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Distribution of Mollusca Fauna in the Streams of Tunceli Province (East Anatolia, Turkey) And its Relationship with Some Physicochemical Parameters

Serap Koşal Şahin[1*], Melek Zeybek[2]

[1] Istanbul University, Faculty of Fisheries, Ordu Street No: 200 Laleli-İstanbul-Turkey

[2] Süleyman Demirel University, Faculty of Arts and Sciences, Department of Biology, 32260 Isparta, Turkey

E-mail: serap@istanbul.edu.tr

Abstract

This study was carried out by the streams of Tunceli province (Turkey) between June 2008 and May 2009 to determine Mollusca fauna. Samples were taken at 20 stations, seasonally. Mollusca fauna of the streams of Tunceli was represented by three species of Prosobranchia (*Bithynia pseudemmericia, Bithynia tentaculata, Anadoludamnicola gloeri),* four species of Pulmonata (*Galba truncatula, Radix labiata, Physella acuta, Acroloxus lacustris)*, and two species of Bivalvia (*Pisidium casertanum, Pisidium lilljeborgii)*. Canonical Correspondence Analysis (CCA) was applied to determine the relationships among the Mollusca fauna and physicochemical variables. CCA explained 31.897 % of the species and environmental variation by the second axis. Water temperature (T), dissolved oxygen (DO), pH, and Ca^{+2} were the most influential variables on the Mollusca fauna. The present study is the first research on the Mollusca fauna in the streams of Tunceli province. Molluscs species were recorded for the first time from the area.

Keywords: Mollusca, Water quality, Physicochemical variables, Tunceli, Turkey

Tunceli İli (Doğu Anadolu, Türkiye) Akarsuları Mollusca Faunasının Dağılımı ve Bazı Fizikokimyasal Parametrelerle İlişkisi

Özet

Bu çalışma, Tunceli İli akarsularının Mollusca faunasını belirlemek amacıyla Haziran 2008 Mayıs 2009 tarihleri arasında gerçekleştirilmiş ve seçilen 20 istasyondan mevsimsel peryotlarla örnekler alınmıştır. Tunceli akarsularında Mollusca faunası Prosobranchia'ya ait 3 tür (*Bithynia pseudemmericia, Bithynia tentaculata, Anadoludamnicola gloeri),* Pulmonata'ya ait 4 tür (*Galba truncatula, Radix labiata, Physella acuta, Acroloxus lacustris),* ve Bivalvia'ya ait 2 tür (*Pisidium casertanum, Pisidium lilljeborgii)* olmak üzere toplam 9 türle temsil edilmiştir. Kanonik Uyum Analizi (CCA) kullanılarak fizikokimyasal değişkenler ile Mollusca faunası arasındaki ilişki belirlenmiştir. CCA'ya göre türler ile çevresel faktörler arasındaki ilişkinin % 31,897'si ikinci aksis tarafından açıklanmıştır. Su sıcaklığı (T), çözünmüş oksijen (DO), pH ve Ca^{+2} Mollusca faunası üzerindeki en etkili faktörler olarak bulunmuştur. Bu çalışma, Tunceli ili akarsularının Mollusca faunasını belirlemeye yönelik yapılan ilk çalışmadır. Mollusk türleri çalışma alanından ilk kez kaydedilmiştir.

Anahtar Kelimeler: Mollusca, Su kalitesi, Fizikokimyasal değişkenler, Tunceli, Türkiye.

Introduction

Freshwater ecosystems are the most valuable water resources and they are affected by numerous types of human influences that have a negative effect on their water quality and ecological condition. Freshwater habitats are being subjected to unprecedented levels of anthropogenic disturbances in the world (Loh et al. 1998). Aquatic ecosystems were influenced by discharging the considerable amounts of polluting matters that originated from anthropogenic activities (Pizarro et al. 2010). Pollution of surface and underground water systems is one of the

