed cost (TFC), ₦2,131.75, the total mean cost of production (TCP), ₦70,250.92, mean total revenue (TR) recorded ₦181,000.00, and mean net income (NI), ₦137,572.08. mean gross margin value (GM) recorded ₦139,635.83, while the profitability index (PI) 1.31. The variables which influenced the profitability of catfish marketing were age, educational level, number of the sales point, and capital. The high cost of transportation, unstable price, and poor access road were the major constraints to catfish marketing. The source of startup capital was personal savings It is recommended that catfish marketers form a cooperative society to enhance their access to finance and regulate pricing with relevant variables that significantly influenced net income and should be considered in policy issues.

**Keywords:** Profitability, catfish marketers, constraint, Obio-Akpor

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## Introduction

Fish farming is a branch of aquaculture that deals with the culture of fish, which can be pond (concretes or earthen), wood, fiberglass, and plastic enclosure in a managed environment Nwokoye et al. (2007). For many developing countries, catfish is one of Africa's most commercially important freshwater fish. Its trade gives local producers significant employment and contributes to curbing food insecurity in the population (FAO 2006). Ebewore (2013) opined that most Nigerians are unable to meet the protein requirement because of their poverty level. The protein needed for growth, particularly in children, was inadequate because the animal protein was expensive. Protein from fish sources within reach is the only cheaper source of protein to bridge the gap of protein deficiency. Despite Nigeria's popularity, fish farming can be better represented as a child in comparison with the huge market potential for production and marketing (Nwiro 2012). Fish supply is from four major sources viz., artisanal fisheries, industrial trawlers, aquaculture, and imported frozen fish (Akinrotimi et al. 2011).

According to Adegeye and Dittoh (1985), marketing is a process that involves identifying the desires and needs of consumers and providing acceptable food and services which meet the needs and wishes of consumers and business managers to the benefit. The transport of goods to the customer requires the production of various types of services, including manufacturing, storage, preservation, distribution, wholesales, and retailing, using economic activities. The process of handling and marketing catfish is very delicate if quality and nutritional value are to be maintained due to its short shelf life. Fish culture has been noted by Eyo et al.

(2003) as the surest way of bridging the widening gap between the demand and supply of food fish in this country. This has fostered increased interest in the production of fish, especially catfish. Consequently, live-catfish marketing experienced fast growth to match the increasing supplies from the production sector. Such growth has created many opportunities for jobs at different marketing levels, thereby improving participants' income and well-being. (Ugwumba and Chukwuji 2010). The increasing demand gap can also be attributed to an inefficient marketing network, due to marketing issues such as lack of knowledge in the sector, weak business structures, high freight costs and lack of resources, inefficient warehousing facilities, restricted markets, and several intermediaries (Ugwumba 2010).

Marketing is a method of bringing the forces of demand and supply together regardless of the location of the market (Adekanye 1988). An effective marketing mechanism means that the supply of products across the year, regardless of the seasonality, no variance in prices, due to high marketing costs including storage. It is against this background that the study was carried out to determine the socio-economic and cost-benefit of catfish marketing in five major markets in Obio-Akpor LGA of Rivers State.

## Materials and Methods

### Study Area

The study was carried out in Obio- Akpor Local Government Area, in the metropolis of Port Harcourt, one of the major centers of economic activities in Rivers State, Nigeria. It is located between latitude 04°49'06.50"N and longitude 04°60'08.00"E (Figure 1). The local government covers 260 km and at the 2006 census held a population of 464,789.00 The original indigenous occupants of the area are the Ikwerre people.

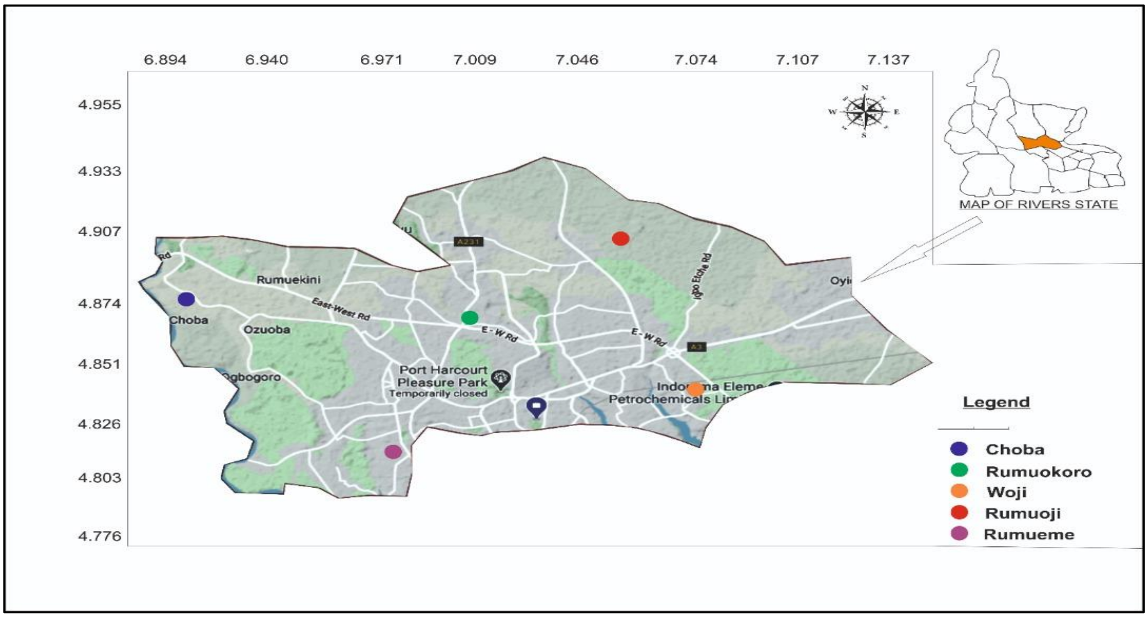


**Figure 1**. Map of five major fish markets in Obio-Akpor LGA.

### Data Collection

The five major catfish markets in the Obio-Akpor Local Government Area were studied. Twelve catfish sellers were randomly selected from each market to make a total of sixty respondents. Data were collected from catfish marketers using a structured questionnaire. The questionnaire administered elicited information on the socio-economic characteristics of respondents, sources of finance, constraints affecting sales, catfish price marketing characteristics of the fresh fish marketers, costs and returns and problems encountered by fresh fish marketers, etc. the response of these farmers formed the primary data used.

### Data Analyses

Descriptive statistics analysis such as percentage, frequencies were used to describe the socio-economic characteristics of the respondents, marketing channel, and constraints to fresh fish marketing in the study area using Statistical Package for Social Science (SPSS) 16.0 windows SPSS software package.

### Cost and Returns Analysis

This analysis was used to determine the profitability of catfish marketing. The profitability analyses employed were fixed cost (*FC*), variable cost (*VC*), total cost (*TC*), total revenue (*TR*), gross margin (*GM*), and profit (Adebayo and Daramola 2013).

*Total Cost =Total Variable Cost + Total Fixed Cost.*

*Total Revenue= P X Q (P = Price and Q = Total output (kg))*

*GM=TR –TVC where:*

*GM = Gross margin*

*TR = Total revenue*

*TVC=total variable cost*

*Profit= GM –TFC where:*

*GM = Gross margin*

*TFC = Total fixed cost*

### Regression Analysis

The regression analysis was carried out to examine the factors affecting the market profit of fresh fish sellers. The dependent variable is profit obtained by sellers in the market, while the exogenous variables are the factors affecting the level of profit, such as marketing experience, level of education, the quantity of fish purchased, and operational cost (Adesina and Djato 1996; Squires et al. 1998). Four functional forms were fitted, these were linear, semi-log, double log, and exponential. The model with the best fit was then chosen as the lead equation following Gujarati (1995), and Olayemi (1998).

## Results

Table 1 showed the socio-economic characteristics of fish sellers, all were females. Half of the respondents were within the age range of 41-50 years, 38.3% within 31-40years while 1.7% were within the 20-30 years old age group. Catfish sellers (33.3%) were married, 31.7% separated, 11.7% single, 18.3% widows while only 5.0% of the respondents were divorced. All the fish sellers (100%) were Christian. The study also revealed that 30% had secondary education, 16.7% had primary education while only 3.3% had non-formal education. Furthermore, the table showed that 90% of the respondents were full-time fish sellers and only 10% combined other economic activities with the selling of fresh catfish. Employment was the only motivation factor reported by the respondents.

**Table 1.** Socio-economic characteristics of fish sellers.

| Item | Frequency | Percentage |
|---|---|---|
| **Sex:** | | |
| Males | 0 | 0 |
| Female | 60 | 100.0 |
| **Total** | **60** | **100.0** |
| **Age (Years)** | | |
| 20-30 | 1 | 1.7 |
| 31-40 | 23 | 38.3 |
| 41-50 | 30 | 50.0 |
| 51-60 | 6 | 10.0 |
| **Marital status** | | |
| Single | 7 | 11.7 |
| Married | 20 | 33.3 |
| Separated | 19 | 31.7 |
| Divorced | 3 | 5.0 |
| Widow | 11 | 18.3 |
| **Total** | **60** | **100.0** |
| **Religion** | | |
| Christian | 60 | 100.0 |
| **Total** | **60** | **100.0** |
| **Educational Level** | | |
| Non-formal education | 2 | 3.3 |
| Primary school education | 10 | 16.7 |
| Secondary school education | 18 | 30.0 |
| Post-secondary school education | 30 | 50.0 |
| **Total** | **60** | **100.0** |
| **Main Occupation** | | |
| Full-Time Fish Seller | 54 | 90.0 |
| Part-Time Fish Seller | 6 | 10.0 |
| **Total** | **60** | **100.0** |
| **Motivating Factor for Employment** | 60 | 100.0 |
| **Total** | **60** | **100.0** |

Source: Field Survey 2019.

The transportation systems and challenges of catfish as shown in table 2 below, revealed that all the respondents use public transportation as a means of transporting the fish (100%) and most of them experienced mortality (91.7%). The mortality rate as a result of transportation challenges ranged from, 5-10pieces (51.7%), 1-5pieces (35.0%) 11-20 pieces (13.3%) respectively. Daily mortality recorded were as follows 1 piece (15.0%), 2 pieces (45.0%) while 4-5 pieces (18.3%) recorded the highest mortality.

**Table 2.** Challenges of transporting Fresh Catfish by fish sellers.

| Item | Frequency | Percentage |
|---|---|---|
| **Transportation System** | | |
| Public transportation | 60 | 100.0 |
| **Total** | **60** | **100.0** |
| **Transport Mortality** | | |
| Yes | 55 | 91.7 |
| No | 5 | 8.3 |
| **Total** | **60** | **100.0** |
| **Mortality Rate** | | |
| 1-5 | 21 | 35.0 |
| 5-10 | 31 | 51.7 |
| 11-20 | 8 | 13.3 |
| **Total** | **60** | **100.0** |
| **Daily Mortality** | | |
| 1 | 9 | 15.0 |
| 2 | 27 | 45.0 |
| 3 | 13 | 21.7 |
| 4-5 | 11 | 18.3 |
| **Total** | **60** | **100.0** |

Source: Field survey 2019

Table 3 below showed the various methods employed by catfish sellers in keeping fish alive. Forty-five percent employed constant changing of water as a means of preservation while 20% made use of sack to cover their catfish. Other unconventional methods were the use of slaughtered fish fat to feed the fish (11.7%), pouring of oil on the water (3.3%), use of leftover bread to feed (8.3%), adding lady's finger (Okra) to water (8.3%) and feeding with indomie waste noodles (3.3%). None of catfish sellers made use of anti-stress on their fish.

**Table 3.** Conventional and unconventional methods used to keep the Fresh fish alive.

| Item | Frequency | Percentage |
|---|---|---|
| Covering with sacks | 12 | 20.0 |
| Feed with fats of slaughtered fish | 7 | 11.7 |
| Use of palm oil | 2 | 3.3 |
| Use of bread to feed | 5 | 8.3 |
| Adding ladies' fingers to water (Okra) | 5 | 8.3 |
| Feeding with noodles | 2 | 3.3 |
| Changing of water | 27 | 45.0 |
| **Total** | **60** | **100.0** |
| **Anti-stress** | | |
| None | 60 | 100.0 |
| **Total** | **60** | **100.0** |

Source: Field survey 2019

The costs and returns associated with marketing catfish in the study area were presented in Table 4. The total mean variable cost (TVC) was ₦68,119.17, the total mean fixed cost (TFC) was ₦2,131.75, the total mean cost of production (TCP) was ₦70,250.92, mean total revenue (TR) recorded was ₦181,000.00, and mean net income (NI) was ₦137,572.08, mean gross margin value (GM) recorded was ₦139,635.83, while the profitability index (PI) was 1.31.

Figure 2 below showed the factors militating against fresh catfish marketing by respondents. The survey revealed that transportation cost (41.7%), unstable price of fish (21.7%), lack of capital (6.7%), hike in the price of fish (5%), inadequate holding/storage facilities (3.3%) and bad roads to access farms (21.7%) were identified by the respondents as limitations and challenges.

**Table 4.** Monthly Costs and Returns Analysis of Fresh catfish marketing in Obio-Akpor LGA.

| Variable | N | Minimum (₦) | Maximum (₦) | Mean (₦) | Std. Deviation (₦) |
|---|---|---|---|---|---|
| Labor cost | 60 | 1000.00 | 1550.00 | 1009.17 | 71.00 |
| Transportation cost | 60 | 500.00 | 1550.00 | 1165.00 | 510.26 |
| Levy and due | 60 | 100.00 | 150.00 | 111.67 | 21.33 |
| Purchase of catfish | 60 | 50000.00 | 975000.00 | 65833.33 | 119405.89 |
| **Total Variable Cost** | 60 | 51600.00 | 977650.00 | 68119.17 | 119454.32 |
| Knife | 60 | 100.00 | 200.00 | 119.17 | 29.24 |
| Bowl | 60 | 200.00 | 450.00 | 294.17 | 83.91 |
| Basket | 60 | 100.00 | 120.00 | 115.17 | 8.53 |
| Sack | 60 | 70.00 | 90.00 | 72.416 | 3.50 |
| Scale | 60 | 1200.00 | 2500.00 | 1530.83 | 566.07 |
| **Total Fixed Cost** | 60 | 1740.00 | 3150.00 | 2131.75 | 563.99 |
| **Total Cost (TVC+ TFC)** | 60 | 53345.00 | 979690.00 | 70250.92 | 119440.67 |
| **Total Revenue** | 60 | 150000.00 | 220000.00 | 181000.00 | 32230.63 |
| Gross Margin (TR-VC) | 60 | 72850.00 | 802650.00 | 139635.83 | 93091.13 |
| Net Income | 60 | 71090.00 | 804490.00 | 137572.08 | 93544.17 |
| Profitability Index | 60 | 1.47 | 1 .69 | 1.31 | 1.07689 |

Source: Field survey 2019

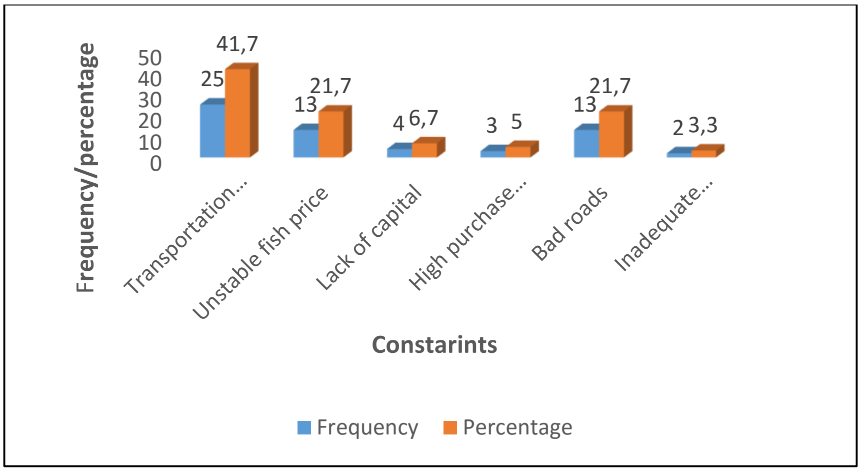


**Figure 2.** Major Constraints to Catfish Marketing System in the Study Area

Figure 3 below revealed the source of startup capital for respondent's personal savings recorded the highest with (78.3%), while (18.3%) of the respondents got finance from daily contribution/private lenders and only (3.3%) obtained loan from the bank.

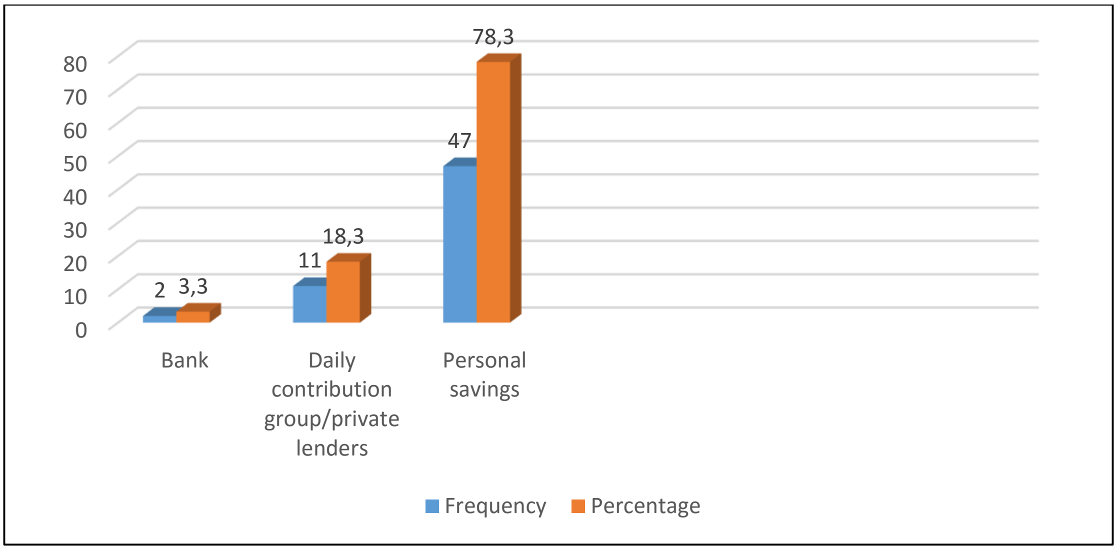


**Figure 3.** Source of startup capital

The result of the ordinary least square (OLS) regression analysis carried out to examine the determinants of profitability of catfish marketing in the study area as shown in Table 5, revealed that age, educational level, number of the sales point, and capital for catfish marketing showed a positive coefficient with the level of profit from catfish marketing and significant (P≥0.01). The coefficients are in line with the prior expectation. The $R^2$ value of 0.815 showed that 81.5 percent of the variation in the level of profit from fresh fish marketing was jointly explained by the independent variables specified in the regression model.

**Table 5.** Determinants of profitability of fresh Catfish marketing in Obio-Akpor LGA.

| Variables | Coefficients | t-value |
|---|---|---|
| (Constant) | -0.214 | -1.567 |
| Age | 0.020** | 0.061 |
| Educational level | 0.044*** | 5.127 |
| Sales point | 0.336*** | 2.587 |
| Labor | -0.007** | -2.033 |
| Catfish sale per day | 0.065 | 0.167 |
| Capital | 0.413*** | 2.557 |
| f-value | | 711 |
| R Square | | 0.835 |
| Adjusted R Square | | 0.815 |

***Significant((P≥0.01).; **Significant(((P≥0.05)
Source: Field survey (2019).

## Discussion

Women are generally involved in marketing fresh catfish in Nigeria, as women are well known to boost the efficiency and competitiveness of any venture in which they are involved, due to their accommodating and diligent approach to activities (Raney et al. 2011; Doss 2018). The result of this study showed that all fresh catfish sellers were female which is in contrast with the findings of Ayanboye et al. (2015) who reported 85% female and 15% male in Ibarapa zone of Oyo, State and Njoku and Offor (2016) who stated that 65% of catfish sellers were males and 35% female in Aba South LGA of Abia State.

Youth appear to be enthusiastic, adapt, and embrace emerging technology more easily and therefore more efficient than those who are perhaps older. Age is a key factor in the productivity and profitability performance of catfish sellers (Ngeywo et al. 2015). The result of this study indicates that most of the marketers were in their middle age class, which is an important factor in catfish marketing activities. This is in agreement with the findings of Ebewore (2013), who reported that people involved in economic activities (Catfish marketers) are in their economic active age and were able to actively participate in the business.

Studies have shown that healthy marriages increase business profitability by about twenty percent (Ahituv and Lerman 2005) and this suggests that marriage will improve employment, efficiency, and profitability. Marriages tend to have more household responsibilities than individuals and thus they meet family life demands. Also, the ability of the household to supply the needed labor in the catfish business depends to a large extent on the marital status (Agbugba et al. 2014). The findings of Ayanboye et al. (2015) corroborate the result of this study that married people dominate the cat-fish marketing business and are also an indication of the productive potential of the catfish business to support household livelihood. Stability provides a favorable atmosphere, essential for efficient management of resources, good citizen training, and personal integrity growth. Nwaru (2004) which is indicated in the findings of this study.

The literacy rate which can be measured through formal education is considered a crucial element for improving human capital, the less expensive training of the literate can be done and the socio-economic status is generally higher. Lareau (2003) noted that higher levels of education were associated with better economic and psychological outcomes. The findings of this study revealed that the majority of the catfish farmers were fairly educated with 50% post-secondary education. An additional year of education has been shown to increase the probability of productivity of an individual by 4.8%. This agrees with the findings of Nkamleu and Adesina (2000) and Adeogun et al. (2008) who found that level of education had a positive and significant influence on catfish marketers economically.

According to FAO (2017b), startup capital can be difficult for aquaculture marketing business. The establishment of this value chain business can take account of private capital from partners, whether active or silent. The ability to acquire sufficient capital is a key factor in which startup capital is a key part of the study for catfish marketers, primarily from personal savings. The catfish sellers used conventional and unconventional methods to keep the fish alive. The final consistency of the product would be influenced by product handling during transport and marketing.

The variables that were significantly included, age, educational level, the number of the sales point, and capital. Salespoint, capital, and educational level were significant (P≥0.01) respectively, and were positively related to the profit from fresh catfish marketing. The higher the capital the catfish marketer was able to invest into the business, the higher the profit accrue to them, which is in line with findings of Sikiru et al. (2009) who identified inadequate finance as a serious problem in catfish production and marketing.

The $R^2$ value of 0.835 was obtained in this study, which implies that 83.5% of the total variation in the dependent variable was accounted for by variation in the independent variables. This indicates the goodness of fit for the model and the relevance of the variables fitted into the model. The educational level was significant (P≥0.01) with a positive coefficient to profit from fresh catfish marketing. This implies that, with an increase in the years of schooling by fresh fish marketers, more profit will be accrued to them. This is also in line with the educational level because as one's educational level increases, it enables one to access and conceptualize improved marketing techniques and other related issues capable of enhancing one's performance (Apata et al. 2010). The proportion of labor involved in catfish marketing was negatively significant (P≥0.05) This implies that as labor increases, net income reduces due to the influenced level of profit that accrues to fresh catfish marketers in the study area. This might be as a result of labor collecting wages from the fresh fish marketers which ought to have been added to the total revenue thereby leading to more profit. The sales point was significant (P≥0.01) and positively related to the net income of the marketers. This denotes that the number of sales points or the number of catfish sold significantly affects the level of net income of the marketers. An increase in the quantity of fish (kg) sold in turn leads to an increase in net income of the catfish marketers. This implies that as the number of sales point increase, net income also increases. This result agrees with the findings of Offor and Nse-Nelson (2015) who opined that marketing experience/number of sales points has a significant influence on net income and marketing efficiency.

Major constraints recorded in this study agreed with the findings of (Davis and Schreck 1997). This result also corroborates the findings of Akankali and Jamabo (2011), who reported that unavailability of adequate transport and capital were hindrances to effective distribution of goods from one point to another. Handling and transport are inherently stressful and excessive crowding of fish before sales can also be stressful, with potential decreases in oxygen levels and water quality increased chances of abrasion, and rapid changes in light intensity (HSA 2005). The net income was positive at ₦137,572.08, this indicates that the business is profitable and this corroborates the finding of Olasunkanmi and Yusuf (2014). The gross margin in this study was ₦139,635.83, which is in line with the findings of Ugwumba and Chukwuji (2010) and Emokaroet al. (2010).

The study examined the socio-economic and cost benefits of marketing fresh catfish in Obio-Akpor Local Government Area of Rivers State. The most significant variables that influenced the profitability of catfish marketing were age, educational level, the number of sales points, and capital, while the major limitations against catfish marketing were the high cost of transportation, unstable price, and poor access road. The startup capital was mostly personal savings among others. Catfish marketers should form fish marketing co-operative, as this would help regulate unstable fluctuation in prices, increase their access to credit from the financial institution, and hence help ease the problem of inadequate capital. There should be the availability of infrastructure such as good feeder roads that link the rural areas to major cities, this would reduce the cost of transportation thereby reducing the total cost of production and increasing net income.

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# *Pseudophoxinus antalyae* Bogutskaya, 1992 (Çiçek Balığı )'nın Helmint Faunası ve Mevsimsel Değişimlerinin Belirlenmesi

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**Ö Z**

Araştırma Mart 2016-Şubat 2017 ayları arasında mevsimsel olarak Antalya İli Döşemealtı İlçesi sınırlarında doğan Kırkgöz Kaynakları'nda yaşayan ve endemik bir tür olan *Pseudophoxinus antalyae* Bogutskaya, 1992 (Çiçek Balığı)'deki Helmint parazitlerinin teşhis edilmesi amacı ile yapılmıştır. *P. antalyae* Bogutskaya, 1992, anılan su kaynağının akış güzergâhı üzerinde bulunan üç istasyondan sepet ağlar kullanılarak yakalanmıştır. Örneklenen balıkların önce boy, ağırlık, yaş ve cinsiyetleri ölçülmüş ve tespit edilmiştir. Kırkgöz kaynağında 120, Kepez I HES Yükleme Göleti ve kanallarında 136 ve Çırnık Köprüsü'nden ise 95 adet olmak üzere toplam 351 adet birey incelenmiştir. İncelenen balık örneklerinden 95 adet konağın çeşitli parazitlerle enfekte olduğu saptanmıştır. Çalışma sonucunda *Paradiplozoon homoion*, *Dactylogyrus* sp., *Rhabdochona denudata*, *Contracaecum* sp. ve *Ligula* sp. parazitleri tespit edilmiştir. Araştırmada *P. antalyae* Bogutskaya, 1992'deki parazitlerin mevsimsel değişimi, cinsiyet, boy ve yaş gruplarına göre; yaygınlık (%), ortalama yoğunluk ve bollukları saptanmıştır.