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most significant environmental problems that numerous studies revealed in developing countries (Yan et al. 2007). Molluscs are a common group of macrozoobenthic in aquatic ecosystems. Gastropoda and Bivalvia are used as indicator organisms for biological monitoring and in hazard and risk assessment (Goldberg, 1986; Borcherding and Volpers. 1994). Molluscs are also distributed in many habitats with their highly adaptation abilities. Because of the high adaptation capabilities to the molluscs, a wide distribution in adapted areas has been observed. Hence, it is convenient to study the relationship between organisms and environment. Distribution of freshwater Bivalvia and Gastropoda is determined by a number of factors such as dissolved oxygen, pH, water temperature, calcium ion, physical nature of the substratum, depth, nutritive content of the water body. However, some studies have revealed toxicity of most substances is affected by such factors as DO, water hardness and pH (Økland, 1990; Duft et al. 2007). The comparative studies in aquatic molluscs have revealed that species' distributions are restricted by environmental conditions (Hunter, 1961; Økland, 1969; Dussart, 1976, Dillon, 2000; Maltchik et al. 2010; Zeybek et al. 2012). As some are edible, many being agricultural pests or hosts to parasitic organisms, they have parasitological importance (Şeşen and Yıldırım. 1993). Although the idea of using molluscs as bioindicator species is critical, it requires detailed knowledge of the relationship between the ecology of species and spatial distribution. Almost a little information is known about the ecological preferences of molluscs in Turkey. Important ecological studies on freshwater molluscs were made by Çabuk et al. 2004; Koşal-Şahin and Yıldırım. 2007; Kalyoncu et al. 2008; Kalyoncu and Yıldırım. 2009; Şereflişan et al. 2009; Yıldız et al. 2010; Zeybek et al. 2012. This study aims to contribute the knowledge of the ecology of these molluscs in the streams and to focus on the importance of molluscs as bioindicators to outline their seasonal differences in the streams.

Material and Methods

Study area

Tunceli province is located at the upper Fırat River basin in the Taurus orogenic belt of the mountainous district of the Eastern Anatolia (Afşar, 1989).The streams have made the area tough and rugged by cutting through the chain of mountains one by one because of heavily rains and altitude in this province. In the present study, water and Mollusca samples were gathered from 20 stations selected of various streams (Figure1).

Sampling of Mollusca

Mollusca samples were collected seasonally (June 2008 and May 2009) at 20 stations using an Ekman Birge grap (225 cm^2). The sediment was sieved by using a sieve mesh of 0.5 mm. Mollusca was preserved in 75% ethanol. In the laboratory, they were identified and counted using a trinocular microscope.

Welch's (1948) method was followed to collect, sift and preserve the samples. The density (D = N/n x 44) of molluscs (ind.m^{-2}) in each sample was calculated according to Clark et al. (1989). Where"D" is density,"N" is the number of specimens collected and "n" is the number of grab samples.

Physicochemical Analysis

Water samples for physicochemical analyses were collected seasonally from each station, using prewashed

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polyethylene bottles. Water temperature (°C), dissolved oxygen (DO mgl^{-1}) and pH were measured by using YSI 556 model multi-parameter instrument as in situ. The levels of NO_2^--N (mgl^{-1}), NO_3^--N (mgl^{-1}) and Ca^{+2} (mgl^{-1}) were analysed in the laboratory according to standard methods (APHA, 1998). All materials were deposited in the laboratory of Istanbul University, Faculty of Fisheries.

Statistical Analysis

The relationships between species and physicochemical variables were examined by applied Canonical Correspondence Analysis (CCA) (Ter Braak, 1986; 1995). Pearson Correlation analysis was performed to determine if there were any correlation between the physicochemical variables and the number of individuals using the SPSS, 2007. Classification of water quality was carried out according to Turkish Water Pollution Control Regulation (TWPCR, 2008).

Results

This study was carried out between June 2008-May 2009 and investigated distribution of mollusca fauna in the streams of Tunceli province (East Anatolia, Turkey) and its relationship with some physicochemical variables.

The average values of measured physicochemical variables and water quality classes at the stations were showed in Table 1. According to the results, the water quality classes varied from fair to high quality. Stations 4, 5, 8-12, 16-19 were found as high quality (class I) according to all parameters; yet stations 1-3, 6, 7, 14, 15, and 20 were as good quality (slightly polluted- class II) based on dissolved oxygen. However, slightly polluted stations were also found to be high quality (class I) in terms of the other parameters. Station 13 was assessed as fair quality (polluted- class III) according to pH values while other parameters showed it as high-quality water (class I) (Table 1).

As a result of the study, 25 723 in per square metre (ind. m^{-2}) mollusca species belong to nine species were collected in this study. Among them three species belong to Prosobranchia (*Bithynia pseudemmericia* Schütt, 1964, *Bithynia tentaculata* (Linnaeus 1758), *Anadoludamnicola gloeri* Koşal Şahin, Koca and Yıldırım, 2012; four species belong to Pulmonata (*Galba truncatula* (O.F. Müller, 1774), *Radix labiata* (Draparnaud, 1805), *Physa acuta* Draparnaud 1805, and *Acroloxus lacustris* (Linnaeus 1758); two species belong to Bivalvia *Pisidium casertanum* (Poli, 1791) and *Pisidium lilljeborgii* (Clessin, 1886).

The abundance of the species at the stations was showed in Table 2. The abundance of Mollusca species differs from each other. The highest abundance of Mollusca was observed at station 20. The most abundant species in the study area throughout the study period were *Galba truncatula, Physella acuta, Bithynia pseudemmericia,* respectively (Table 2). The seasonal density of individuals (ind.m^2) of Molluscs was showed in Figure 2. *P. acuta* was collected from the stations as the most abundant in the summer and spring. 1600 individuals per m^{-2} were found in the summer while 1422 individuals per m^{-2} were detected in the spring (Figure 2).

Also, correlations between the abundance of mollusca species and physiochemical variables of the study area were presented in Table 3. NO_2-N and NH_3-N values were measured under the analysis limits during the study and did not show any correlation with the species. Mollusc species showed significantly positive correlation ($P < 0.05$) with the water temperature apart from *A. lacustris, A. gloeri, P. casertanum, P. lilljeborgii*, and *A.*

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lacustris. Anadoludomnicola gloeri and *Acroloxus lacustris* were positively correlated with DO values ($P < 0.05$). All taxa, except *P. lilljeborgii,* positively correlated with Ca^{+2} ($P < 0.05$) (Table 3).

The CCA was performed to determine the correlations between identified species and physicochemical variables. According to the first axis, the distribution of almost all species was positively correlated DO, Ca^{+2}, pH, water temperature while NO_2^--N and NO_3^--N were showed a negative correlation with the distribution of mollusc species. As a result of this analysis, the second axis of the CCA diagram (Figure 3) showed high values of species-environment correlation (r= 92.9) (Table 3).

Discussion

The freshwater molluscs contribute an important part of aquatic ecosystem. However they have been less investigated in terms of ecologically and biologically (Pal and Dey. 2011) According to the obtained results, the various relationships between mollusc species and physicochemical variables were determined in the current study. Totally, 25 723 individuals (ind. m^{-2}) were found belong to nine species. The most abundance was found in spring and summer seasons. According to Dillon (2000), Mollusca species are more found in spring and summer. This information supported our results.

Pulmonata normally belongs to eurytopic species spreading especially on shallow and muddy bottoms. They can inhabit a wide range of aquatic systems, even those with high trophic content (Hart and Fuller. 1974; Russel Hunter, 1983; Serafiński et al. 1989). The Pulmonata fauna of Turkey, under these paleo zoogeographic conditions, have a simple composition. Therefore, their distribution in Turkey should be evaluated on the ordinary dimensions (Yıldırım et al. 2006). According to correlation analysis, the species belong to Pulmonata were positively correlated with Ca^{+2} ($P < 0.05$) and water temperature except *Acroloxus lacustris.*

The numbers of *R. labiata* were 780 (individual.m^{-2}) in the summer and *R. labiata* was counted 690 individual.m^{-2} in the spring (Figure 2). *R. labiata* is common in Europe, northern Africa, as well as central, northern and eastern Asia (Glöer, 2002), and in Turkey, except south-east of Turkey (Yıldırım et al. 2006). This species was identified at all of the stations except station 3.

Prosobranchs are known to be significant indicators of water quality, due to their widespread distribution in different geographical locations and the presence within aquatic environments (Aldridge, 1983; Duft et al. 2007). The amount of dissolved oxygen in the water is an important indicator of the abundance of some species, particularly Prosobranchia (Ertan et al., 1996; Yıldırım, 1999). Three species were detected belong to Prosobranchia.