**Anahtar kelimeler:** Helmint parazitler, parazitizm, *Pseudophoxinus antalyae*, Kırkgöz

**M A K A L E B İ L G İ S İ**

**ARAŞTIRMA MAKALESİ**

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**Determination of Helminth Fauna and Seasonal Variations of *Pseudophoxinus antalyae* Bogutskaya, 1992**

**Abstract:** This study was carried out between March 2016 and February 2017 to determine the helminth parasites on *Pseudophoxinus antalyae* Bogutskaya, 1992 (Flower Fish), an endemic fish born in the border of Doşemealtı Province (Antalya), living in Kırkgöz Resources. *P. antalyae*, were caught using pots from three stations located on the flow route of the mentioned water source. Firstly, the length, weight, age, and sex of the sampled fish were measured and determined. Then, external, and internal examination was performed. A total of 351 individuals which including 120 in Kırkgöz Spring, 136 in Kepez I HES's forebay dam and canals and 95 from Çırnık Bridge, were examined. *Paradiplozoon homoion*, *Dactylogyrus* sp., *Rhabdochona denudata*, *Contracaecum* sp. and *Ligula* sp. parasites were identified in the result of this study. In the research, prevalence (%), mean density and abundance parameters were evaluated according to seasonal variation, sex, length, and age groups of parasites of *P. antalyae* Bogutskaya, 1992.

**Keywords:** Helminth parasites, parasitism, *Pseudophoxinus antalyae*, Kırkgöz

**Alıntılama**
Kestek S, Emre Y. 2021. *Pseudophoxinus antalyae* Bogutskaya, 1992 (Çiçek Balığı )'nın Helmint Faunası ve Mevsimsel Değişimlerinin Belirlenmesi. LimnoFish. 7(1): 49-60. doi: 10.17216/LimnoFish.709857

## Giriş

Balıkçılık ve balık yetiştiriciliği dünyada milyonlarca nüfusun gelir, beslenme ve geçim kaynağını teşkil etmektedir. 2014 yılındaki verilere göre kişi başına düşen su ürünleri miktarı 20 kg'a ulaşmıştır. Bilindiği üzere Dünya nüfusunun 2050 yılında 9,7 milyara ulaşacağı tahmin edilmektedir (Anonim 2016).

Balık içerdiği besleyici maddelerle günümüzde ve gelecekte başat olan/olacak bir besin kaynağıdır. Bundan dolayı artacak olan Dünya nüfusunun ümit kaynaklarından biridir. Bugün FAO'nun 2016 istatistiklerine göre dünya su ürünleri üretimi toplam 170,9 milyon ton'dur. Bunun 90,9 milyon tonu balıkçılıktan, 80,0 milyon tonu ise yetiştiricilikten gelmektedir (FAO 2018). Geçmiş yıllardaki istatistikler göz önüne alındığında balıkçılıktaki pay sabit kalmakta, ancak yetiştiricilik önemli bir ivme ile balıkçılık oranına yetişmektedir. Aynı eğilim ülkemizde de görülmektedir. Buna göre: toplam

628,631 ton'un 314,094 ton'u balıkçılık, 314,537 ton'u yetiştiricilikten gelmektedir (Tarım ve Orman Bakanlığı Balıkçılık ve Su Ürünleri Genel Müdürlüğü 2020). Geçmiş yıllara baktığımızda balıkçılık üretimi belli bir eşikte kalırken, yetiştiricilik sürekli bir devinim içindedir. Bu stratejik gıda ürününün daha kontrollü, sürdürülebilir ve nitelikli olması için önemli gayretler göstermek gerekmektedir.

Besin piramidindeki statülerini göz önüne alırsak; balıklar parazitlenme konusunda yüksek risk faktörlerine sahiptirler. Gerek doğadan avlanan ve gerekse yetiştiricilikten elde edilen balıklarda bulunan parazitler, öncelikle görünüm itibariyle market kaybına uğrayabilir. Zira yaşamı süresince oluşabilecek diğer bazı epidemik hastalıkların oluşmasına zemin sağlayabilir. Bunun doğada kontrolü oldukça zordur. Ancak yetiştiricilik ortamında bazı ilaç ve solüsyonları kullanarak önlemler mümkündür. Doğada ise yerinde ve zamanında alınacak önleyici tedbirlerle kısmen başarı sağlamak ve konaklardaki parazit yaygınlığını önlemek olasıdır (Olson 1986; Scholz 1999).

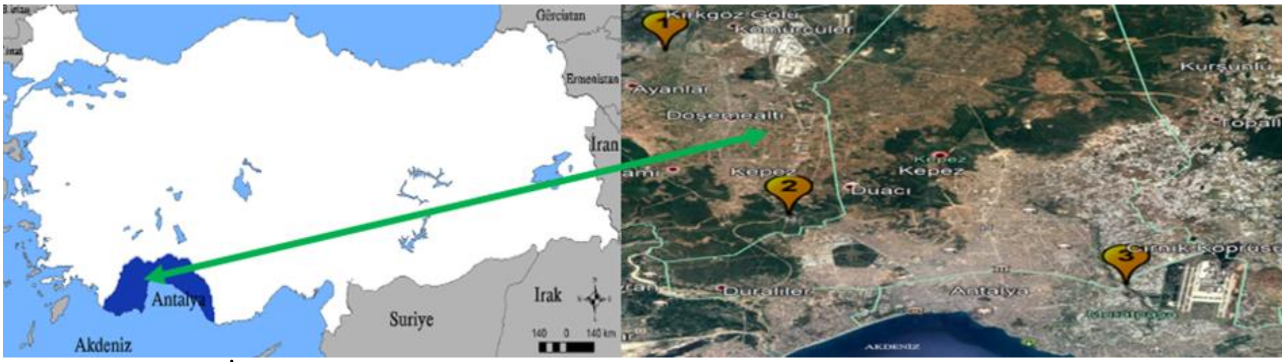
*Pseudophoxinus antalyae* Bogutskaya, 1992 türü Kırkgöz Kaynakları'nda yaşayan endemik bir türdür. Bu balıkla ilgili birçok araştırma yapılmıştır. Bu çerçevede sınırlı alanda parazitlerine yönelik çalışmalar da yapılmıştır (Soylu ve Emre 2007; Soylu 2007). Ancak aradan geçen süre bu kaynak üzerinde artan kirlilik etkisi; aynı kaynak üzerinde daha kapsamlı bir çalışmanın yapılmasını gerekli kılmıştır. Örneğin Antalya Organize Sanayi'nin arıtma suyu Kepez I HES'in ikincil yükleme göletine verilmektedir. Kepez HES'in tahliye kanallarından sonra ve Döşemealtı'ndaki yerleşimin olumsuz katkıları suyun kalitesine olumsuz etkilerde bulunmaktadır. Bu nedenle; tüm olumsuz faktörlerin anılan türün yaşama ortamını etkilemesi kaçınılmazdır. Bu kapsamda; çalışma sürecinde anılan türün helmint balık parazitlerine yönelik "değişen ekolojik koşullar çerçevesinde" yeniden çalışmalar yapılmıştır.

## Materyal ve Metot

Antalya Körfezi' ne dökülen önemli bir su kaynağı olan Kırkgöz Kaynağı *P. antalyae*' nin (Şekil 1) yaşadığı ortamdır. Kaynak kanalla yerleşim yerlerinden geçerek körfeze boşalmaktadır (DSİ 1985; Denizman 1989). Çalışmamız bu güzergah üzerinde üç istasyonda gerçekleştirilmiştir (Şekil 2). Bunlar Kırkgöz Su Kaynağı menbaındaki göllenme alanı, Kepez I HES yükleme göleti ve kanalları, Çırnık Köprüsü civarı şeklinde olmuştur. Anılan istasyonlardan mevsimsel örneklemeler yapılmıştır. Her mevsimsel örnekleme periyodunda 25-40 birey alınmıştır.

**Şekil 1.** *P. antalyae* Bogutskaya, 1992 (Orijinal)

**Figure 1.** *P. antalyae* Bogutskaya, 1992 (Original)




**Şekil 2.** Çalışma İstasyonları ( 1. Kırkgöz, 2. Kepez I HES ve 3. Çırnık Köprüsü) (Kaynak Google Earth)

**Figure 2.** Workstations (1. Kırkgöz, 2. Kepez I HEPP and 3. Çırnık Bridge) (Source: Google Earth)

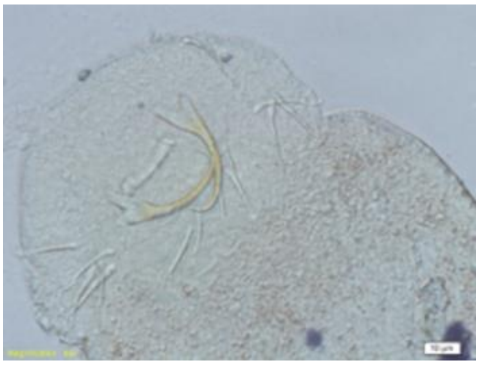
Mart 2016-Şubat 2017 tarihleri arasında avlanan balıkların öncelikle boy ve ağırlıkları belirlenmiştir. Örnekler istasyonlardan; içine yem konulmuş sepetler aracılığıyla avlanılmıştır. Diseksiyonlar 24 saat içerisinde gerçekleştirilmiştir. Diseksiyon işleminden önce gerekli ölçümler yapılmıştır. Solungaç ve bağırsak bakılarından sonra tespit edilen parazitlerin tür, yerleşim ve sayıları kaydedilmiştir. Parazitlerden bir kısmı hemen ve canlı olarak incelemeye tabii tutulmuştur. Diğerleri ise daha sonraki çalışmalar için %70' lik etil alkolde saklanmıştır. Parazitlerin teşhisinde değişik bilim adamlarının (Bychovskaya-Pavlovskaya vd. 1962; Gussev 1985; Gussev vd. 1987; Markevic 1951) düzenlediği anahtarlardan yararlanılmış, parazitlerin boyama ve tespit işlemlerinde ise Fernando vd. (1972)'nin geliştirdiği yöntemden istifade edilmiştir.

Ayrıca, her bireyden yaş tayininde kullanılmak üzere otolit çıkarılmıştır (Murray 1994; Campana vd. 2003; Walsh ve Maloy 2008). Bu yöntemde, otolitin yıllık halkaları merkezden uç kısma kadar eksen boyunca dizilen opak ve hiyalin halkaların sayılması ile yaş tayinleri belirlenmiştir.

Parazitlerin enfeksiyon değerlerini ifade eden terimlerin (Yaygınlık (%), OrtalamaYoğunluk, Ortalama Bolluk) hesaplanmasında Bush vd. (1997), Rózsa vd. (2000) ile Reiczigel vd. (2005)'nin geliştirdiği yöntemlerden yararlanılmıştır.

## Bulgular

Araştırma sonunda; Monogenea'da *Paradiplozoon homoion* ve *Dactylogyrus* sp.; Digenea'dan *Asymphylodora* sp.; Nematoda'dan *Rhabdochona denudata*ve *Contracaecum* sp. ile Cestoda'dan ise *Ligula* sp. parazitleri belirlenmiştir (Şekil 3, 4, 5, 6).



**Şekil 3.** *Dactloygyrus* sp. Kancaları

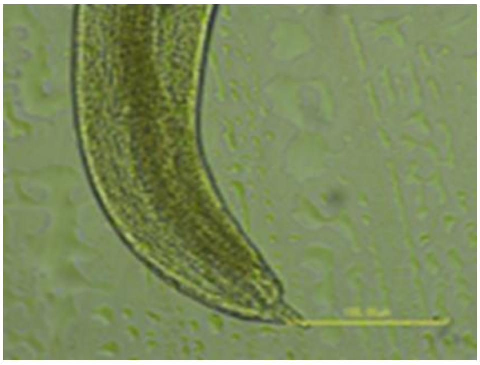
**Figure 3.** Hooks of Dactloygyrus *sp.*


**Şekil 4.** *P. homoion* genel görünümü

**Figure 4.** General view of *P. homoion*

**Şekil 5.** *R. denudata* dişi anteriörü

**Figure 5.** Female anterior of *R. denudata*



**Şekil 6.** *Contracaecum sp. larva, posterior*

**Figure 6.** Larva and pasterior of *Contracaecum* sp.

Kırkgöz Kaynağı'nda ve akış güzergahındaki istasyonlarda yapılan örnekleme çalışmalarında toplam 351 adet farklı boy (2,8-16,8 cm) ve yaşlarda (0–VIII) *P. antalyae* bireyleri yakalanmıştır. Kırkgöz istasyonunda 120 bireyden 16 bireyde; Kepez Göleti istasyonunda 136 bireyden 57 bireyde ve Cırnık Köprüsü istasyonunda ise 95 bireyden 14 adet bireyde parazite rastlanılmıştır. İlk istasyonda, en yüksek yaygınlık oranı (% 30,00) Yaz örneklemesinde görülmüştür. Öte yandan, en yüksek ortalama yoğunluk (8,50) ve bolluk ise 1,96 değerle sonbahar örneklerinde belirlenmiştir. Diğer yandan, Kepez İstasyonu' nda ise en yüksek yaygınlık oranı (% 57,69), ortalama yoğunluk (6,93) ve bolluk (4,00) ise İlkbahar mevsimindeki balıklarda saptanmıştır. Diğer istasyon olan Çırnık'da ise, en yüksek yaygınlık oranı (%46,67) ve ortalama yoğunluk (3,14) ile yaz örneklemesinde görülmüştür. Her üç istasyon içinde ise, en yüksek yaygınlık oranı (%57,69) ile İlkbahar mevsiminde Kepez İstasyonu' nda tespit edilmiştir (Tablo 1).

**Tablo 1**. Kırkgöz/Kepez ve Çırnık İstasyonları’ nda örneklenen *P. antalyae*’ de mevsimlere göre kaydedilen toplam örnek sayısı, enfekte balık sayısı, yaygınlık oranı, ortalama yoğunluk, ortalama bolluk ve tespit edilen toplam parazit sayıları.

**Table 1.** Total number of samples, number of infected fish, prevalence rate, average density, average abundance and total parasite numbers detected in *P. antalyae* sampled at Kırkgöz / Kepez and Çırnık Stations according to seasons.

| İstasyonlar/ Mevsimler | İncelenen Balık Sayısı | Enfekte Balık Sayısı | Yaygınlık (%) | Ortalama Yoğunluk | Ortalama Bolluk | Toplam Parazit Sayısı |
|---|---|---|---|---|---|---|
| **Kırkgöz** | | | | | | |
| **İlkbahar** | 34 | 0 | 0 | 0 | 0 | 0 |
| **Yaz** | 30 | 9 | 30,00 | 3,78 | 1,13 | 34 |
| **Sonbahar** | 26 | 6 | 23,08 | 8,50 | 1,96 | 51 |
| **Kış** | 30 | 1 | 3,33 | 1,00 | 0,03 | 1 |
| **Genel Toplam** | 120 | 16 | 13,33 | 5,38 | 0,72 | 86 |
| **Kepez** | | | | | | |
| **İlkbahar** | 26 | 15 | 57,69 | 6,93 | 4,00 | 104 |
| **Yaz** | 22 | 0 | 0 | 0 | 0 | 0 |
| **Sonbahar** | 58 | 32 | 55,17 | 4,75 | 2,62 | 152 |
| **Kış** | 30 | 10 | 33,33 | 2,00 | 0,67 | 20 |
| **Genel Toplam** | 136 | 57 | 41,91 | 4,84 | 2,03 | 276 |
| **Çırnık** | | | | | | |
| **İlkbahar** | 16 | 0 | 0 | 0 | 0 | 0 |
| **Yaz** | 15 | 7 | 46,67 | 3,14 | 1,47 | 22 |
| **Sonbahar** | 34 | 6 | 17,65 | 4,67 | 0,82 | 28 |
| **Kış** | 30 | 1 | 3,33 | 2,00 | 0,07 | 2 |
| **Genel Toplam** | 95 | 14 | 14,74 | 3,71 | 0,55 | 52 |

Öte yandan, örneklerde bulunan parazit türlerinin mevsimlere göre: İncelenen örnek sayısı, enfekte balık sayısı, yaygınlık oranı, ortalama yoğunluk, ortalama bolluk ve tespit edilen toplam parazit sayıları Tablo 2’de verilmiştir. Buna göre; en yüksek yaygınlık oranı (% 23,73) olarak *P. homoion* paraziti sonbahar mevsiminde görülmüştür. Onu *Dactylogyrus* sp. (%11,94) yaz mevsiminde izlemiştir. En yüksek ortalama yoğunluk ise, *Contracaecum* sp. (11,00) sonbahar’da saptanmıştır. Buna karşın, en yüksek bolluk ise, *P. homoion* paraziti (1,23) ile sonbahar mevsiminde belirlenmiştir.

Her üç istasyondan alınan toplam 351 örnek, cinsiyetlerine göre değerlendirildiğinde; bunların 175 adedi dişi balıklardan oluşmuştur. Bu balıklar en fazla *P. homoion* (37 adedi) ile enfekte olmuştur. *Ligula* sp. ve *Asymphylodora* sp.’ye hiç rastlanmamıştır. En yüksek ortalama yaygınlık 21,14, ortalama yoğunluk (4,62) ve ortalama bolluk (0,98) oranla *P. homoion* parazitine aittir. Buna karşın en düşük ortalama yaygınlık 1,14, ortalama yoğunluk (2,00) ve ortalama bolluk (0,02) oranla *Contracaecum* sp. parazit türünde olmuştur. Dişi balıklarda en fazla toplam 171 adet *P.homoion* ve en az da 4 adet *Contracaecum* sp. bulunmuştur. Her üç istasyondan alınan toplam 351 örneğin 156 adedi erkek balıklardan oluşmuştur. Bu balıklar en fazla *P. homoion* (22 adedi) ile enfekte olmuştur. *Asymphylodora* sp. hiç bulunmamıştır. En yüksek ortalama yaygınlık % 14,10, ortalama yoğunluk (4,18) ve ortalama bolluk (0,59) şeklindeki veriler *P. homoion* parazitine aittir.

**Tablo 2.** Örneklerde bulunan parazit türlerinin mevsimlere göre incelenen örnek sayısı, enfekte balık sayısı, yaygınlık oranı, ortalama yoğunluk, ortalama bolluk ve tespit edilen toplam parazit sayıları

**Table 2**. The number of parasite species in the samples examined according to the seasons, the number of infected fish, the prevalence rate, average density, average abundance and total number of parasites detected.

| Mevsimler | Türler | İncelenen Balık Sayısı | Enfekte Balık Sayısı | Yaygınlık (%) | Ortalama Yoğunluk | Ortalama Bolluk | Toplam Parazit Sayısı |
|---|---|---|---|---|---|---|---|
| **İlkbahar** | *Paradiplozoon homoion* | 76 | 13 | 17,11 | 6,54 | 1,12 | 85 |
| | *Dactylogyrus* sp. | 76 | 4 | 5,26 | 4,75 | 0,25 | 19 |
| | *Asymphylodora* sp. | 76 | 0 | 0 | 0 | 0 | 0 |
| | *Bothriocephalus acheilognathi* | 76 | 0 | 0 | 0 | 0 | 0 |
| | *Rhabdochona denudata* | 76 | 0 | 0 | 0 | 0 | 0 |
| | *Contracaecum* sp. | 76 | 0 | 0 | 0 | 0 | 0 |
| **Yaz** | *Paradiplozoon homoion* | 67 | 7 | 10,45 | 2,29 | 0,24 | 16 |
| | *Dactylogyrus* sp. | 67 | 8 | 11,94 | 3,63 | 0,43 | 29 |
| | *Asymphylodora* sp. | 67 | 0 | 0 | 0 | 0 | 0 |
| | *Bothriocephalus acheilognathi* | 67 | 1 | 1,49 | 1,00 | 0,01 | 1 |
| | *Rhabdochona denudata* | 67 | 1 | 1,49 | 6,00 | 0,09 | 6 |
| | *Contracaecum* sp. | 67 | 2 | 2,99 | 2,00 | 0,06 | 4 |
| **Sonbahar** | *Paradiplozoon homoion* | 118 | 28 | 23,73 | 5,18 | 1,23 | 145 |
| | *Dactylogyrus* sp. | 118 | 8 | 6,78 | 4,25 | 0,29 | 34 |
| | *Asymphylodora* sp. | 118 | 0 | 0 | 0 | 0 | 0 |
| | *Bothriocephalus acheilognathi* | 118 | 0 | 0 | 0 | 0 | 0 |
| | *Rhabdochona denudata* | 118 | 4 | 3,39 | 7,50 | 0,25 | 30 |
| | *Contracaecum* sp. | 118 | 2 | 1,69 | 11,00 | 0,19 | 22 |
| **Kış** | *Paradiplozoon homoion* | 90 | 9 | 10,00 | 1,89 | 0,19 | 17 |
| | *Dactylogyrus* sp. | 90 | 4 | 4,44 | 1,25 | 0,06 | 5 |
| | *Asymphylodora* sp. | 90 | 1 | 1,11 | 7,00 | 0,08 | 7 |
| | *Bothriocephalus acheilognathi* | 90 | 0 | 0 | 0 | 0 | 0 |
| | *Rhabdochona denudata* | 90 | 0 | 0 | 0 | 0 | 0 |
| | *Contracaecum* sp. | 90 | 0 | 0 | 0 | 0 | 0 |

Buna karşın en düşük ortalama yaygınlık % 0,64, ortalama yoğunluk (1,00) ve ortalama bolluk (0,01) ise *Ligula* sp. ve *R. denudata* parazit türlerinde olmuştur. Erkek balıklarda en fazla toplam 92 adet *P. homoion* ve en az da 1'er adet *Ligula sp.* ve *R. denudata* bulunmuştur Öte yandan her üç istasyondan alınan toplam 351 örneğin 20 adedi juvenil balıklardan oluşmuştur. Sadece bir örnekte *Asymphylodora* sp. parazitine rastlanmıştır. Bu parazit türünün ortalama yaygınlığı % 5,00, ortalama yoğunluğu 7,00 ve ortalama bolluğu ise 0,35 şeklinde bulunmuştur. Juvenil örneklerde en fazla toplam 7 adet *Asymphylodora* sp. bulunmuştur (Tablo 3).

**Tablo 3.** Dişi, erkek ve juvenil *P. antalyae* bireylerinde kaydedilen toplam örnek sayısı, enfekte balık sayısı, yaygınlık oranı, ortalama yoğunluk, ortalama bolluk ve tespit edilen toplam parazit sayıları.

**Table 3.** Total number of samples recorded, number of infected fish, prevalence rate, average density, mean abundance and total number of parasites detected in female, male and juvenile individuals of *P. antalyae*.

| Cinsiyet | Türler | İncelenen Balık Sayısı | Enfekte Balık Sayısı | Yaygınlık (%) | Ortalama Yoğunluk | Ortalama Bolluk | Toplam Parazit Sayısı |
|---|---|---|---|---|---|---|---|
| DİŞİ | *Paradiplozoon homoion* | 175 | 37 | 21,14 | 4,62 | 0,98 | 171 |
| | *Dactylogyrus* sp. | 175 | 19 | 10,86 | 3,53 | 0,38 | 67 |
| | *Asymphylodora* sp. | 175 | 0 | 0 | 0 | 0 | 0 |
| | *Bothriocephalus acheilognathi* | 175 | 0 | 0 | 0 | 0 | 0 |
| | *Rhabdochona denudata* | 175 | 8 | 4,57 | 4,38 | 0,20 | 35 |
| | *Contracaecum* sp. | 175 | 2 | 1,14 | 2,00 | 0,02 | 4 |
| ERKEK | *Paradiplozoon homoion* | 156 | 22 | 14,10 | 4,18 | 0,59 | 92 |
| | *Dactylogyrus* sp. | 156 | 5 | 3,21 | 3,80 | 0,12 | 19 |
| | *Asymphylodora* sp. | 156 | 0 | 0 | 0 | 0 | 0 |
| | *Bothriocephalus acheilognathi* | 156 | 1 | 0,64 | 1,00 | 0,01 | 1 |
| | *Rhabdochona denudata* | 156 | 1 | 0,64 | 1,00 | 0,01 | 1 |
| | *Contracaecum* sp. | 156 | 2 | 1,28 | 11,00 | 0,14 | 22 |
| JUVENİL | *Paradiplozoon homoion* | 20 | 0 | 0 | 0 | 0 | 0 |
| | *Dactylogyrus* sp. | 20 | 0 | 0 | 0 | 0 | 0 |
| | *Asymphylodora* sp. | 20 | 1 | 5,00 | 7,00 | 0,35 | 7 |
| | *Bothriocephalus acheilognathi* | 20 | 0 | 0 | 0 | 0 | 0 |
| | *Rhabdochona denudata* | 20 | 0 | 0 | 0 | 0 | 0 |
| | *Contracaecum* sp. | 20 | 0 | 0 | 0 | 0 | 0 |

Her üç istasyondan toplanan örneklerin yapılan yaş tayininde 0 ile 8 yaş gruplarında oldukları görülmüştür. Bu yaş gruplarında bulunan parazitlerin enfekte ettiği balık sayısı, yaygınlık, yoğunluk ve bolluğu ile tespit edilen toplam parazit sayıları Tablo 4'de verilmiştir. Juvenil (0 yaş) grupta sadece bir Digenea türü (*Asymphylodora* sp.) bulunmuştur. Toplam tespit edilen parazit sayısı 7 adettir. Yine 1 yaşındaki grupta toplam 82 adet örnekte en fazla *P. homoion* paraziti belirlenmiştir. Bu yaş grubunda *P. homoion*'unun yaygınlığı %9,76, ortalama yoğunluğu 4,38 ve bolluğu ise 0,43 olmuştur. Bu yaş grubunda ayrıca iki tür nematod (*R. denudata ve Contracaecum* sp.) ve bir tür diğer monogean (*Dactylogyrus* sp.) bulunmuştur.

2, 3 ve 4 yaş gruplarında 84, 82 ve 42 adet örnek incelenmiştir. 2 yaş grubunda 47 adet *P. homoion* tespit edilmiştir. Yaygınlık 16,67, ortalama yoğunluk 3,36 ve bolluk ise 0,19 şeklinde bulunmuştur. 3 yaş grubunda ise, yine en fazla *P. homoion* türüne rastlanmıştır (77 adet). Bu yaş grubunda en fazla bulunan parazitin yaygınlığı %17,07, ortalama yoğunluk 5,50 ve bolluk ise 0,94 olarak hesaplanmıştır. Yine bu gruptaki *Contracaecum* sp. ile enfekte olan 2 balıkta 22 adet olarak kayıt edilmiştir. Bu parazitin yaygınlığı % 2,44, ortalama yoğunluğu 11,00 ve bolluğu ise 0,27 şeklinde bulunmuştur. Bunlara karşın, 4 yaşındaki örneklerde ise, *P. homoion* (37 adet) ve *Contracaecum* sp. (24 adet) baskın parazitler olmuştur. Bunların yaygınlıkları sırası ile %21,43 ve % 4,76 şeklinde tespit edilmiştir.

Yine 5, 6, 7 ve 8 yaşlarındaki gruplarda ise 30, 8, 2 ve 1 adet *P. antalyae* örnekleri incelenmiştir. 5 yaş grubunda da *P. homoion* en fazla bulunan parazit olmuştur (38 adet).