Bithynia has represented a Bithyniid genus of euryoecious characteristic. According to Meyer (1987), *B. tentaculata* is distributed in averagely unpolluted spring water. This information supported our result. Observation of *B. tentaculata* in both summer and spring were 1100 individual/m^{-2} (Figure 2). *B.tentaculata* was also collected from at stations 11, 13, 15, 18, 19 and 20 during the study period (Table 1). *B. pseudemmericia* is endemic to Anatolia. In this study, *B. pseudemmericia* were found at stations 1, 3, 6, 8, 11-15, 19,20 (Table 1). 2200 individual.m^{-2} were collected in the summer and 1133 individual.m^{-2} were gathered in the spring, 44 individual.m^{-2} were gathered in the autumn and 266 individual.m^{-2} were also collected in the winter belong to *B. pseudemmericia.* Another prosobranch in the field, *A.gloeri* is an endemic to Anatolia and its distribution matches the oligotrophic character of the species. Most generally, such as Hydrobiid are abundant and prefer

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highly oxygenated water (Ertan et al. 1996; Thorp and Covich. 2001). This information supported our result. In this study *Anadoludomnicola gloeri* were determined at some stations (e.g. DO levels at station 1: 5.7 mgl^{-1}, station 5: 9.3 mgl^{-1}; station 16: 10.2 mgl^{-1}, station 17:10.3 mgl^{-1}). Stations 5, 16, 17 were determined as unpolluted (high quality) and station 1 was determined as slightly polluted (good quality) (Table 1). Also, four species (*B. pseudemmericia*, *P. acuta*, *A. lacustris* and *A. gloeri*) were determined in all seasons (Figure 2).

P. casertanum and *P. lilljeborgii* belong to Sphaeriidae. They can be recognised without difficulty by looking at their conchological characteristics. This type of claim can survive in a wide spectrum of habitats, most especially ponds, swamps, creeks, and rivers (Herrington, 1962). This taxon prefers to live in mud biotopes but can also exist in lakes and rivers **(**Thorp and Covich, 2001). One of the most widely found species of freshwater Mollusca in the world is *P. casertanum*. It is known from Palearctic and Nearctic regions, as well as parts of South America, Africa and Australia and Asia. It is a cosmopolitan and euryoecious species (Subba Rao, 1989; Ramakrishna Dey, 2007). *Pisidium* genus is predominantly found in areas where the water quality is oligo/ betamesosaprobic (Meyer, 1987). Usually, two *Pisidium* species, *P. personatum* and *P. casertanum* inhabit mountain springs (Glöer and Diercking. 2010). In the present study, they were found to be the most dominant species in the betamesosaprobic area. These species have been found in large numbers at station 20 except the winter season (Figure 2).In this study, the total number of *P. casertanum* was determined 1376 individual.m^{-2} while *Pisidium lilljeborgii* were determin*ed* 1944 individual.m^{-2} *(Figure 2).* According to (Nesemann and Reischütz, 1995), *Pisidium casertanum* is oligosaprobic, betamesosaprobic, and alphamesosaprobic. This species was found at station 20 in the current study. *P. casertanum* was positively correlated with Ca. Similar results were obtained by Kazancı and Dügel (2010).

According to CCA diagram, species were located closer to DO, pH, Ca, T and did show a positive correlation with these parameters. Average pH values in this study were detected within ranged from 6.1 to 8.1 at the stations, yet no significant correlation between mollusc species and the average pH values. According to Gallordo et al. (1994) and Dillon (2000), pH is a determining factor for mollusc species. Not only low pH (pH <6) hampers the development of molluscs, it is also reported that the low pH could be fatal to them (Hart and Fuller. 1974). Zeybek et al. (2012) found that there is a positive correlation between *B. pseudemmericia* and pH values.

Temperature, pH, dissolved oxygen, and Ca^{+2} were the most significant ($P < 0.05$) variables on the distribution of molluscs species. Ca^{+2} is an essential requirement for the successful growth and development of mollusc. Calcium is the primary component of a snail shell. (Briers, 2003; Rycken et al., 2003). CCA results of the present study support Okland's (1990) conclusion that water hardness and pH are often considered major factors determining the distributions of freshwater snails (Figure 3).