Ancak diğer bir monogean olan *Dactylogyrus* sp. ise 34 adet olarak bulunmuştur. Bu yaş grubunda, ayrıca bir Cestod olan *Ligula* sp.'de tespit edilmiştir.

**Tablo 4.** 0-8 yaş gruplarındaki örneklerde kaydedilen toplam örnek sayısı, enfekte balık sayısı, yaygınlık oranı, ortalama yoğunluk, ortalama bolluk ve tespit edilen toplam parazit sayıları.

**Table 4.** Total number of samples recorded, number of infected fish, prevalence rate, average density, average abundance and total number of parasites detected in samples of 0-8 age groups.

| YAŞ | 0 | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|---|
| İncelenen Balık Sayısı | 20 | 82 | 84 | 82 | 42 | 30 | 8 | 2 | 1 |
| Enfekte Balık Sayısı | 0 | 8 | 14 | 14 | 9 | 9 | 2 | 2 | 1 |
| ***Paradiplozoon homoion*** | | | | | | | | | |
| Yaygınlık (%) | 0,00 | 9,76 | 16,67 | 17,07 | 21,43 | 30,00 | 25,00 | 100,00 | 100,00 |
| Ortalama Yoğunluk | 0,00 | 4,38 | 3,36 | 5,50 | 4,11 | 4,22 | 7,00 | 5,00 | 5,00 |
| Ortalama Bolluk | 0,00 | 0,43 | 0,56 | 0,94 | 0,88 | 1,27 | 1,75 | 5,00 | 5,00 |
| Toplam Parazit Sayısı | 0 | 35 | 47 | 77 | 37 | 38 | 14 | 10 | 5 |
| İncelenen Balık Sayısı | 20 | 82 | 84 | 82 | 42 | 30 | 8 | 2 | 1 |
| Enfekte Balık Sayısı | 0 | 9 | 6 | 5 | 4 | 6 | 0 | 1 | 0 |
| ***Dactylogyrus* sp.** | | | | | | | | | |
| Yaygınlık (%) | 0,00 | 10,98 | 7,14 | 6,10 | 9,52 | 20,00 | 0,00 | 50,00 | 0,00 |
| Ortalama Yoğunluk | 0,00 | 0,22 | 2,67 | 3,60 | 2,50 | 5,67 | 0,00 | 7,00 | 0,00 |
| Ortalama Bolluk | 0,00 | 0,02 | 0,19 | 0,22 | 0,24 | 1,13 | 0,00 | 3,50 | 0,00 |
| Toplam Parazit Sayısı | 0 | 2 | 16 | 18 | 10 | 34 | 0 | 7 | 0 |
| İncelenen Balık Sayısı | 20 | 82 | 84 | 82 | 42 | 30 | 8 | 2 | 1 |
| Enfekte Balık Sayısı | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ***Asymphylodora* sp.** | | | | | | | | | |
| Yaygınlık (%) | 5,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| Ortalama Yoğunluk | 7,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| Ortalama Bolluk | 0,35 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| Toplam Parazit Sayısı | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| İncelenen Balık Sayısı | 20 | 82 | 84 | 82 | 42 | 30 | 8 | 2 | 1 |
| Enfekte Balık Sayısı | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| ***Bothriocephalus acheilognathi*** | | | | | | | | | |
| Yaygınlık (%) | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 3,33 | 0,00 | 0,00 | 0,00 |
| Ortalama Yoğunluk | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 1,00 | 0,00 | 0,00 | 0,00 |
| Ortalama Bolluk | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,03 | 0,00 | 0,00 | 0,00 |
| Toplam Parazit Sayısı | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| İncelenen Balık Sayısı | 20 | 82 | 84 | 82 | 42 | 30 | 8 | 2 | 1 |
| Enfekte Balık Sayısı | 0 | 2 | 0 | 1 | 1 | 2 | 0 | 1 | 1 |
| ***Rhapdochona denudata*** | | | | | | | | | |
| Yaygınlık (%) | 0,00 | 2,44 | 0,00 | 1,22 | 2,38 | 6,67 | 0,00 | 50,00 | 100,00 |
| Ortalama Yoğunluk | 0,00 | 1,00 | 0,00 | 1,00 | 1,00 | 1,00 | 0,00 | 6,00 | 1,00 |
| Ortalama Bolluk | 0,00 | 0,02 | 0,00 | 0,01 | 0,02 | 0,07 | 0,00 | 3,00 | 1,00 |
| Toplam Parazit Sayısı | 0 | 2 | 0 | 1 | 1 | 2 | 0 | 6 | 1 |
| İncelenen Balık Sayısı | 20 | 82 | 84 | 82 | 42 | 30 | 8 | 2 | 1 |
| Enfekte Balık Sayısı | 0 | 1 | 0 | 2 | 2 | 0 | 0 | 0 | 0 |
| ***Contracaecum* sp.** | | | | | | | | | |
| Yaygınlık (%) | 0,00 | 1,22 | 0,00 | 2,44 | 4,76 | 0,00 | 0,00 | 0,00 | 0,00 |
| Ortalama Yoğunluk | 0,00 | 3,00 | 0,00 | 11,00 | 12,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| Ortalama Bolluk | 0,00 | 0,04 | 0,00 | 0,27 | 0,57 | 0,00 | 0,00 | 0,00 | 0,00 |
| Toplam Parazit Sayısı | 0 | 3 | 0 | 22 | 24 | 0 | 0 | 0 | 0 |

Nematod grubunda ise *R. denudata* türü saptanmıştır. 6 yaş grubunda diğer parazitlere rastlanılmamışken, sadece *P. homoion* paraziti tespit edilmiştir. Yaygınlık % 25,00, ortalama yoğunluk ve bolluk ise 7,00 ve 1,75 şeklinde hesaplanmıştır. Bu grupta 2 enfekte olan balıkta toplam 14 adet *P. homoion* bulunmuştur. 7 yaş grubunda iki monogen; *P. homoion* ve *Dactylogyrus* sp. belirlenmiştir.

Ayrıca bir nematod olan *R. denudata* tespit edilmiştir. 8 yaş grubunda ise sadece *P. homoion* ve *R. denudata* bulunmuştur. *P. homoion*'unun yaygınlığı % 100,00, ortalama yoğunluk ve bolluğu 5,00, 5,00 şeklinde saptanmıştır. Toplam parazit sayısı ise 5 olmuştur. *R. denudata*'nın yaygınlığı % 100,00, ortalama yoğunluğu 1,00, bolluğu 1,00 ve toplam parazit sayısı ise 1 şeklinde belirlenmiştir.

Alınan örnekler 2,8-4,8 cm (I), 4,9-7,8 cm. (II), 7,9- 12,8 cm. (III) ve 12,9-16,8 cm (IV) şeklinde dört boy gruplarına kategorize edilmiştir (Tablo 5). I. boy grubunda 78 örnek değerlendirilmiştir. Bu boy grubunda belirlenen parazitler içinde *Ligula* sp. hariç diğer parazit türlerinin hepsi yer almıştır. En fazla *P. homoion* türü bulunmuştur. Bu türün yaygınlığı % 6,41, ortalama yoğunluğu 4,00 ve bolluğu ise 0,26 şeklinde hesaplanmıştır. Toplam 78 balıktan enfekte olan 5 balıkta 20 adet *P. homoion* bulunmuştur (Tablo 5). Buna karşın II. grupta (4,9-7,8 cm) 123 balıktan 27 adetinin enfekte olduğu görülmüştür. Bu boy grubunda sadece iki parazit türü belirlenmiştir. Yine en fazla *P. homoion* bulunmuştur (89 adet). *Dactylogyrus* sp. taksonundan 16 adet tespit edilmiştir. *P. homoion'*unun yaygınlığı % 17,07, ortalama yoğunluğu 4,24 ve bolluğu ise 0,72 şeklinde olmuştur. *Dactylogyrus* sp.'nin yaygınlığı % 4,88, ortalama yoğunluğu 2,67 ve bolluğu ise 0,13 olarak hesaplanmıştır.

III. Boy grubunda (7,9-12,8 cm) 123 adet örnek incelenmiştir. Bu grupta da en fazla parazit yine *P. homoion* olmuştur. 21 enfekte balıkta 88 adet parazit bulunmuştur. Buna karşın 14 enfekte balıkta ise, 60 adet *Dactylogyrus* sp. tespit edilmiştir. İki nematod (*R. denudata* ve *Contracaecum* sp.) üçer enfekte balıkta 25 ve 23 adet bulunmuştur. Bir örnekte ise, *Ligula* sp. taksonu saptanmıştır. Bu grupta *P. homoion'*unun yaygınlığı % 17,07, ortalama yoğunluk ve bolluğu ise 4,19 ve 0,72 şeklinde bulunmuştur. Buna karşın *Dactylogyrus* sp.'nin yaygınlığı % 11,38, ortalama yoğunluk ve bolluğu ise, 4,29 ve 0,49 olarak hesaplanmıştır.

IV. Boy (12,0-16,8 cm) grubunda diğer gruplarda olduğu gibi *P. homoion* baskın parazit türdür. Bu boy grubunda ayrıca *Dactylogyrus* sp. ve *R. denudata* türleri de bulunmuştur. *P. homoion* 'unun yaygınlığı % 44,44, ortalama yoğunluk ve bolluğu 5,50 ve 2,44 şeklindedir. Buna karşın 27 balıktan enfekte olan 5 balıkta *R. denudata* türünün yaygınlığı % 14,81 ve ortalama bolluğu 0,33 şeklinde hesaplanmıştır.

## Tartışma ve Sonuç

Antalya için endemik bir tür olan *P. antalyae* Bogutskaya, 1992' deki parazit faunası daha önce bu çalışmada da seçilen bir istasyonda çalışılmıştır (Soylu ve Emre 2007). Ayrıca sadece bizim de tespit ettiğimiz *P. homoion* konusunda müstakil bir çalışma yapılmıştır (Soylu 2007). 60'lı yıllarda Kırkgöz kaynakları üzerinde kurulan Kepez I HES yaklaşık 30 km.'lik bir yatakta ilerleyerek Lara'da şelale şeklinde Antalya Körfezi'ne dökülmektedir. Anılan bu güzergâhın büyük bir kısmı antropolojik müdahalelere açıktır. Bu nedenle kaynağın karakteristik türü olan *P. antalyae* Bogutskaya, 1992'deki parazit faunasının sağlık açısından takip edilmesi ihtiyacı doğmuştur.

Yaptığımız çalışmada 6 tür parazit saptanmıştır. Bu parazitlerin bazıları *P. antalyae* Bogutskaya,1992 için yeni kayıtlardır. Daha önceki çalışmalarda (Soylu ve Emre 2007; Soylu 2007) balığın solungaçlarında saptanan *P. homoion* taksonu 72 bireyden 53'ünde bulunmuştur. Yaygınlık oranı %73,6 olarak belirlenmiştir. Öte yandan Soylu (2007), bu konakta *P. homoion'*a yönelik yaptığı çalışmada ise 240 adet bireyden 131 (%54,6) konağın *P. homoion* ile enfekte olduğunu belirlemiştir. En yüksek yaygınlığın Ocak (%79,3), en düşük yaygınlığın ise Mayıs ayında (%43,2) olduğunu bildirmiştir. Öte yandan Öztürk (2011) Manyas Gölü'nde *Rutilus rutilus* türünde *P. homoion*'unun yaygınlık oranının %5,4; Akmirza ve Yardımcı (2014) ise, Sakarya Nehri'nde yakalanan *Abramis brama* türünde % 39,58, *Blicca björkna*' da da % 55,26 şeklinde olduğunu rapor etmişlerdir. Ayrıca Öztürk ve Özer (2014) Aşağı Kızılırmak Deltası'nda yaptıkları çalışmada *Vimba vimba* ve *Scardinus erythrophthalmus*'daki *P. homoion'*unun yaygınlığını %10,0 ve 28,6 şeklinde bulmuşlardır. Yine Emre (2016) Beyşehir Gölü kollarından Sarıöz Deresi'nden avlanan *Capoeta mauricii*'de bulunan *Paradiplozoon* sp.'nin en yüksek yaygınlık değerini ilkbahar mevsiminde %32,4 olarak hesaplamıştır. Buna karşın dişi bireylerdeki yaygınlığı ise ilkbahar mevsimindeki örneklemede % 46,2 olmuştur. Yapılan bu çalışmada ise en yüksek yaygınlık Kepez İstasyonu'nda (%38,2), ortalama yoğunluk 4,7 ve ortalama bolluk ise 8,16 şeklinde saptanmıştır.

*Asymphylodora* sp. taksonuna ait Digenean *P. antalyae* Bogutskaya, 1992 için ilk kayıttır. Kır ve Tekin-Özan (2005) Kovada Gölü'nden avlanan *Tinca tinca* türünde *Asymphylodora tincae* tespit etmişlerdir. En yüksek yaygınlığı Aralık ayındaki örneklemede %42,8 olarak saptamışlardır. Diğer yandan Aydoğdu vd. (2014) Tuz Gölü Havzası'nda bulunan İncesu/Konya kaynağındaki endemik *Pseudopoxinus crassus'*da *Asymphylodora imitans* saptamışlardır. Yaygınlığı %28,2 ve yoğunluğu ise 10,4 şeklinde hesaplanmıştır. Bu çalışmada ise sadece Kırkgöz Kaynağındaki bir örnekte tespit edilmiştir. Yaygınlığı %0,8, ortalama yoğunluğu 7 ve ortalama bolluğu ise 0,058 şeklinde belirlenmiştir.

Konak balığımızda iki tür nematod saptanmıştır. Bunlar *R. denudata* ve *Contracaecum* sp.'dir. Her iki tür de *P. antalyae* Bogutskaya, 1992 için ilk kayıttır. Aydoğdu vd. (2002) Doğanca Baraj Gölü'nde *Barbus plebejus escherichi* konak balığında *Contracaecum* sp.'nin yaygınlık oranını %27,2 şeklinde bulmuşlardır. Koyun ve Altunel (2007)

**Tablo 5**. I-IV Boy gruplarındaki örneklerde kaydedilen toplam örnek sayısı, enfekte balık sayısı, yaygınlık oranı, ortalama yoğunluk, ortalama bolluk ve tespit edilen toplam parazit sayıları

**Table 5.** Total number of samples recorded, number of infected fish, prevalence rate, average density, average abundance and total number of parasites detected in samples in I-IV size groups

| **Boy grubu (cm)** | **I** | **II** | **III** | **IV** |
|---|---|---|---|---|
| | 2,8-4,8 | 4,9-7,8 | 7,9-12,8 | 12,9-16,8 |
| **İncelenen Balık Sayısı** | 78 | 123 | 123 | 27 |
| **Enfekte Balık Sayısı** | 5 | 21 | 21 | 12 |
| ***Paradiplozoon homoion*** | | | | |
| **Yaygınlık (%)** | 6,41 | 17,07 | 17,07 | 44,44 |
| **Ortalama Yoğunluk** | 4,00 | 4,24 | 4,19 | 5,50 |
| **Ortalama Bolluk** | 0,26 | 0,72 | 0,72 | 2,44 |
| **Toplam Parazit Sayısı** | 20 | 89 | 88 | 66 |
| **İncelenen Balık Sayısı** | 78 | 123 | 123 | 27 |
| **Enfekte Balık Sayısı** | 2 | 6 | 14 | 2 |
| ***Dactylogyrus* sp.** | | | | |
| **Yaygınlık (%)** | 2,56 | 4,88 | 11,38 | 7,41 |
| **Ortalama Yoğunluk** | 1,00 | 2,67 | 4,29 | 4,50 |
| **Ortalama Bolluk** | 0,03 | 0,13 | 0,49 | 0,33 |
| **Toplam Parazit Sayısı** | 2 | 16 | 60 | 9 |
| **Boy grubu (cm)** | I | II | III | IV |
| | 2,8-4,8 | 4,9-7,8 | 7,9-12,8 | 12,9-16,8 |
| **Enfekte Balık Sayısı** | 1 | 0 | 0 | 0 |
| ***Asymphylodora* sp.** | | | | |
| **Yaygınlık (%)** | 1,28 | 0,00 | 0,00 | 0,00 |
| **Ortalama Yoğunluk** | 7,00 | 0,00 | 0,00 | 0,00 |
| **Ortalama Bolluk** | 0,09 | 0,00 | 0,00 | 0,00 |
| **Toplam Parazit Sayısı** | 7 | 0 | 0 | 0 |
| **İncelenen Balık Sayısı** | 78 | 123 | 123 | 27 |
| **Enfekte Balık Sayısı** | 0 | 0 | 1 | 0 |
| ***Bothriocephalus acheilognathi*** | | | | |
| **Yaygınlık (%)** | 0,00 | 0,00 | 0,81 | 0,00 |
| **Ortalama Yoğunluk** | 0,00 | 1,00 | 2,00 | 3,00 |
| **Ortalama Bolluk** | 0,00 | 0,00 | 0,01 | 0,00 |
| **Toplam Parazit Sayısı** | 0,00 | 0 | 1 | 0 |
| **İncelenen Balık Sayısı** | 78 | 123 | 123 | 27 |
| **Enfekte Balık Sayısı** | 2 | 0 | 3 | 4 |
| ***Rhapdochona denudata*** | | | | |
| **Yaygınlık (%)** | 2,56 | 0,00 | 2,44 | 14,81 |
| **Ortalama Yoğunluk** | 1,00 | 0,00 | 8,33 | 2,25 |
| **Ortalama Bolluk** | 0,03 | 0,00 | 0,20 | 0,33 |
| **Toplam Parazit Sayısı** | 2 | 0 | 25 | 9 |
| **İncelenen Balık Sayısı** | 78 | 123 | 123 | 27 |
| **Enfekte Balık Sayısı** | 1 | 0 | 3 | 0 |
| ***Contracaecum* sp.** | | | | |
| **Yaygınlık (%)** | 1,28 | 0,00 | 2,44 | 0,00 |
| **Ortalama Yoğunluk** | 3,00 | 0,00 | 7,67 | 0,00 |
| **Ortalama Bolluk** | 0,04 | 0,00 | 0,19 | 0,00 |
| **Toplam Parazit Sayısı** | 3 | 0 | 23 | 0 |

Enne Baraj Gölü' ndeki çalışmalarında konak balıkta *Contracaecum* sp. enfeksiyonu ile su sıcaklığı arasında negatif bir ilişkinin olduğunu ifade etmişlerdir. Zubaidy (2009) Hilla Nehri, Al-Furat Balık Çiftliği ve Al-Mahaweel Drenajından örneklenen *Liza abu'*daki *Contracaecum* sp.'nin enfeksiyon durumunu irdelemiştir. Yaygınlık ve yoğunluk kış için %11,9 ve 1,1 larva/balık; yaz mevsimi için ise % 47,6 ve 3,5 larva/balık şeklinde belirlenmiştir. Yine her iki sezonda da dişilerde daha yüksek değerler bulunmuştur. Aydoğdu vd. (2011) *Capoeta antalyensis, Pseudopoxinus battalgil* ve *Aphanius mento* türlerindeki nematodları araştırmışlardır. Bu türlerden *R. denudata C. antalyensis'*deki yaygınlık oranını %88,6; *P. battalgil'*deki *Contracaecum* sp. oranını ise %47,6 şeklinde bulmuşlardır. Pazooki vd. (2012) İran'da yaptıkları çalışmada *Capoeta damascine'*de *R. denudata'*nın yaygınlık oranını %73,39, ortalama yoğunluğunu ise 9,45, *Cyprinion watsoni* için ise % 88,60 ve 15,82; bunlara karşın *Schistura sargadensis'*de % 2,94 ve 1; *Channa gachua* için ise, % 13,63 ve 3 şeklinde bulmuştur. *C. damascina*'da *Contracaecum micropapillatum'*un yaygınlığı % 4,58 ve ortalama yoğunluğu ise 1,6 şeklinde saptanmıştır. Koyun vd. (2015) Murat Nehri'ndeki *Barbus lacerta* konağında *R. denudata* için yaygınlığı %15 ve *Contracaecum* sp.'da ise %0,2 olarak bildirmişlerdir. Yine Emre (2016) *Capoeta pestai'* de en fazla yaygınlık oranını %60 kış mevsiminde; *C. mauricii*'de en yüksek yaygınlık oranını ise %65 ile yaz mevsiminde bildirmiştir. Bunlara karşın bizim çalışmamız sonunda *Contracaecum* sp. için en yüksek yaygınlık oranı Kırkgöz İstasyonu'ndan avlanan örneklerden yaygınlık oranı % 2,5, ortalama yoğunluk 8,3 ve ortalama bolluk ise 0,208 şeklinde saptanmıştır. Yine diğer nematod olan *R. denudata* için ise Kepez I-İstasyonu'nda %3,7, Kırkgöz kaynağında ortalama yoğunluk 7,75 ve ortalama bolluk ise 0,228 şeklinde hesaplanmıştır.

Konak balıkta tespit edilen diğer yeni kayıt ise bir Sestod'dur. Cinsi ise *Ligula* sp.'dir. Keskin ve Erk'akan (1987) İç Anadolu'daki su kaynaklarından örneklenen, *Chondrostoma regium, V. vimba, Silurus glanis, Capoeta capoeta, Alburnus orontis, Leuciscus cephalus* ve *Garra rufa* balık türlerinde *Ligula intestinalis* parazitini saptamışlardır. Cengizler vd. (1991), Almus Baraj Gölü' nden örneklenen *Cyprinus carpio* L, 1758, *L. cephalus, C. capoeta, Capoeta tinca* Heckel, 1843, *C. regium* Heckel, 1843, *Barbus plebejus, A. orontis* Sauvage, 1882, *Carassius carassius* L, 1758 Ligulosis varlığı ile alakalı olarak değerlendirilmiştir. Değerlendirme sonucunda *A. orontis*'de %43 ve *L. cephalus*'da %7,4 enfeksiyonu oranlarını rapor etmişlerdir. Kır ve Tekin-Özan (2005) Kovada Gölü'ndeki Kadife balığı (*T. tinca*) helmint parazitlerine yönelik yapmış oldukları çalışmada 6 tür parazit belirlemişlerdir. Bunlardan biri olan *L. intestinalis'*in Ekim ayındaki yaygınlığı (%20) olarak bulunmuştur. İnnal vd. (2007) *Alburnus escherichii, Alburnoides bipunctatus* Bloch, 1782, *C. carpio, T. tinca, Vimba vimba tenella* ve *B. plebejus* türlerinde bulunan *L. intestinalis* parazitinin ilave yeni kayıtlar olduğunu belirtmişlerdir. Tüm bunlara karşın bizim çalışmamızın sonucunda Kırkgöz istasyonundan örneklenen bir tek bireyde tespit edilmiştir. Bunun da yaygınlık oranı %0,8, ortalama yoğunluğu 1 ve ortalama bolluğu ise 0,008 şeklinde belirlenmiştir.

Bu çalışmada dört mevsim boyunca üç istasyondan avlanan toplam 351 *P. antalyae* Bogutskaya, 1992 bireyi incelenmiştir. *Asymphylodora* sp., *R. denudata, Contracaecum* sp. ve *Ligula* sp. türleri *P. antalyae* Bogutskaya, 1992 konağı için yeni kayıt parazitlerdir.

*P. homoion* yaygınlık, yoğunluk ve bolluk yönünden en fazla Kepez İstasyonu'nda tespit edilmiştir. Yine bu parazitte konak boyu arttıkça yaygınlık ve bollukta artışlar anlamlı farklılıklar göstermiştir ($P < 0,05$). Yine yaş arttıkça parazitin yaygınlığı da artmıştır. Soylu (2007)'nun yaptığı çalışmada anılan parazitin enfeksiyon yaygınlık oranının küçük boylarda düşük, orta boylarda yüksek ve büyük boylarda ise yine düşük oranlarda görüldüğü belirtilmiştir. Öte yandan, boyca ve yaşça büyük balıklardaki yaygınlık oranının düşmesinin bağışlık sisteminin gelişmesi ile ilgili olduğu belirtilmiştir (Chapman vd. 2000; Rakauskas ve Blaževičius 2009).

*Dactloygyrus* sp. Kırkgöz İstasyonu'nda en fazla yaygınlık göstermiştir. En fazla yaz mevsiminde yaygınlık düzeyine erişmiştir. En fazla yaygınlık ve yoğunluğa dişi bireylerde rastlanılmıştır. Yaş arttıkça yaygınlık, yoğunluk ve bollukta artış görülmüştür.

*R. denudata*, için en yüksek yaygınlık oranı sonbahar mevsiminde kayıt edilmiştir. Konak boyu arttıkça bu parazitin yaygınlığının arttığı gözlenmiştir. Yine yaygınlık yaş ile artış göstermiştir.

*Contracaecum* sp. paraziti için yaygınlık, yoğunluk ve bolluk yönünden en yüksek değere Kırkgöz istasyonunda ulaşmıştır. Yaygınlık yönünden ise Sonbahar mevsiminde en yüksek değere erişmiştir.

Soylu ve Emre (2007)'nin yaptıkları çalışmadaki söz konusu konağın helmint parazitlerine bir digean (*Asymphylodora* sp.), iki nematod (*R. denudata* ve *Contracaecum* sp.) ve bir Cestod (*Ligula* sp.) olmak üzere toplam dört yeni parazit taksonu ilave edilmiştir. Buna göre; *Asymphylodora* sp., *R. denudata*, *Contracaecum* sp. ve *Ligula* sp. parazit taksonları *P. antalyae* Bogutskaya, 1992 için yeni kayıtlardır.

## Teşekkür

Bu makale Akdeniz Üniversitesi, Fen Bilimleri Enstitüsünde yapılan "*Pseudophoxinus antalyae* Bogutskaya, 1992 (Çiçek Balığı)'nın Helmint Faunası ve Mevsimsel Değişimlerinin Belirlenmesi" başlıklı tezden üretilmiştir.

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# Phytoplankton Community of a Boron Mine Waste Storage Reservoir

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**A B S T R A C T**

This study aimed to assess the composition, seasonality, and abundance of the phytoplankton community of a Boron (B) mine effluent storage reservoir, Çamköy Reservoir, Balıkesir, Turkey. For this purpose, phytoplankton and certain physicochemical parameters were sampled seasonally between April 2015 and January 2016. B concentrations ranged from 554 mg $L^{-1}$ to 689 mg $L^{-1}$. A total of 39 taxa were identified during the study. The percent composition for each phytoplankton group was as follows: Bacillariophyta 67%, Chlorophyta 10%, Cyanobacteria 8%, Euglenophyta 8%, Mioza 5%, and Charophyta 2%. In summer 2015 no phytoplankton was detected in the samples and the excessive B concentrations (above 600 mg $L^{-1}$) in the reservoir seem to be the reason for the lack of phytoplankton in the summer samples. The most common taxa were *Navicula digitoradiata* (Bacillariophyta), *Surirella ovata* (Bacillariophyta), and *Nitzschia amphibia* (Bacillariophyta). The reservoir had a low number of phytoplankton taxa and abundance compared with the natural lakes probably due to the excessive B levels. The phytoplankton community of the reservoir was composed of taxa that preferred alkaline waters.

**Keywords:** Boron, Çamköy Reservoir, phytoplankton, waste

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**Bir Bor Madeni Atık Depolama Barajının Fitoplankton Kommunitesi**

**Öz:** Bu çalışmanın amacı, bir Bor (B) madeni atık toplama barajı, (Çamköy Barajı, Balıkesir) fitoplanktonun kompozisyonu, mevsimselliği ve bolluğunu tespit etmektir. Bu amaçla, Nisan 2015 ile Ocak 2016 tarihleri arasında fitoplankton ve bazı fizikokimyasal parametreler için örnekleme yapılmıştır. B derişimi 554 mg $L^{-1}$ ile 689 mg $L^{-1}$ arasında değişmiştir. Çalışma süresince toplamda 39 takson tespit edilmiştir. Fitoplankton kompozisyonu, %67 Bacillariophyta, %10 Chlorophyta, %8 Cyanobacteria, %8 Euglenophyta , %5 Mioza ve %2 Charophyta 'dan oluşmuştur. 2015 yaz döneminde hiç fitoplankton türü tespit edilmemiş olup bunun sebebinin yüksek B seviyelerinin (600 mg $L^{-1}$ üzeri) olabileceği tahmin edilmiştir. Tespit edilen en yaygın taksonlar, *Navicula digitoradiata* (Bacillariophyta), *Surirella ovata* (Bacillariophyta)_ve *Nitzschia amphibia* (Bacillariophyta) olmuştur. Yüksek Bor içeriğinden dolayı, doğal göllere nazaran gölette daha düşük fitoplankton takson sayısı ve yoğunluğu tespit edilmiştir. Göletin fitoplankton kommunitesi alkali suları tercih eden taksonlardan oluşmuştur.

**Anahtar kelimeler:** Bor, Çamköy Barajı, fitoplankton, atık

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## Introduction

The industrialization has dramatically increased the demand for the mining of minerals worldwide (Stürmer 2013). However, mining has severely affected the sustainability of ecosystems, including surface waters (Lesley et al. 2008). Turkey is one of the leading countries for Boron (B) mining in the world (Türe and Bell 2004). The majority of B reserves in Turkey are in the western part of the country, including Balıkesir (Türker et al. 2016).

The metalloid B is naturally present in freshwater bodies at less than 0.1 mg $L^{-1}$ concentrations, but mining activities have elevated B levels significantly in some water bodies (Nable et al. 1997). The widespread use of B with its high solubility in the water has raised concerns about its excessive levels in some surface waters (Rees et al. 2011).

Although B has been recognized as an essential element for higher plants, studies on B requirements in algae have produced controversial results (Dembitsky et al. 2002; Villavicencio et al. 2007). It has been shown that some aquatic plants can accumulate high levels of B (Damiri 2007). Fernandez et al. (1984) found that after seven days of exposure to B, the bioconcentration factor increased significantly in the green alga *Chlorella pyrenoidosa* H. Chick. Marín and Oron (2007) found that pH significantly affected the bioaccumulation of B in the duckweed (*Lemna gibba L.*).

Phytoplankton populations and their interactions with environmental factors are difficult to generalize. It is more even challenging to examine the interactions between phytoplankton dynamics and water quality parameters in effluent recipient aquatic ecosystems because of their highly dynamic nature (Thomas et al. 2018).

Man-made reservoirs are the main recipients of effluents from mines. Planktonic organisms are directly affected by the effluent inputs. However, our knowledge about phytoplankton in the effluent recipient water bodies is limited. Most of the studies performed so far concentrated on the taxonomy and ecology of phytoplankton in natural waters (Pomati et al. 2017). The resistant phytoplankton species may have adapted to water bodies receiving mine waste.

The link between macronutrient enrichment and increased productivity in lakes is well-established (Schindler 2012). However, the effects of excessive metal concentrations have not been studied comprehensively (Hassler et al. 2012). This study aimed to determine the effects of B mine effluent on the phytoplankton community composition, seasonality, and abundance in Çamköy Reservoir, Balikesir, Turkey as a B mine effluent storage reservoir.

## Materials and Methods

### Research Area

Çamköy Reservoir is located at 39° 27' 43" N and 28° 10' 09" E, 30 km southeast of Balıkesir, Turkey (Figure 1). The construction of the reservoir started in 1987 and was completed in 1991 by the State Water Works for effluent deposition from B mine sites. The reservoir has a maximum depth of 33 m and a surface area of 1 $km^2$. During the mining, a large number of ore is excavated, producing a vast amount of B-rich effluent. The effluent is pumped by pipes from mine sites to the reservoir and it is settled in the bottom (State Water Works 2018).

### Field Work and Sampling

Sampling was carried out seasonally between April 2015 and January 2016. Due to legal restrictions on boat access to the reservoir, samples were taken only at one station. The station was set at the opposite side of the waste entrance point at the edge of the reservoir. Samples were taken below the surface (about 0.5 m) using a Kemmerer water sampler. In the field, phytoplankton samples were placed in 250 ml bottles and fixed with Lugol's solution until processed in the laboratory.


**Figure 1.** The map showing the location of Çamköy Reservoir and the sampling station in it.

In the laboratory, phytoplankton samples were poured into 50 ml graduated cylinders and were allowed to settle for 24 h. After that, 45 ml of water was aspirated from each graduated cylinder and the remaining 5 ml was poured into a small glass vial for microscopic analysis (APHA 1995). The samples were examined by an Olympus compound microscope. Phytoplankton species were identified according to Bourrelly (1966), Huber-Pestalozzi (1983), Round et al. (1990), Krammer and Lange-Bertalot (1991), Hartley (1996), John et al. (2002), and Komarek and Anagnostidis (2005). Taxonomic names were updated and based on www.algabase.org (Guiry and Guiry 2020).

In situ parameters including, water temperature, pH, oxidation-reduction potential (ORP), specific conductance (SC), and dissolved oxygen concentration (DO), were measured using a YSI multiprobe. Total suspended solids (TSS) were determined by filtering 1-liter water through Whatman 934-AH filters that were pre-rinsed, dried (105 °C), ashed (550 °C), and tared (APHA 1995). The concentrations of nitrate-nitrogen ($NO_3$-N), soluble reactive, and phosphorus (SRP) were determined spectrophotometrically in the laboratory according to standard methods (APHA 1995).

Water samples for B analysis were placed in 1-liter dark plastic bottles and transported to the laboratory in a cooler. Borosilicate glassware was used during the analysis to prevent the contamination of samples. Water samples were adjusted to pH 2 with $HNO_3$ being added to each. B levels were determined by a high-resolution continuum source atomic absorption spectrometer by triplicate measurements in the regional laboratory of the State Water Works in Balıkesir.

The nonparametric Spearman rank correlation test was used to measure the degree of association between physicochemical variables, the total number of phytoplankton taxa, and abundance using SPSS (ver. 11.0) software.

## Results

Water temperature ranged from 24.8 ºC in August 2015, to 8.7 ºC in January 2016 (Figure 2a). pH ranged from 9.24 in August 2015, to 8.59 in January 2016 (Figure 2b). SC ranged from 2237 µS $cm^{-1}$ in August 2015, to 736 µS $cm^{-1}$ in January 2016 (Figure 2c).

DO concentrations ranged from 7.4 mg $L^{-1}$ in August 2015, to 10.84 mg $L^{-1}$ in January 2016 (Figure 2d). ORP ranged from 21.4 MV in August 2015, to 4.7 MV in January 2016 (Figure 2e). TSS ranged from 2.1 mg $L^{-1}$ in November 2015, to 28.9 mg $L^{-1}$ in August 2015 (Figure 2f).

B concentrations ranged from 554 mg $L^{-1}$ in April 2015, to 689 mg $L^{-1}$ in August 2015 (Figure 2g). $NO_3$-N concentrations ranged from 0.43 mg $L^{-1}$ in November 2015, to 0.8 mg $L^{-1}$ in January 2016 (Figure 2h). SRP concentrations ranged from 0.078 mg $L^{-1}$ in November 2015, to 0.09 mg $L^{-1}$ in August 2015 (Figure 2i).

In Çamköy Reservoir, a total of 39 taxa were identified (Table 1). Bacillariophta made 67% (26 taxa), Chlorophyta made 10% (4 taxa), Cyanobacteria made 8% (3 taxa), Euglenophyta made 8% (3 taxa), Mioza made 5% (2 taxa) and Charophyta made 2% (1 taxon) of the total number of taxa (Figure 3a). The highest number of phytoplankton taxa (23) was obtained in January 2016 and the lowest (0) in August 2015 (Figure 3b). The highest phytoplankton abundance (55531 cell $ML^{-1}$) was obtained in April 2015 and the lowest (0 cell $ML^{-1}$) in August 2015 (Figure 3c).

## Discussion

The total number of phytoplankton taxa (39) was lower in Çamköy Reservoir compared with the other reservoirs in the same vicinity. Sevindik et al. (2011) reported 192 phytoplankton taxa from Çaygören Reservoir and 174 taxa from Ikizcetepler Reservoir. The reason for this was probably the excessive B levels in Çamköy Reservoir (Davis et al. 2002; Gunes et al. 2006; Marín and Oron 2007; Şaşmaz and Öbek 2009). High levels of B in the reservoir must have prevented the development of sensitive phytoplankton species, resulting in low species numbers due to their low tolerance limits to B toxicity (Reid 2007).

*Navicula digitoradiata* (avg. 20152 cell $L^{-1}$), *Surirella ovata* Kützing (avg. 11151 cell $L^{-1}$), and *Nitzschia amphibia* Kützing (avg. 10151 cell $L^{-1}$) were the most abundant diatoms collected during the study. Diatoms of Çamköy Reservoir were stress-resistant species. *N. digitoradiata* is one of the rarest diatoms that are found in unique waters with moderate salinity (Zeimann et al. 2001). High ionic content (measured as SC) of this waste storage reservoir may have favored the growth of *N. digitoradiata.*

Fore and Grafe (2002) listed *S. ovata* as pollution tolerant species in the diatom assemblages of 23 Idaho rivers subjected to human disturbance. They stated that diatoms were robust indicators of metal contamination of natural waters. *N. amphibia* is commonly collected at sites with heavy metal pollution. Szabo et al. (2005) studied Tisza River in Hungary after the bursting of a mine-storing reservoir to the river and collected high numbers of *N. amphibia* showing that this species is tolerant to metal toxicity.

Chlorophyta was represented by four taxa and they were collected only in spring and fall seasons. *Pandorina morum* (O.F. Müller) Bory in J.V.Lamouroux, Bory, and Deslongschamps (avg. 2151 cell $L^{-1}$) was the most common green algae during the study. Anuja and Chandra (2012) conducted a study on a polluted tank and reported that *P. morum* was a pollution indicator species.

The low species number and abundance of green algae could have been due to high levels of B in the reservoir. Garcia-González et al. (1990) provided sound evidence that B was required by marine and freshwater diatoms, whereas green algae did not require it for growth, and they were intolerant to the high B levels.

Cyanobacteria were represented by three taxa (*Oscillatoria tenuis* C.Agardh ex Gomont (avg. 452 cell $L^{-1}$), *Chroococcus minutus* (Kützing) Nägeli (avg. 332 cell $L^{-1}$) and *Leptolyngbya* sp. Anagnostidis and Komárek (avg. 225 cell $L^{-1}$) at low densities. The low species number and abundance of Cyanobacteria in Çamköy Reservoir is probably due to excessive levels of B in the reservoir (Reid 2007). Low levels of B are required for the nitrogen fixation by Cyanobacteria, but excessive levels are toxic for members of this group (Gerloff 1968).

Euglenophyta was represented by three taxa, *Trachelomonas granulosa* Playfair (avg. 3120 cell $L^{-1}$), *Trachelomonas intermedia* P.A.Dangeard (avg. 1011 cell $L^{-1}$) and *Trachelomonas volvocina* (Ehrenberg) Ehrenberg (avg. 853 cell $L^{-1}$). Except for summer, euglenoids were present at each sampling period. Euglenoids are abundant in moderately polluted water bodies all over the world (Li et al. 2014; Naselli-Flores 2000). *Trachelomonas* species are known to quickly respond to environmental changes in polluted lakes (Wołowski 2002).

Miozoa was represented by two taxa, *Tripos furca* (Ehrenberg) F.Gómez (avg. 712 cell $L^{-1}$) and *Glenodinium* sp. Ehrenberg (avg. 312 cell $L^{-1}$). *T. furca* is a cosmopolitan species mostly collected from salt and brackish waters worldwide (Morton et al. 2011).

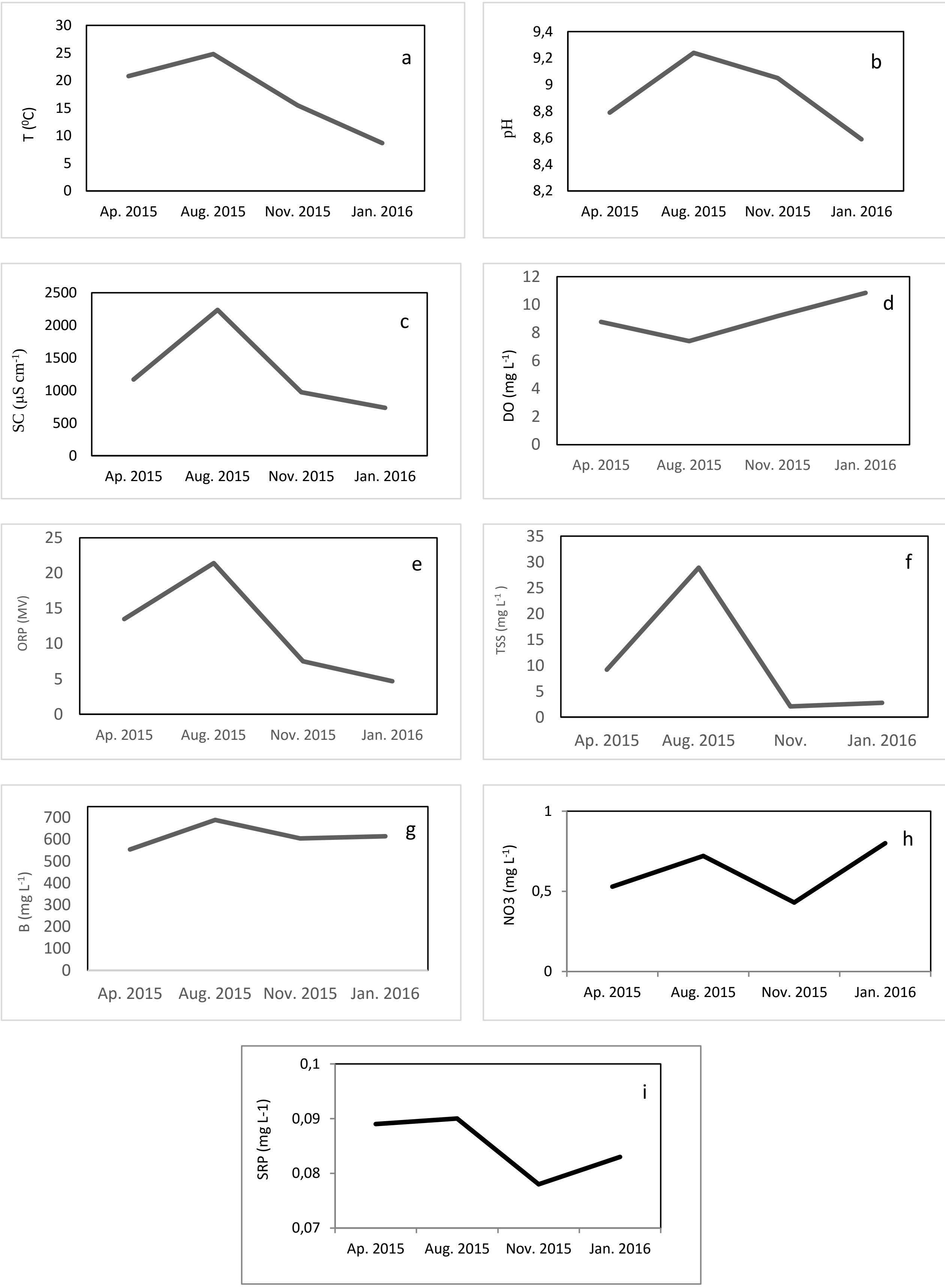


**Figure 2.** Seasonal variations in a) the water temperature (T; ºC), b) pH, c) specific conductance (SC; µS cm$^{-1}$), d) dissolved oxygen (DO; mg L$^{-1}$), e) oxidation-reduction potential (ORP; MV), f) total suspended solids (TSS; mg L$^{-1}$), g) Boron (B; mg L$^{-1}$), h) nitrate-nitrogen ($NO_3$-N; mg L$^{-1}$), i) soluble reactive phosphorus (SRP; mg L$^{-1}$) of Çamköy Reservoir

**Table 1.** The list of phytoplankton taxa collected from Çamköy Reservoir

| Taxa | Spring | Summer | Fall | Winter |
|---|---|---|---|---|
| **Bacillariophyta** | | | | |
| *Amphora eximia* J.R.Carter 1974 | - | - | - | + |
| *Amphora ovalis* Kützing 1844 | + | - | - | - |
| *Achnanthidium affine* (Grunow) Czarnecki 1994 | + | - | - | - |
| *Anomoeoneis sphaerophora* Pfitzer 1871 | - | - | + | - |
| *Aulacoseira italica* (Ehrenberg) Simonsen 1979 | - | - | - | + |
| *Cymbella caespitosa* (Kützing) Brun 1880 | - | - | + | - |
| *Fragilaria capucina* Desmazières 1830 | + | - | - | - |
| *Gomphonema truncatum* Ehrenberg 1832 | - | - | - | + |
| *Melosira varians* C.Agardh 1827 | - | - | - | + |
| *Navicula digitoradiata* (Gregory) Ralfs 1861 | - | - | + | + |
| *Navicula libonensis* Schoeman 1970 | + | - | - | - |
| *Navicula subtilissima* Cleve 1891 | - | - | - | + |
| *Nitzschia* sp. Hassall 1845 | + | - | - | - |
| *Nitzschia pacifica* Cupp 1943 | + | - | + | + |
| *Nitzschia amphibia* Grunow 1862 | - | - | + | - |
| *Nitzschia sigmoidea* (Nitzsch) W.Smith 1853 | - | - | + | + |
| *Pinnularia gibba* Ehrenberg 1843 | - | - | + | - |
| *Navicula cincta* (Ehrenb.) Ralfs 1861 | - | - | + | - |
| *Pinnularia hemiptera* (Kützing) Rabenhorst 1853 | + | - | - | - |
| *Pinnularia microstauron* Cleve 1891 | - | - | - | + |
| *Pinnularia subrostrata* (A.Cleve) Cleve-Euler 1955 | - | - | + | + |
| *Stauroneis phoenicenteron* (Nitzsch) Ehrenberg 1843 | - | - | - | + |
| *Surirella angusta* Kützing 1844 | - | - | + | + |
| *Surirella minuta* Brébisson ex Kützing 1849 | - | - | + | - |
| *Surirella ovata* Kützing 1844 | + | - | - | - |
| *Surirella robusta* Ehrenberg 1841 | + | - | - | - |
| **Chlorophyt**a | | | | |
| *Pandorina morum* (O.F.Müller) Bory 1824 | + | - | - | - |
| *Pediastrum duplex* Meyen 1829 | - | - | - | + |
| *Pediastrum duplex var*. rugulosum Raciborski 1890 | - | - | - | + |
| *Pseudopediastrum boryanum* (Turpin) E.Hegewald 2005 | - | - | + | - |
| **Euglenophyta** | | | | |
| *Trachelomonas granulosa* Playfair 1915 | + | - | - | - |
| *Trachelomonas intermedia* P.A.Dangeard 1902 | - | - | + | - |
| *Trachelomonas volvocina* (Ehrenberg) Ehrenberg 1834 | - | - | - | + |
| ***Cyanobacteria*** | | | - | |
| *Chroococcus minutus* (Kützing) Nägeli 1849 | - | - | - | + |
| *Leptolyngbya* sp. Anagnostidis & Komárek 1988 | - | - | + | - |
| *Oscillatoria tenuis* C.Agardh ex Gomont 1892 | + | - | - | - |
| **Charophyta** | | | - | |
| *Mougeotia* C. Agardh 1824 | - | - | - | + |
| **Mioza** | | | | |
| *Glenodinium* sp.Ehrenberg 1836 | - | - | - | + |
| *Tripos furca* (Ehrenberg) F.Gómez 2013 | - | - | + | + |

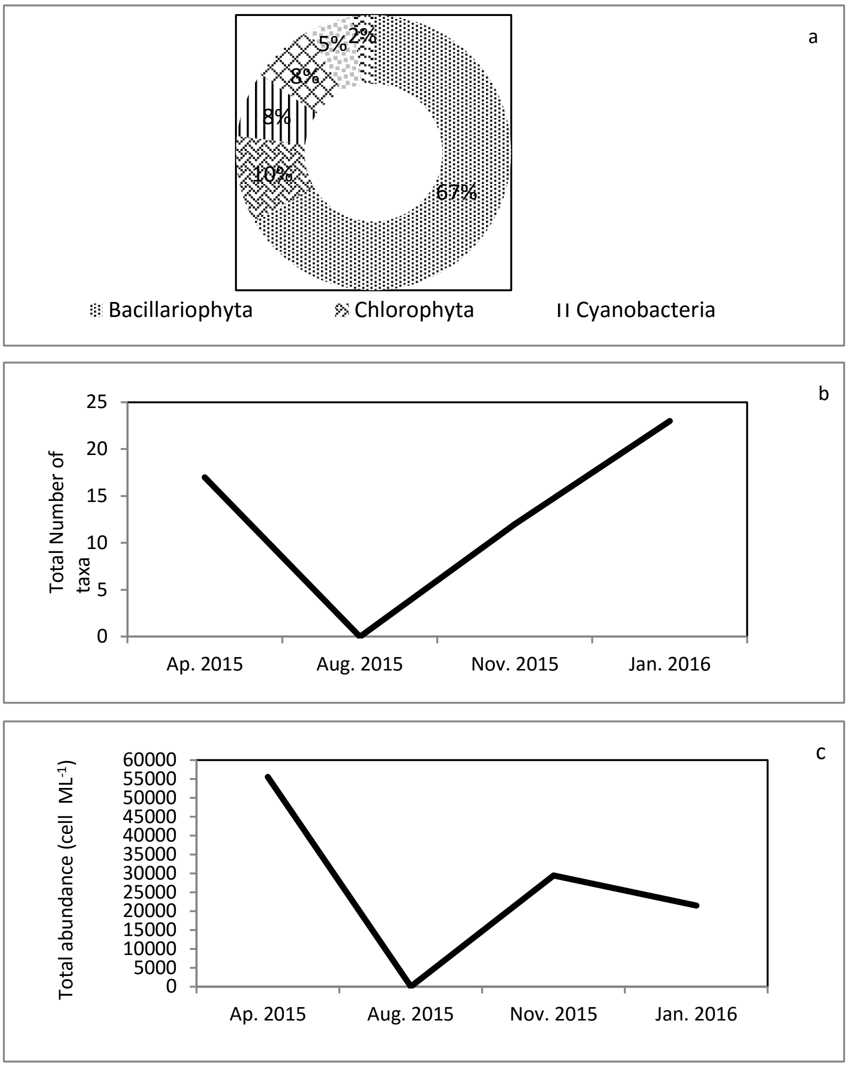


**Figure 3.** a) The percent composition of the phytoplankton groups, b) the total number of phytoplankton taxa, c) the total abundance of the phytoplankton (cell $ML^{-1}$) of Çamköy Reservoir

Miozoa members, although not absent, are seldom collected in freshwater samples. *Glenodinium* sp. has been previously reported by Sevindik et al. (2011) in Çaygören Reservoir which is close to Çamköy Reservoir.

In August 2015, no phytoplankters were observed in the samples. The excessive B concentrations (above 600 mg $L^{-1}$) in the reservoir seem to be the reason for the lack of phytoplankton in the summer samples. Reid et al. (2004) found that *Chara* cells were not affected by the B levels up to 400 mg $L^{-1}$, but when the concentrations were raised to 600 mg $L^{-1}$, the cells died in the experimental chamber. It is possible that no phytoplankton species could tolerate B levels greater than 600 mg $L^{-1}$ in Çamköy Reservoir.

In summary, the nutrient concentrations in Çamköy Reservoir are not at the limiting level for phytoplankton, but the number of taxa and the abundance are low compared with natural lakes. This situation leads to the recognition that the low number of phytoplankton taxa and abundance was a result of the excessive B levels in the reservoir.

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# Determination of Some Biochemical Parameters Changes in *Gammarus pulex* Exposed to Cadmium at Different Temperature and Different Concentration

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**ABSTRACT**

In this study, the oxidative stress effects of cadmium (Cd) toxicity depending on water temperature were investigated on *Gammarus pulex*. The test organism individuals were exposed to sublethal concentrations for 96 hours at certain rates (C1; 1/10, C2; 1/20 and C3; 1/40) of LC50 values of Cd for each temperature (10, 14, 18 °C). Malondialdehyde (MDA) level, glutathione peroxidase (GPx), and catalase (CAT) enzyme activities were investigated at the temperatures determined in *G. pulex* exposed to Cd. With the increasing temperature, the MDA level and CAT enzyme activity increased while GPx enzyme activities decreased. The results of this study revealed that the biochemical response caused by Cd on *G. pulex* had statistically significant differences ($p<0.05$) with temperature. In this study, the use of MDA levels with CAT and GPx-related enzymes, Cd exposure, toxicity, and temperature change as biomarkers for risk assessment may be useful.

**Keywords:** *Gammarus pulex*, cadmium, malondialdehyde, glutathione peroxidase, catalase

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**Farklı Sıcaklık ve Farklı Konsantrasyonlarda Kadmiyuma Maruz Bırakılan *Gammarus pulex*'te Bazı Biyokimyasal Parametrelerin Değişikliklerinin Belirlenmesi**

**Öz:** Bu çalışmada *Gammarus pulex* üzerinde kadmiyum (Cd) toksisitesinin su sıcaklığına bağlı olarak oksidatif stres etkileri araştırılmıştır. Test organizması bireyleri, her sıcaklık (10, 14, 18 °C) için belirli oranlarda (C1; 1/10, C2; 1/20 ve C3; 1/40) LC50 değerlerinin 96 saat boyunca subletal konsantrasyonlara maruz bırakıldı. Cd'ye maruz kalan *G. pulex*'te belirlenen sıcaklıklarda malondialdehid (MDA) seviyesi, glutatyon peroksidaz (GPx) ve katalaz (CAT) enzim aktiviteleri araştırıldı. Sıcaklık arttıkça MDA seviyesi ve CAT enzim aktivitesi artarken GPx enzim aktiviteleri azaldı. Bu çalışmanın sonuçlarına göre, *G. pulex* üzerinde Cd'nin neden olduğu biyokimyasal yanıtın sıcaklık ile istatistiksel olarak anlamlı farklılıklara ($p<0,05$) sahip olduğu belirlenmiştir. Bu çalışmada, risk değerlendirmesi için biyobelirteç olarak MDA seviyelerinin CAT ve GPx ile ilişkili enzimler, Cd maruziyeti, toksisite ve sıcaklık değişimi ile kullanılması yararlı olabilir.