Several studies have investigated the relationship between mollusc species with environmental factors by using CCA (Akbulut et al., 2009; César et al., 2012; Strzelec et al., 2014).

Finally, nothing was known about the life cycle and ecological requirements of these gastropod and bivalvia species in some countries. We found that the most of these species showed a positive relation by Ca and water temperature. Dissolved oxygen level is important for *Acroloxus lacustris, Anadoludamnicola glöeri.* Although our knowledge of species ecology is still somewhat limited, results can not be generalised to many species. However, the levels and the type of such variables differ from species to species knowledge on species

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characteristic can help increase our understanding of aquatic mollusc and their importance in ecological and biological studies. Further detailed studies on each of these individual parameters are needed

Conclusion

According to results of the study, the most of the stations in the area were unpolluted and yet some others were slightly polluted. Therefore, it can be concluded that their habitat qualities were high. It would perhaps be fair to conclude that this study shows that water quality is better in the areas away from anthropogenic activities. Such ecological studies should be conducted to save the rich biodiversity of eastern and south-eastern Anatolia. Furthermore, there has been no study in Mollusca fauna and their relationships to physicochemical parameters in this study area. This study also is important in this respect. All taxa identified for the region have been recorded for the first time.

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Table 1. The Mollusca fauna and average values of physicochemical parameters at the stations in Tunceli

Stations	GPS-coordinates	Water Quality Class (TWCPR, 2008)	pH	DO (mgl^{-1})	T ºC	NO_{3}-N (mgl^{-1})	NO_{2}-N (mgl^{-1})	Ca^{+2} (mgl^{-1})
1-Hormek	39° 01´ 055″ N, 39° 55´ 065″ E	II (Good quality)	7.2	5.7	17.3	< 0.02	< 0.01	325.4
2-Geçitveren (1)	38° 39´ 862″ N, 39° 50´ 141″ E	II (Good quality)	7.1	6.7	16.2	< 0.02	< 0.01	297.8
3-Geçitveren (2)	38° 58´ 453″ N, 39° 48´ 731″ E	II (Good quality)	7.4	7.2	12.8	< 0.02	< 0.01	514.3
4-Darıkent	38° 59´ 260″ N, 39° 45´ 768″ E	I (High quality)	8.1	10.2	12.9	< 0.02	< 0.01	451.2
5-Kartutan	38° 59´ 655″ N, 39° 42´ 822″ E	I (High quality)	7.1	9.3	18.6	< 0.02	< 0.01	325.1
6-Gelincik	38° 59´ 608″ N, 39° 41´ 729″ E	II (Good quality)	7.2	6.2	17.8	< 0.02	< 0.01	412.2
7-Aktarla	38° 59´ 560″ N, 39° 41´ 388″E	II (Good quality)	7.2	5.6	12.7	< 0.02	< 0.01	321.8
8-Dalamer	38° 59´ 512″ N, 39° 41´ 065″ E	I (High quality)	6.9	13.8	11.8	< 0.02	< 0.01	457.3
9-Bulgurcular (1)	38° 58´ 865″ N, 39° 44´ 924″ E	I (High quality)	6.9	10.5	10.9	< 0.02	< 0.01	356.8
10-Bulgurcular (2)	39° 10´ 677″ N, 39° 27´ 691″ E	I (High quality)	7.2	9.7	11.6	< 0.02	< 0.01	523.1
11-Koyungölü	39° 21´ 638″ N, 39° 13´ 505″ E	I (High quality)	6.5	12.3	19.2	< 0.02	< 0.01	298.7
12-Ovacık	39° 21´ 373″ N, 39° 13´ 624″ E	I (High quality)	6.5	11.7	14.9	< 0.02	< 0.01	365.8
13-Değirmendere	39° 19´ 873″ N, 39° 03´ 253″ E	III (Fair quality)	6.1	8.2	17.9	< 0.02	< 0.01	523.1
14-Millipark (1)	39° 20´ 163″ N, 39° 04´ 832″ E	II (Good quality)	6.8	7.3	15.8	< 0.02	< 0.01	421.8
15-Millipark (2)	39° 25´ 503″ N, 39° 21´ 062″ E	II (Good quality)	6.7	7.2	16.8	< 0.02	< 0.01	435.2
16-Munzur (1)	39° 21´ 198″ N, 39° 07´ 627″ E	I (High quality)	7.2	10.2	13.5	< 0.02	< 0.01	398.2
17-Munzur (2)	38° 51´ 682″ N, 39° 19´ 950″ E	I (High quality)	7.5	10.3	10.8	< 0.02	< 0.01	365.7
18-Yeşilyazı	38° 58´ 620″ N, 39° 41´ 720″ E	I (High quality)	7.3	8.2	10.5	< 0.02	< 0.01	432.1
19-Mercan	39° 22´ 196″ N, 39° 10´ 252″ E	I (High quality)	7	7.9	19.2	< 0.02	< 0.01	432.5
20-Pertek	39° 19´ 873″ N, 39° 02´ 250″ E	II (Good quality)	7.4	5.6	10.9	< 0.02	< 0.01	398.7