**Anahtar kelimeler:** *Gammarus pulex*, kadmiyum, malondialdehit, glutatyon peroksidaz, katalaz

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## Introduction

Aquatic environments are widely accepted today as a simple and inexpensive disposal option that is considered an ideal discharge area for most waste. This has led to increased ecological poisoning due to the bioaccumulation of toxic chemicals and some long-standing pollutants, including developed countries (Taylan and Özkoç 2007). Increasing industrial, urban, and agricultural developments increase the environmental problems of today and these environmental problems have a negative synergy effect with living things along with global warming. Heavy metals, which make up the majority of industrial pollutants, can enter into the structures of aquatic organisms through wastewater (Bat et al. 2000). One of the most important sources of ecosystem health is heavy metal pollution and it poses stress, threat, and a great risk to organisms in aquatic ecosystems (Del Valls et al. 1998). When a metal enters the biological system of any organism, it can damage the vital functions of that organism (Hu 2000; Kayhan 2006). Increasing concentrations of heavy metals in aquatic environments are taken up by aquatic organisms and transported to upper trophic levels via food chains. Examination of heavy metal accumulation in living organisms living in the water environment is important in determining the species susceptible to heavy metals as well as in determining the structural and functional disorders that occur in the organism (Kayhan 2006).

Cadmium (Cd), one of the heavy metals with toxic effects in environmental pollutants, is very harmful to aquatic organisms even at low concentrations (Katalay and Parlak 2002; Asri et al. 2007). Cd is the heaviest metal element with the highest water solubility. For this reason, the broadcast speed is high. It is also not one of the necessary elements of human life. Because of its solubility property, it is released into biological systems by plant and aquatic organisms in the form of $Cd^{+2}$ and has accumulation properties (Duffus 1980).

An indirect mechanism for the free radical production caused by Cd is suggested. Cd increases the amount of non-bound forms of these metals by taking the place of zinc (Zn), calcium (Ca), copper (Cu), and iron (Fe) in metalloenzymes. It binds to thiol groups of free radical scavengers such as glutathione (GSH) and inhibits antioxidant enzymes such as catalase (CAT), superoxide dismutase (SOD), and glutathione peroxidase (GPx). Although it is Fenton metal, it is thought that it causes the production of superoxide and nitric oxide, and many other free radicals and thus leads to peroxidation, DNA damage, and protein oxidation of cell membrane structures (Brzóska and Moniuszko-Jakoniuk 2001; Waisberg et al. 2003; Bertin and Averbeck 2006).

One of the methods of determining pollution in the aquatic environment is to determine the levels of the organisms living in the environment that are affected by this pollution. The evaluation of biological markers as an early warning of adverse changes and damage has been shown as a suitable tool for *Gammarus pulex* (Dat et al. 2000; Achary et al. 2008; Yildirim et al. 2018; Serdar 2019). Reactive oxygen species (ROS) suppress the antioxidant system, inducing oxidative stress, lipid peroxidation, and oxidation of proteins during metabolism (Almroth et al. 2008; Tatar et al. 2018; Cimen et al. 2020). There is an important balance between the production of ROS and the removal of antioxidant defense systems by organisms. ROS is cleared by antioxidant enzymes and non-enzymatic antioxidants (Hermes-Lima 2004; Halliwell and Gutteridge 2007; Serdar et al. 2018). Lipid peroxidation is chain reaction in which oxidants break down membrane phospholipids with polyunsaturated fatty acids. Lipid peroxidation causes damage to bio-membranes, which can lead to significant consequences for living organisms (Hermes-Lima 2004; Jemec et al. 2012; Serdar et al. 2018).

This study was designed to determine the effect of pollution in the water environment on the organism in the water together with the global temperature with the development of the industrial sector. Therefore, it is aimed to experimentally determine the effect of sublethal Cd concentrations on *G. pulex*, a water organism, at different temperature levels.

## Materials and Methods

### Test Organisms

The test organism *G. pulex* used in the study was collected from the source part of the tributaries of the Munzur River of Tunceli province, with hand nets from the areas that are virgin in terms of domestic and industrial pollution. Before the experimental study, organisms were adapted at 10, 14, and 18 ± 0.5 °C, respectively, at the test temperature. Ambient lighting 12:12 bright: dark it is set to be climate controlled in its cycle. In this process, the test organisms were fed with rotten willow leaves. Organisms were checked daily.

### Acute Toxicity ($LC_{50}$)

Serdar et al. (2019a) determined their Cd LC50 values in *G. pulex* at 10, 14, and 18 ºC. LC50 values for 10, 14, and 18 ºC temperatures are 51.79 ± 1.2 µg $L^{-1}$ Cd, 47.67 ± 0.6 µg $L^{-1}$ Cd, and 33.93 ± 0.6 µg $L^{-1}$ Cd, respectively. LC50 values used in this study Serdar et al. (2019a)'s taken from the work they have done.

### Experimental Design

It was recorded that the water temperature in the natural environment where the test organism was collected varied between 12 and 14 ºC throughout the year. In the study, experimental temperatures were chosen as 10, 14, and 18 ºC to prevent the test organism from adapting to laboratory conditions.

In this study, the test organisms were adapted for at least 25 days for each determined temperature. To minimize systematic errors, healthy, similar-sized (w: 0.0474 ± 0.0053 g and L: 10.35 ± 0.055 mm) and male organisms were selected.

### Exposure of *G. pulex* to Sublethal Cd Concentrations

Sublethal concentrations in this study were chosen from Cd concentrations of 1/40, 1/20, and 1/10 ratios of LC50 values for each temperature. For this purpose, four different experimental groups, one of which is the control group, were created. These experimental groups created as follows are applied for each temperature experiment;

1. Group C0, control group, Cd-free
2. Group C1, 1/40 LC50 values of Cd
3. Group C2, 1/20 LC50 values of Cd
4. Group C3, 1/10 LC50 values of Cd

In the experimental design, glass aquariums and containing 0.5 L Cd concentrations were used. 15 test organisms were added to the aquariums for each group. Test organisms were exposed to three different Cd concentrations for 96 hours for each temperature group. All experimental procedures were performed in three replicates. Test organisms were not fed in all experimental procedures, including Cd toxicity tests.

**Preparation of Homogenates**

The *G. pulex* specimens for the preparation of homogenates were passed through pure water. A pool was created from 15 individuals to be able to form homogenates from the samples. After the water was removed with the drying paper, organisms were weighed and homogenized by diluting 1/10 in 1.15% potassium chloride (KCl). The obtained homogenates were centrifuged at +4 ºC for 15 minutes at 3200 rpm in a glass tube, after which the supernatants were separated.

**Biochemical Analyses**

Changes in the MDA levels were measured spectrophotometrically according to Placer et al. (1966) the modified method. The CAT activity was determined according to Aebi (1984). The determination of the GPx activity was made according to the method described by Beutler (1975). Protein quantities were determined according to Lowry et al. (1951) to calculate specific enzyme activities and MDA levels.

Biochemical analyzes have shown changes in oxidant/antioxidant parameters were evaluated by Two Way-ANOVA variance analysis.

## Results

**The MDA Level**

The changes in MDA level of control and experimental groups in *G. pulex* which exposed to sublethal Cd concentrations were given in Table 1.

When the MDA level at 10 ºC was examined, C3 group was higher than the control and the difference between them was statistically significant ($p<0.05$). The MDA levels at 14 ºC were found to be higher in C1, C2, and C3 groups compared to the control, but the difference between them was statistically insignificant ($p>0.05$). The MDA levels at 18 ºC were found to be higher in C1, C2, and C3 groups compared to the control and the difference between them was statistically ($p<0.05$).

Belong to temperature the changes in MDA levels of control and experimental groups in *G. pulex* which exposed to sublethal Cd concentrations were given in Table 1.

When the MDA levels at 10, 14, and 18 ºC temperatures of control group samples were examined, the MDA level of the group 14 ºC was higher than at 10 and 18 ºC and the difference between them was statistically significant ($p<0.05$).

When the MDA levels at 10, 14, and 18 ºC temperatures of the C1 group samples were examined, the MDA level of group 10 ºC was lower than the other groups and between differences were found to be significant ($p <0.05$).

When the MDA levels at 10, 14, and 18 ºC temperatures of C2 group samples were examined, MDA level at 18 ºC was found to be statistically higher than 10 ºC temperature ($p <0.05$). The MDA level at 14 ºC was found to be similar to the temperature values of 10 and 18 ºC ($p>0.05$).

When the MDA levels of C3 group samples were examined at 10, 14, and 18 ºC temperature, the MDA level determined at all temperatures was not been shown any statistically significant difference ($p>0.05$).

**Table 1.** Changes in MDA levels at different Cd concentrations depending on temperature

| Temperature (ºC) | Control | Sublethal Cd Concentration Groups | | |
|---|---|---|---|---|
| | C0 | C1 | C2 | C3 |
| 10 | $1.03 \pm 0.4^{bcY}$ | $0.75 \pm 0.3^{cY}$ | $1.41 \pm 0.4^{abY}$ | $1.85 \pm 0.7^{aX}$ |
| 14 | $1.93 \pm 0.6^{aX}$ | $1.86 \pm 1.0^{aX}$ | $1.81 \pm 1.7^{aXY}$ | $2.13 \pm 1.7^{aX}$ |
| 18 | $0.90 \pm 0.3^{cY}$ | $2.02 \pm 1.0^{bX}$ | $2.71 \pm 0.2^{aX}$ | $3.15 \pm 1.0^{aX}$ |

a, b, c: The difference between the values of different letters in the same row was statistically significant ($p<0.05$).
X, Y: The difference between the values carrying different letters in the same column was statistically significant ($p<0.05$).

**The GPx Activity**

The changes in the GPx activity of the control and experimental groups in *G. pulex* which exposed to sublethal Cd concentrations were given in Table 2.

The GPx activity at 10 ºC was higher in the C1, C2, and C3 groups than Control, and the difference between them was statistically significant ($p<0.05$). The GPx activity at 14 ºC was higher in the Control and C2 groups than C3 and C1 groups and the difference between them were statistically significant ($p<0.05$). The GPx activity at 18 ºC was higher in the C1, C2, and C3 groups than in the control group, and the difference between them was statistically significant ($p<0.05$).

Belong to temperature the changes in GPx activity in the C0, C1, C2, and C3 groups of *G. pulex* which were exposed to sublethal Cd concentrations were given in Table 2.

When the GPx activity of the control group was examined at 10, 14, and 18 ºC temperatures, the GPx activity was the highest at 10 ºC and the lowest at 18 ºC, and the difference between groups was statistically significant ($p<0.05$).

When the GPx activity of the C1 group was examined at 10, 14, and 18 ºC. The GPx activity was the highest in the C1 group. Between them, the difference was statistically significant ($p <0.05$).

When the GPx activity of the C2 group, at temperatures of 10, 14, and 18 ºC was examined in the GPx activity was the highest at 10 ºC and the lowest at 18 ºC and the difference between groups was statistically significant ($p<0.05$).

When the GPx activity of the C3 group at temperatures of 10, 14, and 18 ºC was examined GPx activity was lowest at 18 ºC. Between them, the difference was statistically significant ($p <0.05$).

**Table 2.** The GPx activity changes in Cd concentrations depending on temperature

| Temperature (ºC) | Control | Sublethal Cd Concentration Groups | | |
|---|---|---|---|---|
| | $C_0$ | $C_1$ | $C_2$ | $C_3$ |
| 10 | $24.54 \pm 0.4^{aX}$ | $7.29 \pm 0.2^{dY}$ | $19.67 \pm 0.7^{cX}$ | $20.88 \pm 1.6^{bX}$ |
| 14 | $17.03 \pm 0.2^{bY}$ | $20.33 \pm 0.9^{aX}$ | $17.48 \pm 0.9^{bY}$ | $19.67 \pm 0.7^{aX}$ |
| 18 | $3.54 \pm 0.8^{cZ}$ | $7.15 \pm 0.8^{bY}$ | $11.64 \pm 2.8^{aZ}$ | $13.18 \pm 0.3^{aY}$ |

a, b, c, d: The difference between the values of different letters in the same row was statistically significant ($p<0.05$).
X, Y, Z: The difference between the values carrying different letters in the same column was statistically significant ($p<0.05$).

**The CAT Enzyme Activity**

The changes in the CAT activity of the control and experimental groups in the *G. pulex* organisms exposed to sublethal Cd concentrations were given in Table 3.

When the CAT activity at 10 ºC was examined, C2, and C3 groups it was found to be statistically higher than the control group ($p<0.05$). When the CAT activity at 14 ºC was examined, the C1 group was found statistically higher than the other groups ($p <0.05$). When the CAT activity at 18 ºC was examined, C2 and C3 groups were higher than the control group and the difference between them was found statistically significant ($p<0.05$).

Belong to temperature the changes in CAT activity of control and experimental groups in *G. pulex* which exposed to sublethal Cd concentrations were given in Table 3.

When the CAT activities of the control group were examined at 10, 14, and 18ºC temperatures, the CAT activity was higher at 14 ºC and the lowest at 18 ºC temperature, and the difference between groups was statistically significant ($p<0.05$).

When the CAT activities of the C1 groupwere examined at 10, 14, and 18 ºC temperatures, the CAT activity was higher at 14 ºC and the lowest at 18 ºC temperature, and the difference between groups was statistically significant ($p<0.05$).

When the CAT activities of the C2 group were examined at 10, 14, and 18 ºC temperatures, the CAT activity was the highest at 10 ºC and the lowest at 18 ºC, and the difference between groups was statistically significant ($p<0.05$).

When the CAT activities of the C3 group were examined at 10, 14, and 18 ºC temperatures, the CAT activity was the highest at 10 ºC and the lowest at 18 ºC, and the difference between groups was statistically significant ($p<0.05$).

**Table 3.** The CAT activity changes in Cd concentrations depending on temperature

| Temperature (ºC) | Control | Sublethal Cd Concentration Groups | | |
|---|---|---|---|---|
| | $C_0$ | $C_1$ | $C_2$ | $C_3$ |
| 10 | $64.40 \pm 40.4^{bY}$ | $76.91 \pm 60.7^{bY}$ | $159.66 \pm 66.6^{aX}$ | $179.94 \pm 78.8^{aX}$ |
| 14 | $82.16 \pm 33.7^{bX}$ | $157.02 \pm 13.1^{aX}$ | $103.42 \pm 39.0^{bY}$ | $108.32 \pm 32.7^{bX}$ |
| 18 | $4.86 \pm 1.8^{cZ}$ | $9.20 \pm 2.5^{cZ}$ | $28.29 \pm 3.6^{bZ}$ | $45.32 \pm 17.6^{aY}$ |

a, b, c: The difference between the values of different letters in the same row was statistically significant ($p<0.05$).
X, Y, Z: The difference between the values carrying different letters in the same column was statistically significant ($p<0.05$).

## Discussion

Toxicology examines the damage and destructive effects of physical or chemical agents on living organisms. In this context, aquatic toxicology tests aim to determine at what concentration any substance harms organisms on aquatic organisms (Karataş 2005).

Bat et al. (2000) determined the LC50 values of zinc (Zn), copper (Cu), and lead (Pb) toxicity in freshwater amphipods at *G. pulex* at three different temperatures (15, 20, and 25 °C). They reported that LC50 values were decreased with temperature. Zauke (1982) investigated the relationship between Cd's acute toxicity to seasonal variation and environmental variables in *Gammarus tigrinus* natural populations and reported that there is a relationship between Cd concentration and water temperature. Piazza et al. (2016), conducted a study to evaluate the nature of the toxicity test in the study, in particular, the temperature and salinity changes in the presence of a toxic substance, and the environmental impact of information on the role of these parameters. Changes in temperature and salinity were observed separately, regardless of whether reference toxic substances were present, to obtain initial information on the final test results. As a result, they reported that temperature and salinity were effective in organisms. Qiu and Qian (1999), were indicated that *Amphitrite amphitrite* at the larval stage is significantly affected by temperature, as well as markedly by both survival and development. Nasrolahi et al. (2013), showed that model organisms' low temperature and low salinity stress affect larval growth after 7 and 40 days and that these environmental changes can directly affect.

In the aquatic environment, pollution can cause toxic effects such as lipid peroxidation by increasing ROS production resulting from the imbalance between ROS concentration and antioxidant defense system (Regoli et al. 2004). Key antioxidant enzymes and non-enzymatic antioxidants are influenced by various single pollutants known to increase ROS levels (Valko et al. 2006; Ryter et al. 2007). Oxidative stress, detoxification, and neurotoxicity biomarkers were used in Gammarids (Yildirim et al. 2019).

Lipid peroxidation, considered as a valuable indicator of oxidative damage of cellular components known as the first step in cellular membrane damage, is caused by pesticides, metals, and other xenobiotics (Gamble et al. 1995; Regoli et al. 1998). Duman and Kar (2015) reported that the MDA content of Cd accumulation in organisms increased depending on the exposure concentration and duration. Similarly, in this study, the MDA levels were also increased in sublethal Cd concentration groups when compared to the control group ($p<0.05$). Chandran et al. (2005) investigated how to change the MDA levels of Cd and Zn in *Achatina fulica*. They reported that the MDA levels increased with increasing Cd concentration compared to the study data. In this study, the MDA levels increased with the concentration of Cd, and the data of the study showed parallelism.

Vellinger et al. (2013) found that the MDA levels in *G. pulex*, where Cd and arsenic (As) were single and co-administered, were higher than the control group. They also reported a significant increase (67.2%) in the MDA levels with increasing Cd concentration in the individuals. In this study, it was found that the MDA levels increased due to both temperature and concentration increase. Sroda and Cossu-Leguille (2011) investigated the effect of seasonal changes on antioxidant markers in *Gammarus roeselli*. In parallel with the increase in temperature, the model reported the increase of MDA level in living organisms. In this study, MDA levels increased with temperature.

The GPx is a component of a complex antioxidant defense system and its response is possibly accompanied by responses of other antioxidant enzymes and scavenger molecules; however, its induction may provide an indication of defense against oxidative stress (Tsangaris et al. 2007). Inhibition of the GPx activity may reflect the failure of the antioxidant system in contact with polluting (Ballesteros et al. 2009) or may be related to the direct effect of superoxide radicals or pollutes on enzyme synthesis (Bainy et al. 1993). In this study, GPx activity in *G. pulex* exposed to Cd decreased at 10 ºC compared to the control group. As well as GPx activity decreased with the temperature of exposure to Cd in the *G. pulex* organism ($p <0.05$). In this study, GPx activity decreased with increasing temperature of exposure to Cd in *G. pulex* organism ($p <0.05$). Depending on the temperature, the reduction of observed GPx activities may be associated with decreased glutathione levels. This decrease in GPx activity in the study is in line with the studies performed (Serdar et al. 2019b; Kutlu and Susuz 2004). However, in another study, CAT activity increased with Cd exposure and this increase suppressed the increase in GPx (Zhang et al. 2011). The reason for the increase in GPx activity at 14 and 18 ºC temperatures in this study can be explained by the decrease in CAT activity.

The CAT is a very common enzyme found in virtually all living organisms that use oxygen. It acts in water and oxygen formation by catalyzing the decomposition of hydrogen peroxide (Chelikani et al. 2004). The elevation of these antioxidant enzymes would be critical in minimizing cellular injury

(Rajeshkumar et al. 2013). On the other hand, CAT activity may increase or decrease in contaminated environments depending on the substance (Sobjak et al. 2017). In previous studies, it had been expressed that ROS species can inhibit CAT activity (Kono and Fridovich 1982; Escobar et al. 1996; Duman and Kar 2015). In this study, while CAT activity decreased due to increasing temperature but increased due to increased concentration (Table 3) ($p<0.05$). Antioxidative stress activity can change depending on sexuality, physiological phase, and species (Felten et al. 2008; Zhang et al. 2011). However, it was found that Cd exposure concentration and exposure duration can also alter antioxidative stress activity (Duman and Kar 2015). They further revealed that short-term exposure to organic chemical pollutants leads to the induction of antioxidant enzymes in aquatic organisms. However, CAT activity was negatively affected by redox-cycling-inducing chemicals (Pandey et al 2008; Rajeshkumar et al. 2013). In this study, the CAT enzyme activity is inhibited by the organisms under stress with temperature and Cd exposure. Similar to the present study, decrease in CAT activity have been reported in aquatic organisms exposed to various pollutants (Thomas and Murthy 1976; Hasspieler et al. 1994; Sayeed et al. 2003; Zhang et al. 2004; Crestani et al. 2007; Yildirim et al. 2018). According to the results found in the literature related to the activity of this enzyme, potential antioxidant changes by species, habitat, etc. can be explained (Glusczak et al. 2007).

Many factors that cause chemical pollution arising from various industrial activities, which accumulated in living organisms, can be transported in ecosystems from the lowest of the food chain to in the top ring chain of the food chain.

Physiological factors, such as temperature and salinity, can be an important factor in ecotoxicological analyses when exposed to the stressors of organisms (Piazza et al. 2016).

In this study, it was determined the oxidative response of exposure to at different temperature sublethal Cd concentrations of *G. pulex*, which is used as a clean water indicator in ecotoxicological evaluations. In this study, it can be concluded that stress conditions provided by Cd exposure at sublethal concentrations and different temperatures evoked specific responses in *G. pulex*. Therefore, the above results indicate that Cd and temperature an environmental pollutants as oxidative stress.

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# Age and Growth of *Garra rufa* (Heckel, 1843) from Merzimen Stream, Euphrates River Basin, Turkey

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**ABSTRACT**

This study was carried out to determine the population parameters of *Garra rufa* in Merzimen Stream, Euphrates River Basin between May and November 2013. A total of 365 specimens were caught by electro shocker. The age of the sampled specimens ranged from 0 to V age groups. Total length and weight varied from 2.9 to 16.8 cm with a mean of 9.67±3.52 cm and 0.21 to 69.27 g with a mean of 15.69±14.75 g, respectively. The length-weight relationship was obtained as $W=0.0124L^{2.9888}$ and the b value indicated the isometric growth. Estimated population parameters were calculated as $L_\infty$: 19.98 cm, k: 0.275, $t_0$: -1.157. Fulton's condition factor and growth performance index were estimated as K: 1.24 and Φ': 2.04. Total (Z), natural (M), and fishing (F) mortalities and the exploitation rate (E) were estimated 0.452, 0.295, 0.156, and 0.347, respectively.

**Keywords:** Mortality, exploitation rate, Gaziantep, population parameters

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**Merzimen Çayı (Fırat Havzası) *Garra rufa* (Heckel, 1843) Popülasyonuna Ait Yaş ve Büyüme Parametreleri**

**Öz:** Bu çalışma Merzimen Çayı *Garra rufa* popülasyonuna ait populasyon dinamiği parametrelerini belirlenmesi amacıyla Mayıs-Kasım 2013 tarihleri arasında yürütülmüştür. Elektroşok kullanılarak toplam 365 örnek yakalanmıştır. Yakalanan bireylerin yaşları 0 ile V. yaş grupları arasındadır. İncelenen bireylerin boy değerlerinin 2,9-16,8 cm ve ağırlık değerlerinin ise 0,21-69,27 g arasında değişim gösterdiği belirlenmiş olup ortalama total boy ve ağırlık değerleri sırasıyla 9,67±3,52 cm ve 15,69±14,75 g olarak hesaplanmıştır. Boy-ağırlık ilişkisi $W=0,0124L^{2,9888}$ olarak belirlenmiş olup izometrik büyüme özelliği sergilediği görülmüştür. Diğer populasyon değişkenleri ise $L_\infty$: 19,98 cm, k: 0,275 ve $t_0$: -1,157 olarak hesaplanmıştır. Fulton'un kondisyon faktörü ve büyüme performans endeksi K: 1,24 ve Φ': 2,04 olarak tahmin edilmiştir. Toplam (Z), doğal (M) ve balıkçılık (F) nedeniyle olan ölüm oranları ve stoktan yararlanma düzeyi (E) sırasıyla 0,452, 0,295, 0,156 ve 0,347 olarak hesaplanmıştır.

**Anahtar kelimeler:** Ölüm oranı, sömürülme oranı, Gaziantep, populasyon parametreleri

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## Introduction

*Garra rufa* is a benthopelagic, non-migratory freshwater fish live in a variety of habitats including rivers, small muddy streams, small ponds, and lakes (Krupp and Schneider 1989). Its native distribution includes the Jordan, Orontes (=Asi), Quwayq, and Tigris-Euphrates river basins and coastal drainages of the eastern Mediterranean as well as much of southern Iran (Coad 2015). This species is relatively small (typically less than 15 cm) and short-lived with the cooperation of other cyprinid species (Jarvis 2011). *Garra rufa* is a bottom dweller resident to a variety of freshwater habitats such as rivers, small muddy streams, small ponds, and lakes but it appears most often in lotic environments and hiding under and among stones and vegetation (Krupp and Schneider 1989). Briefly, *G. rufa* has been recorded in a wide range of water temperatures (5.8-35.0ºC) and appears capable of tolerating degraded systems (Jarvis 2011).

The species is known to adhere by suction to rocks with its ventral crescent-shaped mouth to feed on benthic algae (Özer et al. 1987; Yalçın-Özdilek and Ekmekçi 2006). It is a generalist feeder but periphyton tends to make up most of its diet as a benthic grazer. *Garra rufa* is not considering an economic value as a food source however it is an appropriate prey for piscivorous fishes. Eutrophication resulting from the input of various contaminants may result in favorable algae growth, important as a food source for *G. rufa* (Yalçın-Özdilek and Ekmekçi 2006). Additionally, in the aquariums, juveniles' specimens acting as cleaner fish on ectoparasites of other aquarium species (Baensch and Riehl 2004). This species also occurs in Kangal hot springs in Central Anatolia, where it feeds on the skin scales of bathers, reducing illnesses such as neurodermatitis (Özçelik et al. 2000; Grassberger and Hoch 2006). This feeding behavior has piqued the interest of the spa industry in North America, where the fish is being imported to be utilized in a novel form of pedicure and manicure service (Jarvis 2011).

To estimate weight corresponding to a given length, growth rates, length and age structures, and other components of fish population dynamics, length, and weight data are needed (Froese 2006). Also, the length-weight data of a species in different habitats will be useful to compare the life history and morphological aspects of populations inhabiting different habitats (Segherloo et al. 2015). Therefore, investigations on the biological characteristics of fish are very important for fisheries management and the protection of wildlife of species.

Compared with other economically important species, little attention has been paid to the biology of small size species that have no commercial value (Abdoli et al. 2002). While there are some studies carried out on distribution, hematology, genetic, and morphology (Ergene and Çavaş 2004; Kara and Alp 2005; Karahan 2007; Kuru et al. 2010; Duman 2010; Durna et al. 2010; Yedier et al. 2016) up to now only one study found on the population features of *G. rufa* (Kırankaya et al. 2008) Valuable studies also conducted on the species to provide some information on the morphology, reproductive characteristics, life history aspects, length-weight relationships (Esmaeili et al. 2005; Yazdanpanahi 2005; Esmaeili and Ebrahimi 2006; Patimar et al. 2010; Teimori et al. 2011; Hamidan and Britton 2013) in Iran. There are very limited data available on age structure, growth, mortality rates of this species in Turkey or any country until now. Because of a few studies conducted on the population features of the species, little is known about the population parameters of the species. The aim of this study provides some information on age, growth, mortality, and exploitation rates of the *G. rufa* living in Merzimen Stream.

## Materials and Methods

This sampling was carried out from May to November 2013 by monthly intervals in Merzimen Stream (Gaziantep), Euphrates River Basin. A total of 365 specimens were caught using a backpack electrofisher (SAMUS 725MP). The collected specimens were fixed in 10% formalin, and then transferred to the laboratory, and stored in 70% ethanol for further processing. In the laboratory, to determine the population parameters, the total length and weight of each sample were determined to be the nearest 1 mm and 0.01 g, respectively. Remove the scale samples from the left side of the abdomen to the dorsal fin to determine the age. Immerse the fish scales in water and check them twice independently, without reference to previous readings, or to the length or weight of the fish under a stereo binocular microscope. The assessment of age is based on the determination of the number of rings on each scale.

Length-frequency data is plotted at 1 cm length intervals. The length-weight relationship (LWR) is determined according to the allometric equation $W = a*L^b$ (Sparre and Venema 1998). In this equation, W is the total weight, L is the total length, and a and b are regression constants. The increase in length and weight is represented by von Bertalanffy equation $L_t = L_\infty[1-e^{-k(t-to)}]$ and $W_t = W_\infty [1-e^{-k(t-t_0)}]^b$. The growth parameters $L_\infty$, k and $t_o$ and are estimated using the least square method recommended by Sparere and Venema (1998).

The least-squares method used to estimate the LLR with the total length between different body lengths to fit a simple linear regression model, where Y = a+bX, where Y: various body lengths, X: body length, a: ratio constant, b: regression coefficient. The percentage of length growth rate is calculated by the formula $GR = ((L_{t+1}-L_t)/(L_t))*100$. Where $L_t$: fish length at age t, $L_{t+1}$: fish length at age t+1.

The following formula used to calculate the growth performance index ($\Phi''$): $\Phi'' = \log k + 2\log L_\infty$ (Pauly and Munro, 1984). The Fulton condition factor (K) is calculated by the following formula: K = 100 W / L ^ 3 where; W: total weight, L: total length (Sparre and Venema 1998).

The correspondence between the empirical data and the expected distribution was tested by Khi2 test. The b value was tested by t test to verify that it is significantly different from isometric growth (b: 3).

## Results

A total of 365 specimens were caught during the sampling period. Age of *G. rufa* varied from 0 to V age groups and the most frequent age groups were 0 (29.6%), II (29.3%), and I (21.4%), respectively (Table 1). The total length ranged from 2.9 to 16.8 cm with a mean of 9.67±3.52 cm and total weight varied from 0.21 to 69.27 g with a mean of 15.69±14.75 g. It was evident that *G. rufa* grew rapidly in its first year after which the growth rate decreased with increasing age.

**Table 1.** Age, length, and weight-frequency distribution of *Garra rufa* from Merzimen Stream.

| Age | n | %n | Total Length (cm) | | | Total Weight (g) | |
|---|---|---|---|---|---|---|---|
| | | | Range | Mean±SD | Growth Rate (%) | Range | Mean±SD |
| 0 | 108 | 29.6 | 2.9-7.4 | 5.31±1.06 | | 0.21-7.58 | 2.08±1.28 |
| I | 78 | 21.4 | 6.7-12.1 | 8.86±1.33 | 66.85 | 3.5-24.80 | 9.15±4.57 |
| II | 107 | 29.3 | 9.3-13.7 | 11.57±1.12 | 30.58 | 8.51-40.43 | 20.00±7.45 |
| III | 54 | 14.8 | 11.1-15.5 | 13.45±1.23 | 16.24 | 16.40-53.60 | 30.58±11.05 |
| IV | 10 | 2.7 | 13.6-15.9 | 15.04±0.84 | 11.82 | 19.12-55.92 | 38.61±12.16 |
| V | 8 | 2.2 | 15.3-16.8 | 16.29±0.48 | 8.31 | 24.55-69.27 | 62.34±6.32 |
| Σ | 365 | | 2.9-16.8 | 9.67±3.52 | | 0.21-69.27 | 15.69±14.75 |

The LLRs with total length among different body lengths were obtained as FL=(0.9374*TL)-1.9924, SL=(0.866*TL)-3.1849 and SL=(0.9252*FL)-0.2015. Relationship equations among different body length parameters were found highly significant ($p<0.01$). The LWRs for *G. rufa* is presented in Figure 1. The relationship was determined as $W=0.0124*L^{2.9888}$ (95% CI of b: 2.9386-3.0409). The b value was not significantly different from 3.0 ($p<0.001$), which indicates isometric growth of *G. rufa* in the Merzimen Stream.

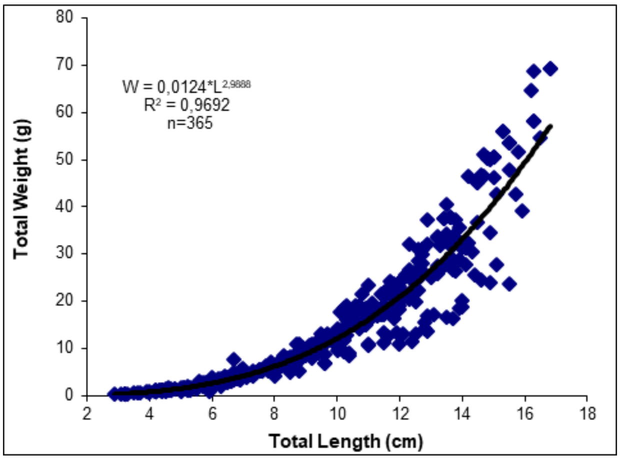


**Figure 1.** Length-weight relationship of *Garra rufa* from Merzimen Stream.

The von Bertalanffy growth parameters were estimated as follows $L_\infty$: 19.98 cm, $W_\infty$ : 96.07 g, k: 0.275 year$^{-1,}$ and $t_0$: -1.157 years. The von Bertalanffy growth parameters calculated using the mean total length and total weight at ages were; $Lt = 19.98[1-e^{-0.275(t+1.157)}]$, $W = 96.07[1-e^{-0.275(t+1.157)}]^{2.9888}$. The growth performance index (Φ') and Fulton's Condition Factor (K) were estimated as 2.04 and 1.24±0.25 (0.47-2.52), respectively.

Instantaneous total (Z), natural (M), and fishing (F) mortalities were estimated 0.452, 0.295, and 0.156 year$^{-1}$, respectively. The exploitation rate (E) was calculated as 0.347.

## Discussion

The oldest fish in this study was V years old and the age was not determined older IV age in the previous studies (Kırankaya et al. 2008; Abedi et al. 2011; Pazira et al. 2013). The instantaneous growth rate also increased up to age I and then decreased with increasing age.

The maximum length was given as 14.1 cm in total length by Froese and Pauly (2019). However, a specimen is 16.8 cm in length was caught in this study. Therefore, it suggested that the maximum length of the species may reach moreover the observed length. Theoretical maximal length and weight were estimated at 19.98 cm and 96.07 g, respectively in this study. The value of $L_\infty$ was 16.82 cm in the Dalaki and Shapour rivers population in Iran (Pazira et al. 2013). The value estimated in this study seems to be realistic.

The LLRs are useful for standardization of length type. The LLRs with total length among different body lengths were obtained as FL = (0.9374*TL)-1.9924, SL = (0.866*TL)-3.1849 and SL = (0.9252*FL)-0.2015. Relationship equations among different body length parameters were found highly significant ($p<0.01$). Gerami et al. (2013) reported the LLRs as SL = 0.728TL-1.030 in Cholvar River, Iran. The LLRs has highly correlated with Gerami et al. (2013). For the variations of LLRs in the same species from different locations, the ecological conditions of the habits or variation in the physiology of animals, or both, are responsible (Le Cren 1951).

The calculated coefficient b varied among the species from a minimum of 2.74 to a maximum of 3.196 with the median value of 3.02 in the previous studies (Table 2). According to these values, the growth characteristic of the species is generally isometric; however, it was also reported as negative allometric growth in some habitats (Table 2). According to the b value estimated in this study the growth type of *G. rufa* is isometric (b=2.9888, CI of b: 2.9386-3.0409) and show similarity with the median value of the previous studies given in Table 2.

Changes in the b exponents of the same species may be due to differences in sampling, sample size, or length range. Also, differences in age, maturity, growth in food and environmental conditions (such as temperature and seasonality) also affect the b value of the same species (Weatherley and Gill 1987). In addition, it is known that there are differences in biological characteristics between populations of the same species living in different regions (Pazira et al. 2013). Growth is affected by many factors, including gender, life history strategy, food type and availability, and temperature (Sarıhan et al. 2007).

**Table 2.** Length-weight relationship and von Bertalanffy growth parameters for *Garra rufa*

| a | b | $L_\infty$ (cm) | k (year$^{-1}$) | $t_0$ (year) | K | Habitat | References |
|---|---|---|---|---|---|---|---|
| 0.0119 | 3.139 | | | | | Iran | Esmaeili and Ebrahimi 2006 |
| 0.0063 | 3.112 | | | | 2.03 (0.87-3.14) | Armand Stream, Iran | Abedi et al. 2011 |
| 0.0075 | 3.149 | | | | | Euphrates River, Turkey | Birecikligil and Ciçek 2011 |
| 0.0223 | 2.91 | 16.82 | 0.198 | -1.14 | | Dalaki and Shapour rivers, Iran | Pazira et al. 2013 |
| 0.000005 | 3.196 | | | | 1.218±0.18 | Cholvar River, Iran | Gerami et al. 2013 |
| 0.00005 | 2.74 | | | | | Tange River, Iran | Segherloo et al. 2015 |
| 0.00002 | 2.86 | | | | | Beshar River, Iran | |
| 0.00001 | 2.99 | | | | | Mazoo River, Iran | |
| 0.05 | 2.95 | | | | | Palangan River, Iran | |
| 0.01 | 3.00 | | | | | Sirvan River, Iran | |
| 0.00002 | 2.96 | | | | | Kheirabad, Iran | |
| 0.00001 | 3.19 | | | | | Gamasiab River, Iran | |
| 0.00001 | 3.16 | | | | | Ghalate River, Iran | |
| 0.00001 | 3.08 | | | | | Cheshme gerdab River, Iran | |
| 0.00001 | 3.14 | | | | | Maroon , Iran River | |
| 0.00001 | 3.02 | | | | | Dashte chenir River, Iran | |
| 0.00001 | 2.82 | | | | | Kheirak-shekarak, Iran | |
| 0.00001 | 2.86 | | | | | Tange faryab River, Iran | |
| 0.0044 | 3.06 | | | | | Jarrahi River, Iran | Keivany and Zamani-Faradonbe 2017 |
| 0.0124 | 2.9888 | 19.98 | 0.275 | -1.157 | 1.24±0.25 | Merzimen Stream, Turkey | This study |

Estimated Fulton's Condition Factor is highly correlated with Cholvar River population (Gerami et al. 2013), however, the value was found lower than that of the Armand Stream population (Abedi et al. 2011).

The growth performance index (Φ') was estimated as 2.04 in this study. This value has been estimated 1.71 and 1.79 for females and males, respectively by Pazira et al. (2013).

According to Froese (2006) and Clark (1928) had pointed out that condition factors can only be compared directly if either b is not significantly different from 3 or the specimens to be compared are of similar length. The growth type is isometric because of b value is not different from 3. The estimated K value is highly correlated with Cholvar River (Gerami et al. 2013) however smaller than Armand Stream populations Abedi et al. (2011). The condition factor of a fish reflects physical and biological circumstances and fluctuations by interaction among feeding conditions, parasitic infections, and physiological factors (Le Cren 1951) ecosystems. According to Khristenko and Kotovska (2017) and Pravdin (1966) condition factors of the population may depend on not only its age and gender composition but also environmental elements and season as well.

Mortality estimates are important for fisheries management. Knowing these ratios can help managers set the harvest limit to maximum sustainable yield (MSY) or optimal sustainable yield (OSY) so that resource stakeholders get the most benefit (Sparre et al. 1999). However, there was not found any study on the mortality rates of *G. rufa*. The mortality rates were estimated for the first time for this species in this study. According to mortality and exploitation rates, there was no overfishing pressure on the population.

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# Current and future potential habitat suitability prediction of an endemic freshwater fish species *Seminemacheilus lendlii* (Hankó, 1925) using Maximum Entropy Modelling (MaxEnt) under climate change scenarios: implications for conservation

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## ABSTRACT

Climate change is one of the important phenomena of the century. Species distribution models have become very popular in recent years for conservation planning. When making management and conservation plans for a species, it is essential to know the current and future distributions. Expected temperature and precipitation changes will significantly affect the distribution areas of the species. These changes may result in habitat losses for some species and habitat expansion for others. This study, which current and future distribution area of *Seminemacheilus lendlii*, occurred in a very narrow area in Turkey, which is categorized as 'Vulnerable' by the International Union for Conservation of Nature (IUCN) was explored. Bioclimatic variables (Bio 1-19) were applied to determine the habitat suitability of *S. lendlii* under a current and a future (CCSM4, RCP's 2.6, 4.5, and 8.5 2070) scenario using MaxEnt software. The most influential variables were respectively bio_15, bio_14, bio_8, bio_4, bio_3, and the environmental variable that decreases the gain the most when it is omitted was the precipitation seasonality (Coefficient of Variation) (bio_15). *S. lendlii* is a sensitive species, with a not endurance to environmental stress. As a result of the modeling, it has been observed that there will be a significant decrease in the suitable habitats until 2070.

**Keywords:** Climate change, *Seminemacheilus lendlii*, Ecological Niche Modeling, Maxent

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## Maksimum Entropi Modellemesi (MaxEnt) kullanarak endemik bir tatlı su balık türünün olan *Seminemacheilus lendlii* (Hankó, 1925)'in güncel ve gelecek potansiyel habitat uygunluğunun tahmini: koruma için çıkarımlar

**Öz:** İklim değişikliği, yüzyılın önemli olaylarından biridir. Son yıllarda tür dağılım modelleri tür koruma planlamaları için popüler hale gelmiştir. Bir tür için yönetim ve koruma planları yaparken, mevcut ve gelecekteki potansiyel dağılım alanlarının bilinmesi esastır. Beklenen sıcaklık ve yağış değişiklikleri, türlerin dağılım alanlarını önemli ölçüde etkileyecektir. Bu değişiklikler, bazı türler için habitat kayıplarına ve bazı türleri için ise habitat genişlemesine neden olabilir. Bu çalışmada Türkiye'de çok dar bir alanda dağılım gösteren ve Uluslararası Doğa Koruma Birliği (IUCN) tarafından koruma statüsü 'Vulnerable' olarak kategorize edilen *Seminemacheilus lendlii*'nin güncel ve gelecekteki potansiyel uygun habitatların araştırılması yapılmıştır. *S. Lendlii*'nin güncel ve gelecekteki uygun habitatlarının belirlenmesi için 19 bioklimatik değişken (Bio 1-19) ve gelecek uygun habitat tahmini için CCSM4' ün üç emisyon senaryosu (RCP 2.6, 4.5 ve 8.5 2070) kullanılmıştır. Türün dağılımında en fazla katkıyı sağlayan iklim değişkenleri sırasıyla bio_15, bio_14, bio_8, bio_4, bio_ 3' tür. Modele kazanımı en fazla etkileyen değişken mevsimsel yağış (Bio 15) olmuştur. *S. lendlii*, çevresel strese dayanıklı olmayan hassas bir türdür. Yapılan modelleme sonucunda 2070 yılına kadar türün uygun habitatlarında önemli bir azalma olacağı görülmüştür.

**Anahtar kelimeler:** İklim değişikliği, *Seminemacheilus lendlii*, Ekolojik Niş Modellemesi, Maxent

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## Introduction

Species distribution models (SDMs) are used in ecology, biogeography, and species conservation (Qin et al. 2017). SDMs are beneficial devices and make an essential contribution in determining the current and future distribution habitats of a species. The usage and frequency have been increasing in recent years.

Biotic, abiotic factors, movement factors, and climate change determine the species' geographical distribution limits (Yousefi et al.2020). Climate change is responsible for the expansion and contraction of distribution areas of terrestrial and freshwater species (Walls 2009). Anthropogenic effects have an essential role in the distribution of species. Studies have shown that climate changes the phenology and distribution of freshwater species (Yousefi et al. 2020). Species have three responses to climate change; adapting to the new climate, migrating to suitable habitats, or extinction (Olusanya and van Zyll de Jong 2018). Many species are likely to be negatively affected by climate change, but all of them. It is crucial to determine the expansion or contraction of the distribution area of the species as a result of climate change. Once the responses to climate change are determined, it will be possible to make species protection action plans (Kafash et al. 2018).

Geological structure, topography, different features of aquatic ecosystems, and different eco-zones are the main factors affecting the species diversity of Turkey (Çiçek et al. 2018a). The fish species diversity of Anatolia is plentiful, and 47.4% of the fish fauna endemic. However, a significant part of the endemic species is endangered or have population decreasing (18 species 9.3% Critically Endangered (CR) and 38 species 19.6% Endangered (EN), 17 species 8.8% Vulnerable (VU) (Çiçek et al. 2018b).

In Turkey, species distribution model studies have usually been carried out for plants, mammals, and reptilian (Afsar et al. 2016; Tok et al. 2016; Dülgeroğlu and Aksoy 2018; Koç et al. 2018; Gül et al. 2018; Süel et al. 2018; Svenning and Avcı 2018; Rodríguez-Rey et al. 2019) however there are no species distribution modeling studies for freshwater fish. This study will make an essential contribution to filling this gap.

There are six species of the genus *Seminemacheilus* distributing in Turkey. General distribution areas of the genus are the Eastern Mediterranean basin, Sakarya Basin, Göksu river, Konya province, Sultan Marshes (Sungur et al. 2018; Çiçek 2020). *S. lendlii*, distributed the Lakes Akşehir and Eber basins besides from the upper Porsuk stream basin (Çiçek 2020). The IUCN protection status of the *S. lendlii* is VU (Freyhof 2014). Eber Lake and Akşehir Lake surface volume is gradually decreasing (Şener et al. 2010). Also, Porsuk stream and its tributaries, which are accepted as the type locality of the species (Yoğurtçuoğlu et al. 2020), are under the pressure of agriculture, settlement areas, and increasing industry (Köse et al. 2018). As a result of climate change, a decrease in precipitation, and an increase in temperatures (Öztürk 2002) may cause the loss of the habitats of the species. For this reason, determining the current and future suitable habitats of the species is important for the protection of the species.

The main goal of the study is to determine the current and future potential distribution habitats of *S. lendlii* using SDM.

## Materials and Methods

There are many species distribution models (SDM); however, MaxEnt has demonstrated corrected prediction potential in simulations and assessment with presence-only data (Hijmans and Graham 2006; Phillips and Dudik 2008). One of the most broadly used SDMs in the last years is the software Maxent (Kramer-Schadt et al. 2013).

*Seminemacheilus* genus is represented by six species, *Seminemcaheilus ahmeti, Seminemacheilus attalicus, Seminemacheilus dursunavsari, Seminemacheilus ekmekciae, Seminemacheilus ispartaensis,* and *Seminemacheilus lendlii* in Turkey (Çiçek et al. 2018b; Sungur et al. 2018; Çiçek 2020; Fricke et al. 2020; Yağurtçuoğlu at al.2020). The occurrence records of the *S. lendlii* were obtained from the literature (Çiçek 2020; Mangıt et al. 2017; Sungur et al. 2018) and GBIF (Global Biodiversity Information Facility) database (GBIF.org 2020) (Figure 1).

High resolution (30 arc second, ~ 1 km$^2$) climate data were used in the current and future estimation (Table 1) (Hijmans et al. 2005). General Circulation Model (GCM) Representative Climate Community Climate System Model version 4 (CCSM4) is a climate model with ingredient representing the atmosphere, ocean, sea ice, and land surface connected by a flux coupler (Colins et al. 2006; Gent et al. 2011), was used to predict the influence of the future climate on *S. lendlii*. CCSM4 model is an effective climate projection to give notice the impact of future climatic changes on the distribution of animal species (Liang et al. 2018; Mohammedi et al. 2019)

To determine habitat suitability range in the 2070s (2061–2080), RCP2.6 (the optimistic scenario for greenhouse gas emissions), RCP4.5 (the stabilized scenario for greenhouse gas emissions), and RCP8.5 (the pessimistic scenario for greenhouse gas emissions) were used the version 1.4 (www.worldclim.org) (Hijmans et al. 2005).

Using the Pearson correlation test (ENM Tools, 1.4.4) (Warren et al. 2010), similar variables were removed from the model. In models, $r^2$ <0.90 threshold value was taken, and variables with a coefficient higher than 0.90 were excluded from the model (Table 2). MaxEnt Modeling was used in the study (MaxEnt version 3.4.1) (Phillips et al. 2017). MaxEnt operated with maximum iterations of 5000, convergence threshold of 0.0001, and six background points. 80% of occurrence records were randomly selected and used for training data, the rest were used test data (20%), and twelve times replicated. To evaluate the performance of the model, the area under the curve (AUC), the receiver operating characteristic (ROC) were used. AUC model performance is a measure, ranges between 0 and 1, and excellent discrimination demonstrates a value of 1 (Gebrewahid et al. 2020).

We gathered six reliable sites of the current presence of *S. lendlii*, distributed across the Porsuk stream, Eber lake, and Akşehir lake (Figure 1), which corresponded to previously described areas (Çiçek 2020; Freyhof et al. 2011; Mangıt et al. 2017). The complete model was trained with the twelve variables already selected. After working this model with MaxEnt, an adjustment of variables that significantly subscribed to explain the geographic distribution of the species, by % contribution, or permutation significances were chosen for an ultimate predictive model. All environmental and climate layers are prepared in ArcMap 10.8 version (ESRI Inc.; www.esri.com).

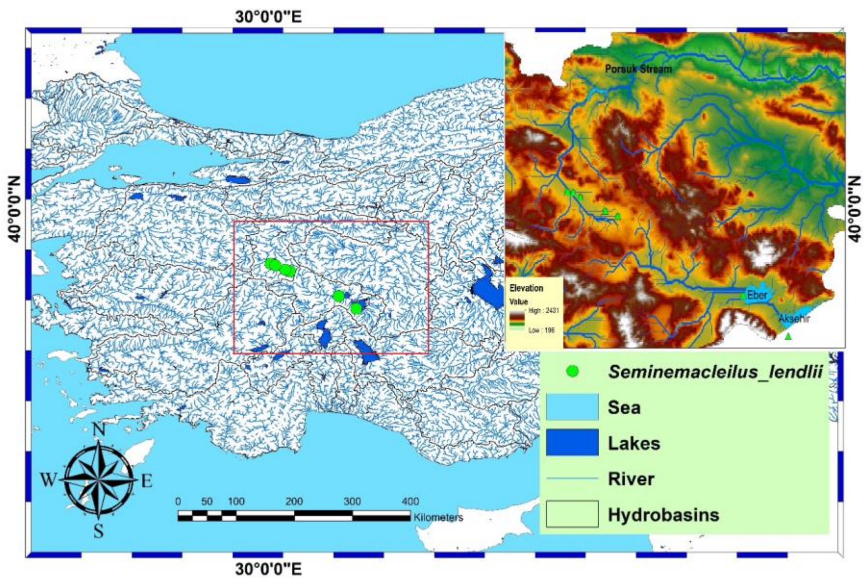


**Figure 1.** Distribution map with the occurrence localities of the *S. lendlii*

**Table 1.** Environmental variables used for modeling the potential distribution of *S. lendlii*.

| Variable | Description | Source |
|---|---|---|
| Bio1 | Annual Mean Temperature | http://www.worldclim.org |
| Bio 2 | Mean Diurnal Range (Mean of monthly (max temp/min temp) | http://www.worldclim.org |
| Bio 3 | Isothermality (BIO2/BIO7) * 100) | http://www.worldclim.org |
| Bio 4 | Temperature Seasonality (standard deviation *100) | http://www.worldclim.org |
| Bio 5 | Max Temperature of Warmest Month | http://www.worldclim.org |
| Bio 6 | Min Temperature of Coldest Month | http://www.worldclim.org |
| Bio 7 | Temperature Annual Range (BIO5-BIO6) | http://www.worldclim.org |
| Bio 8 | Mean Temperature of Wettest Quarter | http://www.worldclim.org |
| Bio 9 | Mean Temperature of Driest Quarter | http://www.worldclim.org |
| Bio 10 | Mean Temperature of Warmest Quarter | http://www.worldclim.org |
| Bio 11 | Mean Temperature of Coldest Quarter | http://www.worldclim.org |
| Bio 12 | Annual Precipitation | http://www.worldclim.org |
| Bio 13 | Precipitation of Wettest Month | http://www.worldclim.org |
| Bio 14 | Precipitation of Driest Month | http://www.worldclim.org |
| Bio 15 | Precipitation Seasonality (Coefficient of Variation) | http://www.worldclim.org |
| Bio 16 | Precipitation of Wettest Quarter | http://www.worldclim.org |
| Bio 17 | Precipitation of Driest Quarter | http://www.worldclim.org |
| Bio 18 | Precipitation of Warmest Quarter | http://www.worldclim.org |
| Bio 19 | Precipitation of Coldest Quarter | http://www.worldclim.org |

**Table 2.** Correlation Test of nineteen bioclimatic variables ($r^2$> 90 are bold).

| | bio_1 | bio_2 | bio_3 | bio_4 | bio_5 | bio_6 | bio_7 | bio_8 | bio_9 | bio_10 | bio_11 | bio_12 | bio_13 | bio_14 | bio_15 | bio_16 | bio_17 | bio_18 | bio_19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| bio_1 | 0 | 0,28 | 0,49 | 0,17 | 0,81 | 0,79 | 0,15 | 0,25 | 0,82 | 0,92 | 0,88 | 0,38 | 0,49 | -0,21 | 0,64 | 0,51 | -0,18 | -0,25 | 0,64 |
| bio_2 | 0 | 0 | 0,80 | 0,75 | 0,72 | -0,28 | 0,87 | 0,20 | 0,37 | 0,53 | -0,09 | 0,11 | 0,12 | -0,17 | 0,48 | 0,12 | -0,15 | -0,08 | 0,09 |
| bio_3 | 0 | 0 | 0 | 0,40 | 0,66 | 0,11 | 0,52 | 0,28 | 0,44 | 0,56 | 0,27 | 0,36 | 0,34 | 0,12 | 0,40 | 0,33 | 0,16 | 0,20 | 0,34 |
| bio_4 | 0 | 0 | 0 | 0 | 0,69 | -0,45 | **0,97** | 0,06 | 0,37 | 0,53 | -0,31 | 0,24 | 0,15 | -0,15 | 0,47 | 0,18 | -0,16 | -0,13 | 0,08 |
| bio_5 | 0 | 0 | 0 | 0 | 0 | 0,30 | 0,69 | 0,22 | 0,80 | **0,96** | 0,45 | 0,37 | 0,42 | -0,27 | 0,75 | 0,44 | -0,25 | -0,27 | 0,49 |
| bio_6 | 0 | 0 | 0 | 0 | 0 | 0 | -0,48 | 0,14 | 0,54 | 0,51 | **0,98** | 0,21 | 0,36 | -0,12 | 0,30 | 0,37 | -0,09 | -0,18 | 0,55 |
| bio_7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,10 | 0,33 | 0,50 | -0,32 | 0,18 | 0,11 | -0,16 | 0,46 | 0,13 | -0,16 | -0,11 | 0,04 |
| bio_8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,10 | 0,23 | 0,20 | -0,05 | -0,04 | 0,14 | -0,06 | -0,05 | 0,18 | 0,22 | -0,13 |
| bio_9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,85 | 0,62 | 0,29 | 0,37 | -0,38 | 0,66 | 0,40 | -0,35 | -0,45 | 0,53 |
| bio_10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,64 | 0,42 | 0,49 | -0,25 | 0,74 | 0,51 | -0,23 | -0,28 | 0,59 |
| bio_11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,27 | 0,43 | -0,13 | 0,41 | 0,43 | -0,10 | -0,19 | 0,60 |
| bio_12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,88 | 0,39 | 0,41 | 0,90 | 0,41 | 0,30 | 0,81 |
| bio_13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,07 | 0,67 | **0,99** | 0,09 | -0,01 | 0,94 |
| bio_14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0,57 | 0,06 | **0,99** | **0,94** | -0,08 |
| bio_15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,68 | -0,56 | -0,58 | 0,73 |
| bio_16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,08 | -0,02 | **0,95** |
| bio_17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,95 | -0,06 |
| bio_18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0,16 |
| bio_19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## Results

The calibration of the model for *S. lendlii* was excellent (AUCmean=0.957 and standard deviation 0.079, Figure 2). The results indicated that *S. lendlii*'s current distribution, characterized by the selected variables, is excellent. Maxent models with adequate predictive power were applied to present and future climate data to assess the potential distribution of *S. lendlii* in these periods. The test of the jackknife analysis indicates the distribution of *S. lendlii* was mainly influenced by the mean temperature of the wettest quarter (Bio 8), temperature seasonality (standard deviation *100) (Bio 4), and isothermality (BIO2/BIO7) * 100) (Bio 3) (Figure 3). The average temperatures of the rainiest season (1980-2010) natural distribution areas of the species are between 0.7-15.3 °C, and the annual average temperatures are in the range of 0 - 22.5 °C (MGM 2020). The region where *S. lendlii* is distributed in the Porsuk River (Eymir), water temperature 4.80, 19.7 °C, pH 7.31-8.02, Dissolved Oxygen 7.74-12.13 mg / L, Salinity (0.27-0.33) and EC (326-1767 µs/cm) (Köse et al. 2016).

The AUC values and standard deviations were 0.957 and 0.079 respectively, indicating that the expected findings were correct. The species habitat model was by twelve environmental variables (Figure 3 and Table 3). In this study, five climatic parameters (Bio_8, Bio_15, Bio_14, Bio_3, Bio_4) for contributed more than 10% (Table 3). Predictions of the relative contributions of bioclimatic variables to the target species are indicated in Table 3. Mean Temperature of Wettest Quarter (Bio_8) was the climatic variable with the highest percentage contribution for *S. lendlii*.

According to the result of future modeling, the distribution range of the species will dramatically change in 2070, suggesting that *S. lendlii* would lose a significant part of its suitable habitats (Figure 4).

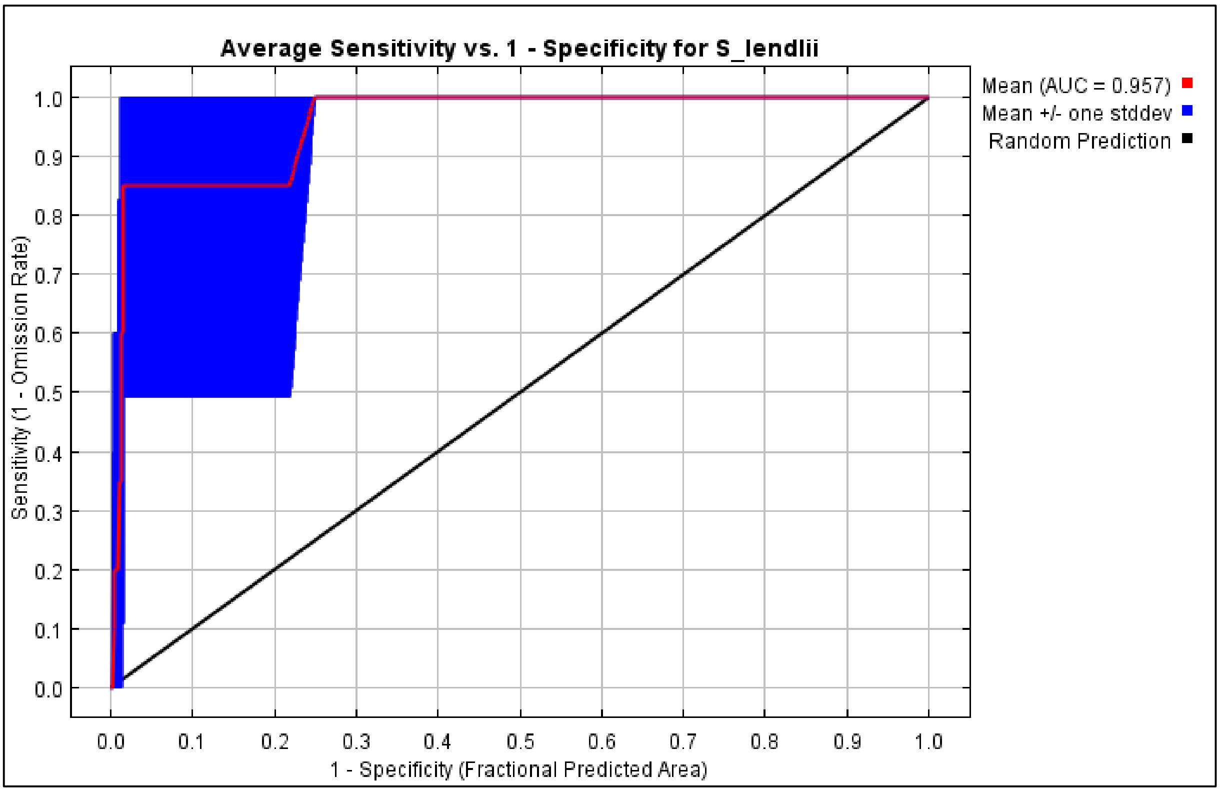


**Figure 2.** ROC curve and AUC values for Maxent model

**Table 3.** Prediction of relative contributions and permutation significance of the predictor environmental variables to the MaxEnt model.

| Variable | Bio 8 | Bio 15 | Bio 14 | Bio 3 | Bio 4 | Bio 6 | Bio 1 | Bio 2 | Bio 9 | Bio 5 | Bio 13 | Bio 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Percent contribution | 25.6 | 25 | 22.6 | 12 | 9.5 | 3.8 | 0.9 | 0.3 | 0.1 | 0.1 | 0 | 0 |
| Permutation importance | 12.2 | 20.6 | 36.9 | 1.2 | 10.3 | 6.9 | 8.8 | 2.2 | 0 | 0.9 | 0 | 0 |

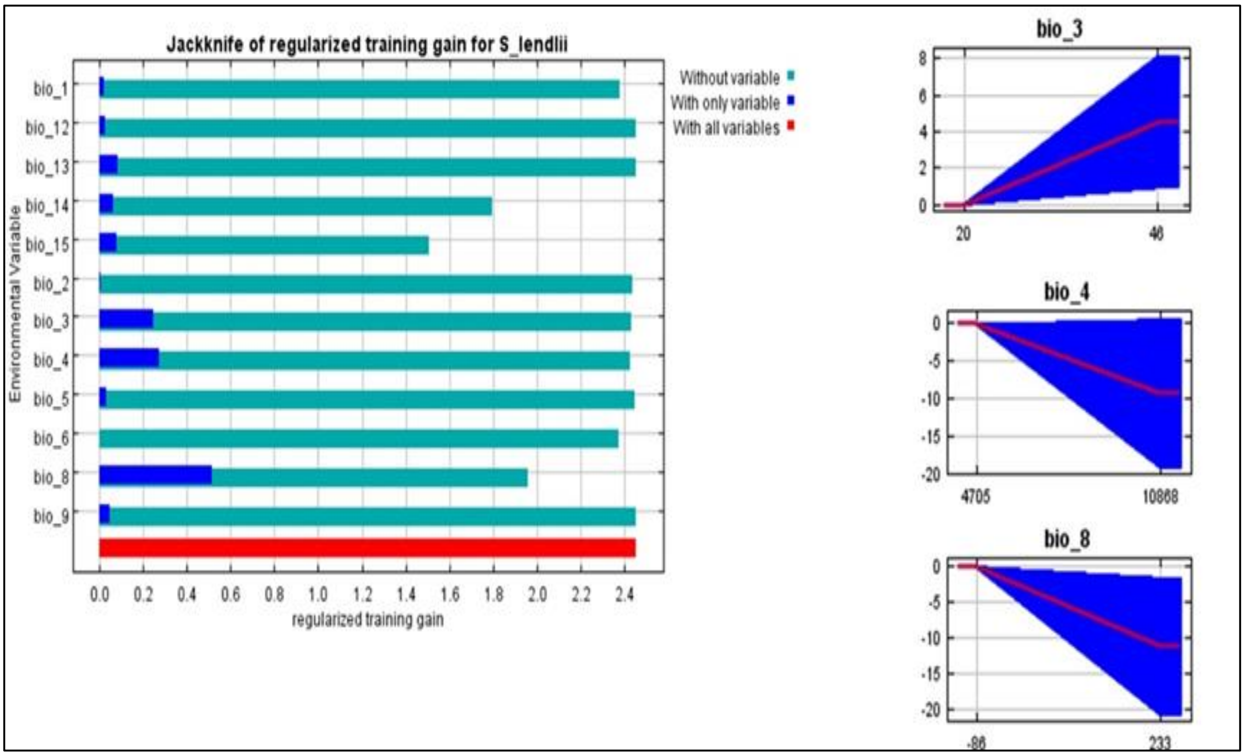


**Figure 3.** Jackknife test of variable importance of *S. lendlii*.

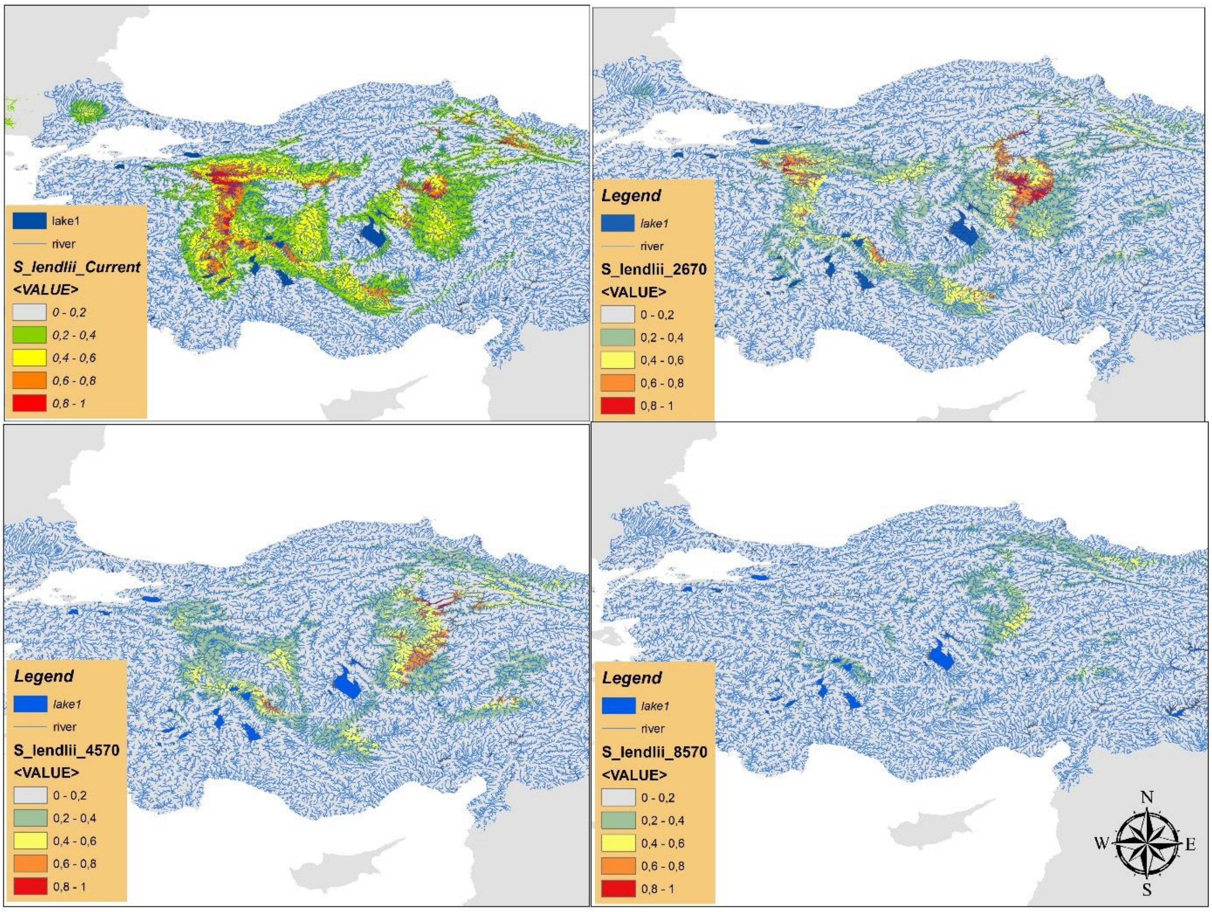


**Figure 4.** Habitat suitability maps of *S.lendlii* under current conditions and future CCSM4 emission scenario for the year 2070.

## Discussion

This study provided important data on the future projection of *S. lendlii*. According to the most pessimistic climate scenario of the species, it has been observed that it is likely to lose a significant part of its suitable habitats.

It is predicted that climate change would affect the distribution of species. Some species expand their distribution areas as a result of climate change, while others may decrease (Yousefi et al. 2020). Aquatic organisms are likely to be directly affected by climate change. Especially the settlement of invasive species, anthropogenic pressures, and changes in water structures will create significant changes in freshwater fish habitats, which collectively might impact native and endemic fish species, in particular, with restricted distribution range and low abundance populations.

Global climate change causes significant changes in temperature and precipitation patterns. Expected changes are predicted that the temperature will increase by 4.5 degrees, and the precipitation will decrease according to the pessimistic scenarios (RCP8.5) (Demircan et al. 2014). This may result in some water sources drying out. This negative change in water systems may result in the extinction of species that are distributed in limited areas.

The IUCN protection status of the *S. lendlii* species is vulnerable. Its population exists in limited areas (Freyhof 2014). Although the existence of the species is known in the Sakarya Basin, the records about it are recent. It was recorded from only one point of Sakarya basin (Çiçek 2020), Lake Eber (Mangıt et al. 2017), and Akşehir lake (Freyhof et al. 2011). Eber and Akşehir lakes have reached the point of losing a significant part of their water (Sener et al. 2010), and Sakarya basin is under pollution pressure (Köse et al. 2018). Further, increasing industrial and agricultural pollution will significantly affect fish habitats. These adverse conditions would end up with the loss of valuable habitat areas of the species.

In the areas where *S. lendlii* species are currently distributed, there is a decrease in water resources in summer. There are intense irrigation activities in the current habitat regions of the species. The Porsuk stream sampling localities have water almost to dry up due to irrigation in summer, and there is only water in rainy seasons. Dissolved oxygen levels can decrease as much as (1.96-7.74 mg/l) due to pollution pressure in the Eber lake basin where the species is distributed (Köse et al. 2016). Eber Lake and Akşehir Lake lose a significant part of the water body in the summer months due to the unconscious use of water and the decrease in precipitation. As a result of climate change (RCP 8.5, 2070-2100), an approximate temperature increase of 4-6 $^{o}$C and a decrease in precipitation are expected in Sakarya and Akarçay basins (Akçakaya et al. 2015). This may result in the reduction of spring waters and loss of suitable habitats.

The variables that most affect the current and future distribution of the species are Mean Temperature of Wettest Quarter (bio_8), Temperature Seasonality (standard deviation × 100) (bio_4), Bio 3 Isothermality (BIO2/BIO7) * 100), Precipitation of Driest Month (Bio-14), and Precipitation Seasonality (Coefficient of Variation) (Bio_15). It was seen that the decrease in precipitation and the increase in temperature would change the future habitats of *S. lendli* (Figure 4). Population decline over the past ten years for *S. lendlii* is inferred to be at least 30% (Freyhof 2014). These losses will increase rapidly with the effect of climate change.

SDM is a reliable tool to determine the future distribution of invasive and native fish species. It is essential to determine the distribution range for the protection and implementing proper conservation of endemic species distributed in a limited area. Fishes can be used as indicators of organism at individual, population, environmental, and community levels (Yousefi et al. 2020); therefore, fish can be continuously monitored to determine how freshwater ecosystems respond to climate change. This study recommends that all freshwater ecosystems in Turkey have to be monitored regularly for the successful conservation of freshwater fishes under climate change.

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# Alabalık İşletmelerinin Yapısal Özellikleri ve Su Ürünleri Desteklemelerine İlişkin Görüşlerinin Değerlendirilmesi: Kahramanmaraş, Gaziantep ve Şanlıurfa İlleri Örneği

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### ÖZ

Bu çalışmada Kahramanmaraş, Gaziantep ve Şanlıurfa illerinde alabalık üretimi yapan balıkçılık işletmelerinin su ürünleri desteklemelerine ilişkin yargıları analiz edilmiştir. İllerde toplam 77 adet işletme bulunmakta olup, toplam 21 işletme ile anket çalışması yürütülmüştür. Yetiştiricilerin su ürünleri desteklemeleri ile ilgili yargılarının analizinde çok boyutlu ölçekleme yönteminden yararlanılmıştır. Yetiştiricilerin kültür balıkçılığı deneyimi 14,62 yıl olarak bulunmuştur. Yetiştiricilerin sahip oldukları işletmelerin yıllık kapasitesi ortalama 271,29 ton, ortalama yıllık üretim miktarı ise 152,57 ton olarak belirlenmiştir. İşletmelerin kapasite kullanım oranı %78 olarak hesaplanmıştır. Desteklemelerin kaldırılmasının daha olumlu olacağı, desteklemelerin piyasa dengesini bozduğu ve ihracatta olumsuz etki gösterdiği yönündeki yargılara yetiştiricilerin genel olarak katıldıkları ve yetiştiriciler tarafından benzer şekilde algılandıkları belirlenmiştir. Desteklemeler sayesinde sektörün büyüdüğü ve işletme alt yapısının geliştiği yönündeki yargılara yetiştiricilerin çoğunlukla katılmadıkları tespit edilmiştir. Desteklemeler sayesinde nitelikli personel çalıştırma, üretim miktarının ve balık kalitesinin arttığı yönündeki yargıların da üreticiler tarafından genelde kabul görmediği sonucuna ulaşılmıştır.

**Anahtar kelimeler:** Alabalık, su ürünleri, destekleme, çok boyutlu ölçekleme

### MAKALE BİLGİSİ

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## Structural Characteristics of Trout Enterprises and the Assessment of Their Views on Aquaculture Supports: Cases of Kahramanmaraş, Gaziantep and Şanlıurfa Provinces

**Abstract:** In this study, the views of the aquaculture enterprises conducting trout production related with aquaculture supports in Kahramanmaraş, Gaziantep and Şanlıurfa provinces were analyzed. Total of 77 enterprises made production in the provinces and surveys were conducted with total of 21 enterprises. It was utilized from multi-dimensional scaling method on the analysis of the conclusions of the producers related with fisheries supports. Average culture fishing experiences of the breeders were found as 14.62 years. Average annual capacity and production amount of the enterprises were determined as 271.29 and 152.57 tons, respectively. Capacity usage ratio was calculated as 78%. It was determined that the producers generally agreed with the conclusions that the remove of the supports would be favorable, and the supports affected the market equilibrium and export negatively and these conclusions were perceived by the producers similarly. It has been determined that the breeders mostly do not agree with the judgments that the sector has grown and the business infrastructure has improved thanks to the supports. Besides, it was determined that the conclusions that qualified personnel staff and the increase of production amount and fish quality by means of the supports were not generally accepted by the producers.

**Keywords:** Salmon trout, aquaculture, support, multi-dimensional scaling

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## Giriş

Günümüzde artan nüfus, sağlıklı beslenmeye olan ilginin her geçen gün artması ve deniz mahsullerinin sağladığı faydalarla birlikte gerek dünyada gerekse ülkemizde su ürünlerine olan ilgi ve ihtiyaç sürekli olarak artmaktadır (Boran 2017).

Su ürünleri sektörü ucuz ve kaliteli hayvansal protein sağlaması nedeniyle insan beslenmesinde giderek çok önemli bir konuma gelmiştir. Bu itibarla

1984'den beri ortalama yıllık %11'in üzerindeki büyümeyle, gıda ürünleri arasında en hızlı büyüyen ve gelişen sektör unvanını almıştır (Çavdar 2009).

Türkiye'de su ürünleri sektörü, artan nüfusun beslenme ihtiyacını karşılaması, istihdam sağlaması, ülkemizin hayvansal gıda olarak tek ihracat kalemini oluşturması gibi nedenlerle ekonomi üzerindeki stratejik önemini arttırarak sürdürmektedir (Arslan 2019).

Türkiye, dünyadaki konumu ve üç tarafının denizlerle çevrili bir yarımada olması nedeniyle farklı ekolojik özellikteki 8333 km'lik bir deniz kıyı şeridine, doğal göletlerle birlikte, sayıları her gün artan baraj ve göllere sahiptir. Türkiye'de su ürünleri üretimi avcılık ve yetiştiricilik yoluyla gerçekleştirilmektedir.

Su ürünleri, ülkemiz ekonomisine belirli bir yatırım, bilimsel ve teknik çaba karşılığında sürekli girdi sağlayan, önemli doğal canlı kaynaklardandır. Türkiye birçok denize sahil vermesi ve birçok göl ve göletleri ile su ürünleri bakımından büyük bir potansiyele sahiptir. Deniz ve içsu kaynaklarının toplam yüzey alanı 25 milyon hektar olup, bu değer Türkiye'deki toplam tarım alanlarına yakındır. Bu nedenle balıkçılık kaynaklarının etkin kullanımı büyük önem taşımaktadır (Şahin 2011).

Türkiye'de su ürünleri yetiştiriciliği sektöründe 2018 yılı verilerine göre denizde faaliyet gösteren tesis sayısı 426 adet, iç sularda faaliyet gösteren tesis sayısı 1860 adet, toplamda faaliyet gösteren işletmelerin sayısı ise 2286 adet bu işletmelerin toplam proje kapasiteleri ise 486.786 ton/yıl olarak bildirilmiştir (Anonim 2020).

Hem gelişmiş hem de gelişmekte olan ülkelerde, sosyo-ekonomik açıdan önemli olan balıkçılık, ülke kalkınmasına katkısının artırılması amacıyla çeşitli politika araçlarıyla desteklenmektedir. Bu kapsamda alabalık, levrek, çipura ve diğer su ürünlerini üreten işletmelere, yıllara göre farklılık göstermekle birlikte, üretilen balık miktarına göredestekleme ödemesi yapılmaktadır. Bu desteklerin de katkısı ile Türkiye, kültür balıkçılığı üretiminde, dünyada önde gelen ülkeler arasında yerini almıştır. Tarım ve Orman Bakanlığı, 2016 yılında iç su ve denizde alabalık yetiştiriciliğine 0,75 TL/kg ve çipura-levrek yetiştiriciliği için 0,85 TL/kg destekleme ödemesi yaparken, 2017 yılında çipura levrek yetiştiriciliği için yapılan desteklemeler kaldırılmıştır (Anonim 2020).

Türkiye'de alabalık işletmeleri üzerine bir çok çalışma yapılmış (Soylu 1989; Çetin ve Bilgüven 1991; Zengin ve Tabak 1997; Üstündağ vd. 2000; Kocaman vd. 2002; Bozoğlu vd. 2006; Dağtekin 2008; Aydın ve Sayılı 2009; Emre vd. 2011; Öztürk 2011; Birici vd. 2016) ve yayınlanmıştır. Tarımsal destekler üzerinde birçok çalışma yapılmış olup (Özçelik ve Özer 2006; Erdal vd. 2013; Çobanoğlu vd. 2017; Aksu ve Dellal 2016; Daldal 2016; Aydın ve Özkan 2017; Semerci ve Çelik 2017; Kızılaslan ve Somak 2019) su ürünleri işletmelerinde uygulanan tarımsal destekleme politikalarına ilişkin çalışmalara rastlanılmamıştır.

Bu çalışmada Kahramanmaraş, Gaziantep ve Şanlıurfa illerinde alabalık üretimi yapan balıkçılık işletmelerinin su ürünleri desteklemelerine ilişkin yargıları analiz edilmiştir. Söz konusu desteklerin tarım işletmelerinin devamlılığı ve su ürünleri üretiminin sürdürülebilirliği üretici yaklaşımı temelinde ele alınmıştır.

## Materyal ve Metot

Çalışmanın ana materyalini Kahramanmaraş, Gaziantep ve Şanlıurfa illerinde alabalık işletmeleri ile yapılan anket çalışmaları oluşturmaktadır. Ayrıca, konu ile ilgili yapılan yerli ve yabancı literatürlerden ve istatistiklerden de yararlanılmıştır.

Kahramanmaraş ilinde 2017 yılında 40 adet balıkçılık işletmesinde 2932 ton, Gaziantep ilinde 14 işletmede 2452 ton, Şanlıurfa ilinde 23 işletmede 2450 ton üretim yapılmıştır. Söz konusu illerde toplam 77 adet işletme bulunmakta olup, işletmelerin yaklaşık %30'u ile anket çalışması yürütülmüştür. Toplam 21 işletme ile anket çalışması yapılmıştır.

Elde edilen verilerin analizinde öncelikle ortalama, yüzde gibi basit hesaplama yöntemlerinden ve çapraz tablolardan yararlanılmıştır. Yetiştiricilerin su ürünleri destekleri üzerine yargıları Likert Ölçeği ile belirlenmiş olup, elde edilen veriler bakımından üretici yargılarını arasındaki ilişkilerçok boyutlu ölçekleme analizi ile incelenmiştir.

Çok boyutlu ölçekleme analizinde n nesne ya da birime ait p değişkenle, nesneler arasındaki belirlenen uzaklıklara göre nesnelerin k (k<n) boyutlu bir uzayda gösterimi sağlanarak nesneler arasındaki ilişkiler belirlenmektedir. Böylece nesneler arasındaki ilişkiler bilinmese bile aralarındaki uzaklıklar hesaplanabiliyorsa, bu uzaklıklardan yararlanılarak nesneler arasındaki ilişki ortaya çıkarılabilmektedir. Nesneler p boyutlu bir uzayda tanımlandığı için bu orijinal konumlarına yakın fakat daha az boyutlu kavramsal bir uzayda gösterilerek aralarındaki ilişki belirlenebilmektedir (Alpar 2013).

Çok boyutlu ölçekleme analizi, verinin tipine göre metrik ve metrik olmayan olmak üzere iki gruba ayrılmaktadır. Metrik metot veri oranlı veya eşit aralıklı ölçek ile elde edilmiş olduğunda, metrik olmayan metot veriler sınıflayıcı veya sıralı ölçek ile elde edilmiş olduğunda kullanılmaktadır. Birimler arası uzaklıkların sıralamasının kullanıldığı metrik olmayan çok boyutlu ölçeklemede, uzaklık değerleri ile tahmini uzaklıklar arasındaki uygunluğun belirlenmesinde, uzaklık değerleri sıra numaraları temel alınarak Kruskal stress istatistiği hesaplanmaktadır. Metrik olmayan ölçekleme için stress değeri aşağıdaki gibidir (Johnson ve Wichern 1992):

$$Stress = \left(\frac{\sum_{i<j}\left(d_{ij} - \hat{d}_{ij}\right)^2}{\sum_{i<j} d_{ij}^2}\right)^{1/2}$$

Stress değerlerine ait uyum düzeyleri Tablo 1'de verilmiştir (Özdamar 2013).

Diğer çok değişkenli tekniklerde olduğu gibi $R^2$ uyum indeksi ile verinin kurulan model ile ne oranda uyum sağladığına bakılmaktadır. 0,60 ve üzeri değerler uygun görülmektedir. Fakat daha yüksek $R^2$ ile daha iyi uyumsağlanacaktır (Hair vd. 2014).

Yetiştiricilerin su ürünleri desteklemelerine yönelik yargılarını içeren verilere ALSCAL çok boyutlu yöntemi ve veri tipine göre de Öklit modeli uygulanmıştır.

**Tablo 1.** Stress değerlerine ait uyumluluk düzeyleri

**Table 1.** Compatibility levels of stress values

| Stress değeri | Uyumluluk |
|---|---|
| >0,20 | Uyumsuz gösterim |
| 0,10-0,20 | Düşük uyum |
| 0,05-0,10 | İyi uyum |
| 0,025-0,05 | Mükemmel uyum |
| <0,025 | Tam uyum |

## Bulgular

### İşletme Sahibi ile İlgili Bilgiler ve İşletmelerin Yapısı

Yetiştiricilerin ortalama kültür balıkçılığı deneyimi 14,62 yıl olarak bulunmuştur. Yetiştiricilerin sahip oldukları işletmelerin yıllık kapasitesi ortalama 271,29 ton, ortalama yıllık üretim miktarı ise 152,57 ton olarak belirlenmiştir. İşletmelerin kapasite kullanım oranı %78 olarak hesaplanmıştır. Bu durum, işletmelerin kapasitelerinin %22'sinin değerlendirilmediği şekilde yorumlanabilir (Tablo 2).

**Tablo 2.** İşletme sahibi ve işletme ile ilgili bazı istatistikler

**Table 2.** Some statistics about owner of enterprices and facilities

| Tanımlayıcı istatistikler | Minimum | Maksimum | Ortalama | Standart sapma |
|---|---|---|---|---|
| Kültür balıkçılığı deneyimi (yıl) | 2 | 30 | 14,62 | 7,63 |
| İşletme kapasitesi (ton/yıl) | 20 | 950 | 271,29 | 314,31 |
| Ortalama yıllık üretim miktarı (ton/yıl) | 10 | 600 | 152,57 | 144,53 |
| Kapasite kullanım oranı (%) | 0,28 | 1,72 | 0,78 | 0,36 |

Yetiştiricilerin işletmelerdeki görevleri de çalışma kapsamında belirlenmiş olup, %66,67'sinin işletmenin sahibi, %14,29'unun ise işletme yöneticisi olduğu belirlenmiştir. Yetiştiricilerin %42,86'sının üniversite mezunu, %23,81'inin ise lise mezunu olduğu tespit edilmiştir. Yetiştiricilerin %66,67'sinin balıkçılık dışında herhangi bir gelirlerinin ve balık yetiştiriciliği dışında yatırımlarının olmadığı sonucuna ulaşılmıştır.

İşletmelerin büyük çoğunluğunun (%71,43) şahıs işletmesi olduğu, %23,81'inin ise Limited şirket olduğu belirlenmiştir. Yetiştiricilerin %61,90'ı balık yetiştiriciliğinde su kaynağı olarak baraj gölü kullandıklarını ve büyük çoğunluğu (%85,71) elle yemleme yaptıklarını ifade etmişlerdir (Tablo 3).

Araştırma kapsamında, destekten yararlanan işletmelerin desteklere ilişkin görüşleri incelenerek Tablo 4'te verilmiştir. İşletmeler, desteklerin işletmelerin büyümesi (%61,90), sektörün gelişmesi (%66,67) ve alt yapı geliştirme üzerinde etkisi olmadığını (%61,90) ifade etmektedirler. Benzer şekilde işletmeler desteklerin nitelikli personel çalıştırma (%85,71), balık üretim miktarı (%80,95) ve balık kalitesi (%85,71) üzerinde etkili olmadığını belirtmektedirler. Ayrıca, işletmeler desteklerin piyasa dengesini bozduğunu (%66,67) ve desteklerin kaldırılmasının sektörü olumsuz etkilemeyeceğini (%76,19) ifade etmektedirler. Bununla birlikte işletmelerin %42,86'sı desteklerin ihracatı olumsuz etkilediğini belirtirken, %42,86'sı ise bu konuda kararsız olduklarını ifade etmişlerdir. Sonuç olarak, işletmelerin büyük çoğunluğunun desteğe bağlı üretim yapmadıkları ve desteklerin kaldırılması (%66,67) kanaatinde oldukları saptanmıştır.

**Tablo 3.** İşletme sahibi ve işletme ile ilgili genel bilgiler
**Table 3.** General information of enterprices' owner and the business

| Genel bilgiler | Adet | % |
|---|---|---|
| İşletmedeki görevi | | |
| İşletme sahibi | 14 | 66,67 |
| Sorumlu | 2 | 9,52 |
| Sorumlu mühendis | 2 | 9,52 |
| Yönetici | 3 | 14,29 |
| Eğitim durumu | | |
| İlkokul | 6 | 28,57 |
| Ortaokul | 1 | 4,76 |
| Lise | 5 | 23,81 |
| Üniversite | 9 | 42,86 |
| Balıkçılık dışında gelir | | |
| Yok | 14 | 66,67 |
| Var | 7 | 33,33 |
| Balık yetiştiriciliği dışında yatırım | | |
| Yok | 14 | 66,67 |
| Var | 7 | 33,33 |
| İşletmenin hukuki statüsü | | |
| Anonim şirket | 1 | 4,76 |
| Limited şirket | 5 | 23,81 |
| Şahıs işletmesi | 15 | 71,43 |
| Yetiştiricilikte kullanılan su kaynağı | | |
| Akarsu | 6 | 28,57 |
| Baraj gölü | 13 | 61,90 |
| Doğal kaynak | 2 | 9,52 |
| Yemleme sistemi | | |
| Elle | 18 | 85,71 |
| Karma | 2 | 9,52 |
| Otomatik | 1 | 4,76 |

**Tablo 4.** İşletmelerin alabalık üretim desteği hakkındaki düşünceleri
**Table 4.** Thoughts of enterprises about trout production support

| Yetiştirici yargıları | Katılmıyor (%) | Kararsız (%) | Katılıyor (%) |
|---|---|---|---|
| Desteklemeler olmasa bu kadar büyüyemezdik | 61,90 | 0,00 | 38,10 |
| Desteklemeler sayesinde alt yapımızı geliştirdik | 61,90 | 9,52 | 28,57 |
| Desteklemeler sayesinde nitelikli personel çalıştırıyoruz | 85,71 | 0,00 | 14,29 |
| Desteklemeler olmasaydı sektör bu kadar gelişmezdi | 66,67 | 4,76 | 28,57 |
| Desteklemeler kaldırılırsa sektör olumsuz etkilenir | 76,19 | 4,76 | 19,05 |
| Destekleme miktarı artarsa üretim miktarı da artar | 80,95 | 4,76 | 14,29 |
| Destekleme sayesinde üretilen balık kalitesi arttı | 85,71 | 4,76 | 9,52 |
| Desteklemeler kaldırılırsa daha iyi olur | 28,57 | 4,76 | 66,67 |
| Desteklemeler piyasa dengesini bozuyor | 19,05 | 14,29 | 66,67 |
| Desteklemeler ihracatta olumsuz etki gösteriyor | 14,29 | 42,86 | 42,86 |

**Çok Boyutlu Ölçekleme Analizi Sonuçları**

İşletmelerin su ürünleri desteklemelerine yönelik düşüncelerine verdikleri yanıtların ortalamaları belirlenmiştir. Desteklemeler sayesinde balık kalitesinin arttığı, üretim miktarının arttığı, nitelikli personel çalıştırıldığı ve desteklemelerin kaldırılması durumunda sektörün olumsuz yönde etkileneceği yönündeki yargılara katılmamaktadır. Desteklemeler ile işletmenin büyüdüğü ve alt yapının geliştiği, desteklemeler ile sektörün geliştiği ve ihracatta olumsuz etki gösterdiği yönündeki yargılara verilen cevaplar ortalama olarak 3’e yakın olup, yetiştiricilerin bu konularda kararsız oldukları göze çarpmaktadır. Desteklemelerin piyasa dengesini bozduğu ve kaldırılmasının daha olumlu olacağı yönündeki yargılara verilen cevapların ortalamasının 4’e yakın olduğu ve yetiştiricilerin genel olarak desteklemelerle ilgili olumlu görüş bildirmedikleri sonucuna ulaşılmıştır (Tablo 5).

**Tablo 5**. Su ürünleri desteklemeleri üzerine yetiştiricilerin yargıları

**Table 5**. Judgments of enterprises owners on aquaculture

| Üretici yargıları | Kodu | Ortalama | Standart Hata |
|---|---|---|---|
| Desteklemeler olmasa bu kadar büyüyemezdik | V1 | 2,76 | 0,25 |
| Desteklemeler sayesinde alt yapımızı geliştirdik | V2 | 2,62 | 0,24 |
| Desteklemeler sayesinde nitelikli personel çalıştırıyoruz | V3 | 2,19 | 0,18 |
| Desteklemeler olmasaydı sektör bu kadar gelişmezdi | V4 | 2,67 | 0,25 |
| Desteklemeler kaldırılırsa sektör olumsuz etkilenir | V5 | 2,19 | 0,25 |
| Destekleme miktarı artarsa üretim miktarı da artar | V6 | 2,09 | 0,24 |
| Destekleme sayesinde üretilen balık kalitesi arttı | V7 | 1,95 | 0,19 |
| Desteklemeler kaldırılırsa daha iyi olur | V8 | 3,62 | 0,30 |
| Desteklemeler piyasa dengesini bozuyor | V9 | 3,62 | 0,27 |
| Desteklemeler ihracatta olumsuz etki gösteriyor | V10 | 3,29 | 0,23 |

1. Kesinlikle katılmıyorum 2. Katılmıyorum 3. Kararsızım 4. Katılıyorum 5. Kesinlikle katılıyorum

Değişkenlere göre uzaklık matrisinin hesaplandığı analizde 6 iterasyon gerçekleşmiştir. Stress istatistiği değeri 0,05622 ve uyumluluk düzeyi iyi uyum olarak belirlenmiştir. $R^2$ değeri ise kabul edilebilecek en düşük değer olan 0,60 değerinden büyük olup, 0,98805 olarak bulunmuştur. Yani stress istatistiği verileri %98,805 oranında açıklamaktadır (Tablo 6).

Değişkenlerin iki boyutlu koordinat değerleri Tablo 7’de verilmiştir. “Destek miktarı artarsa üretim miktarı da artar” ve “Destekleme sayesinde üretilen balık kalitesi de arttı” değişkenleri birinci boyutta pozitif ve 1’in üzerinde değere sahiptir. Bu yargılar, desteklerin balık üretimi üzerine etkisini içermekte olup, yetiştiriciler tarafından diğer yargılardan farklı olarak algılanmaktadır. “Desteklemeler kaldırılırsa daha iyi olur”, “Desteklemeler piyasa dengesini bozuyor” ve “Desteklemeler ihracatta olumsuz etki gösteriyor” değişkenleri birinci boyutta negatif ve 1’in üzerinde değere sahiptir. Yetiştiricilerin sadece bu yargılara verdikleri cevapların ortalamasının 3’ün üzerinde olduğu ve bundan dolayı, bu yargıların yetiştiriciler açısından benzer özelliklere sahip olduğu sonucuna ulaşılmıştır.

“Desteklemeler olmasa bu kadar büyüyemezdik” değişkeni ikinci boyutta negatif ve 1’in üzerinde değere sahiptir. Yetiştiricilerin %61,90’ının bu yargıya katılmadığı, %38,10’unun ise bu yargıya katıldığı belirlenmiş olup, bu yargı ile ilgili kararsız görüş bildiren üreticiye rastlanmamıştır. Bundan dolayı, bu yargı yetiştiriciler tarafından diğer yargılardan farklı şekilde algılanmıştır.

**Tablo 6.** İterasyon geçmişi

**Table 6.** Iteration history

| İterasyon | S-stress değeri | Gelişme |
|---|---|---|
| 1 | 0,04808 | - |
| 2 | 0,03453 | 0,1354 |
| 3 | 0,03158 | 0,0296 |
| 4 | 0,02997 | 0,00161 |
| 5 | 0,02889 | 0,00108 |
| 6 | 0,02809 | 0,00080 |
| Stress İstatistiği | 0,05622 | |
| RSQ | 0,98805 | |

**Tablo 7**. Yetiştiricilerin yargıları için hesaplanan koordinatlar

**Table 7.** Coordinates calculated for judgments of owner of enterprises

| Üretici yargıları | Kodu | Boyut 1 | Boyut 2 |
|---|---|---|---|
| Desteklemeler olmasa bu kadar büyüyemezdik | V1 | 0,4561 | -1,0006 |
| Desteklemeler sayesinde alt yapımızı geliştirdik | V2 | 0,4938 | -0,8936 |
| Desteklemeler sayesinde nitelikli personel çalıştırıyoruz | V3 | 0,8680 | 0,1682 |
| Desteklemeler olmasaydı sektör bu kadar gelişmezdi | V4 | 0,7940 | -0,3664 |
| Desteklemeler kaldırılırsa sektör olumsuz etkilenir | V5 | 0,9646 | 0,9608 |
| Destekleme miktarı artarsa üretim miktarı da artar | V6 | 1,1999 | 0,2413 |
| Destekleme sayesinde üretilen balık kalitesi arttı | V7 | 1,0103 | 0,4079 |
| Desteklemeler kaldırılırsa daha iyi olur | V8 | -2,3331 | 0,2128 |
| Desteklemeler piyasa dengesini bozuyor | V9 | -1,9937 | 0,0074 |
| Desteklemeler ihracatta olumsuz etki gösteriyor | V10 | -1,4598 | 0,2622 |

Farklılıklar matrisi dikkate alındığında, 0'a yakın değerlere sahip olan yargılar birbirine benzer olarak algılanırken, 1'in üzerinde değer alan yargılar ise birbirinden farklı olarak algılanmaktadır. "Desteklemeler sayesinde nitelikli personel çalıştırıyoruz" ve "Destekleme sayesinde üretilen balık kalitesi arttı" yargılarının ve "Desteklemeler kaldırılırsa daha iyi olur" ve "Desteklemeler piyasa dengesini bozuyor" yargılarının üretici algısı açısından sırayla birbirine en çok benzeyen yargılar olduğu görülmektedir (Tablo 8).

Yargıların yetiştiriciler açısından benzerlik ve farklılıklarına ilişkin çok boyutlu ölçekleme ile elde edilen iki boyutlu uzayda elde edilen koordinatlara ilişkin grafiksel gösterim Şekil 1'de verilmiştir. Şekil 1 incelendiğinde, desteklemelerin kaldırılmasının daha olumlu olacağı, desteklemelerin piyasa dengesini bozduğu ve ihracatta olumsuz etki gösterdiği yönündeki yargıların konumlarının birbirine yakın oldukları ve yetiştiriciler tarafından benzer şekilde algılandıkları görülmektedir.

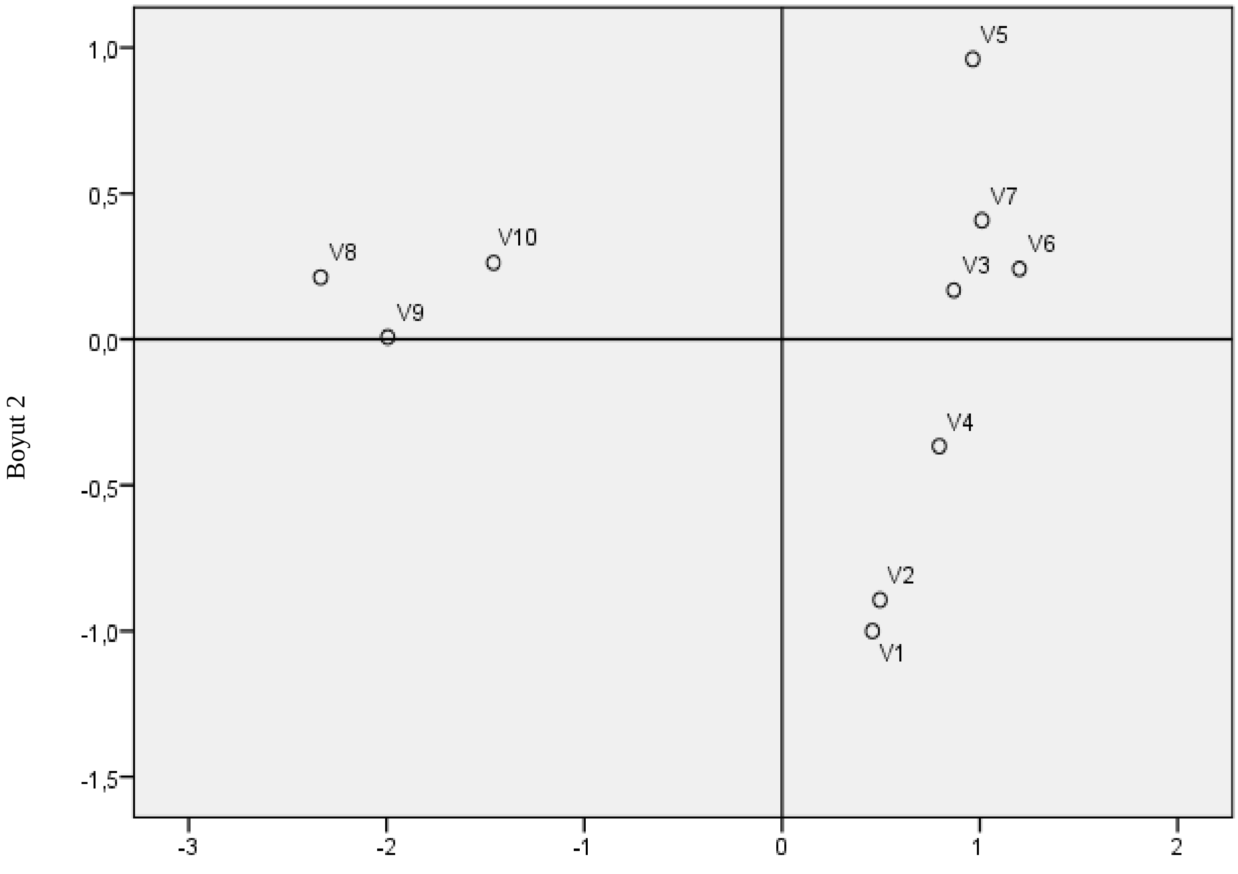
Desteklemeler sayesinde sektörün büyüdüğü ve işletme alt yapısının geliştiği yönündeki yargıların konumlarının birbirine çok yakın olduğu ve yetiştiriciler tarafından benzer şekilde algılandıkları belirlenmiştir.

Desteklemeler sayesinde nitelikli personel çalıştırma, üretim miktarının ve balık kalitesinin arttığı yönündeki yargıların da her iki boyutta pozitif değerler aldığı ve konumlarının birbirine çok yakın olduğu görülmektedir.

**Tablo 8.** Üretici yargıları için farklılıklar matrisi

**Table 8.** Matrix of differences for producer judgments

| | V1 | V2 | V3 | V4 | V5 | V6 | V7 | V8 | V9 | V10 |
|---|---|---|---|---|---|---|---|---|---|---|
| V1 | 0,000 | | | | | | | | | |
| V2 | 0,624 | 0,000 | | | | | | | | |
| V3 | 1,354 | 0,816 | 0,000 | | | | | | | |
| V4 | 0,816 | 0,816 | 0,673 | 0,000 | | | | | | |
| V5 | 1,971 | 1,971 | 0,673 | 1,354 | 0,000 | | | | | |
| V6 | 1,354 | 1,354 | 0,420 | 0,816 | 0,673 | 0,000 | | | | |
| V7 | 1,514 | 1,354 | 0,279 | 0,816 | 0,673 | 0,420 | 0,000 | | | |
| V8 | 3,036 | 3,036 | 3,195 | 3,195 | 3,381 | 3,533 | 3,349 | 0,000 | | |
| V9 | 2,654 | 2,646 | 2,866 | 2,813 | 3,108 | 3,195 | 3,036 | 0,397 | 0,000 | |
| V10 | 2,302 | 2,302 | 2,330 | 2,302 | 2,523 | 2,654 | 2,474 | 0,624 | 0,420 | 0,000 |




**Şekil 1.** Değişkenlerin iki boyutlu uzayda gösterimi

**Figure 1**. Representation of variables in two-dimensional space

Üreticilere desteklemelerin kaldırılması veya destekleme almama durumundaki düşünceleri de sorulmuştur. Tablo 9 incelendiğinde, yetiştiricilerin %61,90'ı desteklemelerin kaldırılması durumunda üretim miktarını azaltmayacaklarını ve %80,95'i ise destekleme alamama durumunda üretime aynı şekilde devam edeceklerini ifade etmişlerdir.

**Tablo 9.** Yetiştiricilerin desteklemelerin kaldırılması veya destekleme almama durumundaki düşünceleri

**Table 9.** Breeders ' thoughts on removing supports or not receiving support

| Desteklemenin kaldırılması durumunda düşünceleri | Adet | % |
|---|---|---|
| Üretim miktarını azaltırım | 2 | 9,52 |
| Aynı üretim miktarında devam ederim | 13 | 61,90 |
| Üretim miktarını arttırırım | 6 | 28,57 |
| Destekleme alamama durumunda üretime devam kararı | Adet | % |
| Daha küçük ölçekte üretim yaparım | 3 | 14,29 |
| Üretimden/yatırımdan vazgeçerim | 1 | 4,76 |
| Üretimi aynı şekilde devam ederim | 17 | 80,95 |

## Tartışma ve Sonuç

Balık, insanların sağlıklı beslenmesi açısından çok önemli bir protein kaynağıdır. Ülke nüfusunun sürekli olarak artması, avcılık yolu ile elde edilen balık miktarının sürekli olarak azalması ve su ürünleri ihracatının ülke ekonomisine yaptığı katkı, su ürünleri yetiştiriciliğini her geçen yıl daha da önemli bir sektör haline getirmektedir.

Bu çalışmada, alabalık işletmelerinin su ürünleri desteklemelerine yönelik düşünceleri irdelenmiştir. Yetiştiricilerin büyük çoğunluğu desteklerin piyasa dengesini bozduğu ve ihracatta olumsuz etki gösterdiğini belirtmişlerdir. Ayrıca, desteklemelerin bu haliyle üretim miktarında ve ürün kalitesinde olumlu etki göstermediği yönünde görüş bildirirken, balıkçılık sektörünün gelişmesine katkısı olmadığını belirtmişlerdir. Uygulanan destekleme politikaları ile sektör sürdürülebilir bir forma dönüşmüş, uluslararası pazarlarda Türkiye önde gelen ülkelerden biri haline gelmiştir. Bu sebeple levrek ve çipura yetiştiriciliğinde uygulanan kg başına yapılan destekleme ödemeleri 2017 yılında kaldırılmıştır. Çalışma sonuçları levrek ve çipura yetiştiriciliğinde olduğu gibi alabalık yetiştiriciliğinde de söz konusu desteklerin kaldırılmasının üretim miktarında büyük bir azalmaya sebep olmayacağını göstermektedir.

Destekleme alamama durumunda yetiştiricilerin üretim kararlarında ortaya çıkan sonuçlar incelendiğinde, desteklerin çalışmaya katılan işletmelerin %14,29'unda ölçek etkisi yarattığı, üretimden vazgeçmeksizin kapasite azaltmaya yönelik bir davranış sergileyeceği tespit edilmiştir. Bu sonuca ek olarak destekleme ödemelerine bağlı olarak üretim yapan işletme oranı ise yalnızca %4,76 olarak saptanmıştır. Bu sonuçlar ışığında alabalık işletmelerine uygulanan desteklemelerin yaklaşık %95'inin yetiştiriciler üzerinde üretimi artıcı ve/veya yönlendirici bir etki yaratmadığı sonucuna ulaşılmıştır. Ekonomik olarak sürdürülebilir bir sektör haline gelen alabalık yetiştiriciliğinde nakdi destekler yerine verimliliği artırıcı teknolojiler veya kapasite artırıcı finansman desteklerinin (düşük faizli kredi, teknoloji transferi vb.) verilmesi kamu kaynaklarının daha etkin bir şekilde dağıtılmasını sağlayacaktır. Çalışma kapsamında desteklemelerin ne şekilde verilmesi gerektiği de irdelenmiş olup, yetiştiricilerin büyük çoğunluğunun desteklemelerin kaldırılarak KDV'nin %1'e düşürülmesi yönünde görüş bildirdikleri tespit edilmiştir. Bunun yanında, nakit destek yerine girdi desteği verilmesinin de yetiştiriciler tarafından daha olumlu olacağı belirlenmiştir. Alabalık yetiştiricileri nakit desteğin üretime faydalı olmadığını, yem, ağ, ilaç vb. ihtiyaçlarının karşılanmasının üretime daha olumlu katkısı olacağını belirtmişlerdir.

## Teşekkür

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