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Table 2. Total abundance of Mollusca (ind. m $^{-2}$) in the study area

	Sta 1	**Sta 2**	**Sta 3**	**Sta 4**	**Sta 5**	**Sta 6**	**Sta 7**	**Sta 8**	**Sta 9**	**Sta 10**	**Sta 11**	**Sta 12**	**Sta 13**	**Sta 14**	**Sta 15**	**Sta 16**	**Sta 17**	**Sta 18**	**Sta 19**	**Sta 20**	**TOTAL**
Galba truncatula	228	346	332	328	308	544	244	488	678	110	242	100	496	44	242	142	320	440	88	-	5720
Bithynia pseudemmericia	410	-	400	-	-	142	-	270	-	-	739	100	416	200	466	-	-	-	456	44	3643
Bithynia tentaculata	-	-	-	-	-	-	-	-	-	-	500	-	374	-	660	-	-	100	500	66	2200
Radix labiata	22	620	-	202	96	44	22	44	44	22	22	22	44	44	44	44	22	88	22	22	1490
Physella acuta	132	164	332	210	122	353	22	270	268	78	110	343	254	328	382	344	22	288	-	-	4022
Acroloxus lacustris	376	52	-	120	-	-	120	220	1200	400	-	88	22	-	-	-	-	-	-	-	2598
Anadoludomnicola gloeri	466	-	-	-	638	-	-	-	-	-	-	-	-	-	532	700	364	-	-	-	2700
Pisidium casertanum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1376	1376
Pisidium liljeborgi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1944	1944
TOTAL	1634	1182	1064	860	1164	1083	408	1292	2190	610	1613	653	1606	616	2326	1230	728	916	1066	3452	25723

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Table 3. Pearson's correlation coefficients between abundance of Mollusca species and examined physicochemical variables (* p< 0.05)

	Anadoludomnicola gloeri	*Acroloxus lacustris*	*Galba truncatula*	*Radix labiata*	*Bithynia pseudemmericia*	*Bithynia tentaculata*	*Physella acuta*	*Pisidium casertanum*	*Pisidium lilljeborgii*
DO	0.932*	0.968*	0.314	0.365	0.257	0.024	0.387	0.420	0.521
PH	0.827	0.827	0.598	0.586	0.615	0.814	0.753	0.364	0.893
T	0.956	0.977	0.895*	0.996*	0.985*	0.955*	0.983*	0.843	0.913
Ca^{+2}	0.898*	0.968*	0.983*	0.998*	0.968*	0.929*	0.991*	0.960*	0.648
NO_2^--N	0.573	0.866	-0.645	-0.737	0.866	0.705	0.844	0.917	0.113
NO_3^--N	-0.898	-0.585	-0.694	-0.972	-0.495	-0.897	-0.687	-0.989	-0.683

Table 4. The results of canonical correspondence analysis.

	Axis 1	**Axis 2**	**Axis 3**	**Axis 4**	**Total inertia**
Eigenvalues	0.186	0.176	0.215	0.311	4.983
Total value %	18.893	31.897	26.012	23.198	
Cumulative percentage variance of species data	21.47	50.836	44.105	10.251	
species–environment correlations	0.889	0.929	0.512	0.321	
Sum of all eigenvalues					4.983
Sum of canonical eigenvalues					0.678

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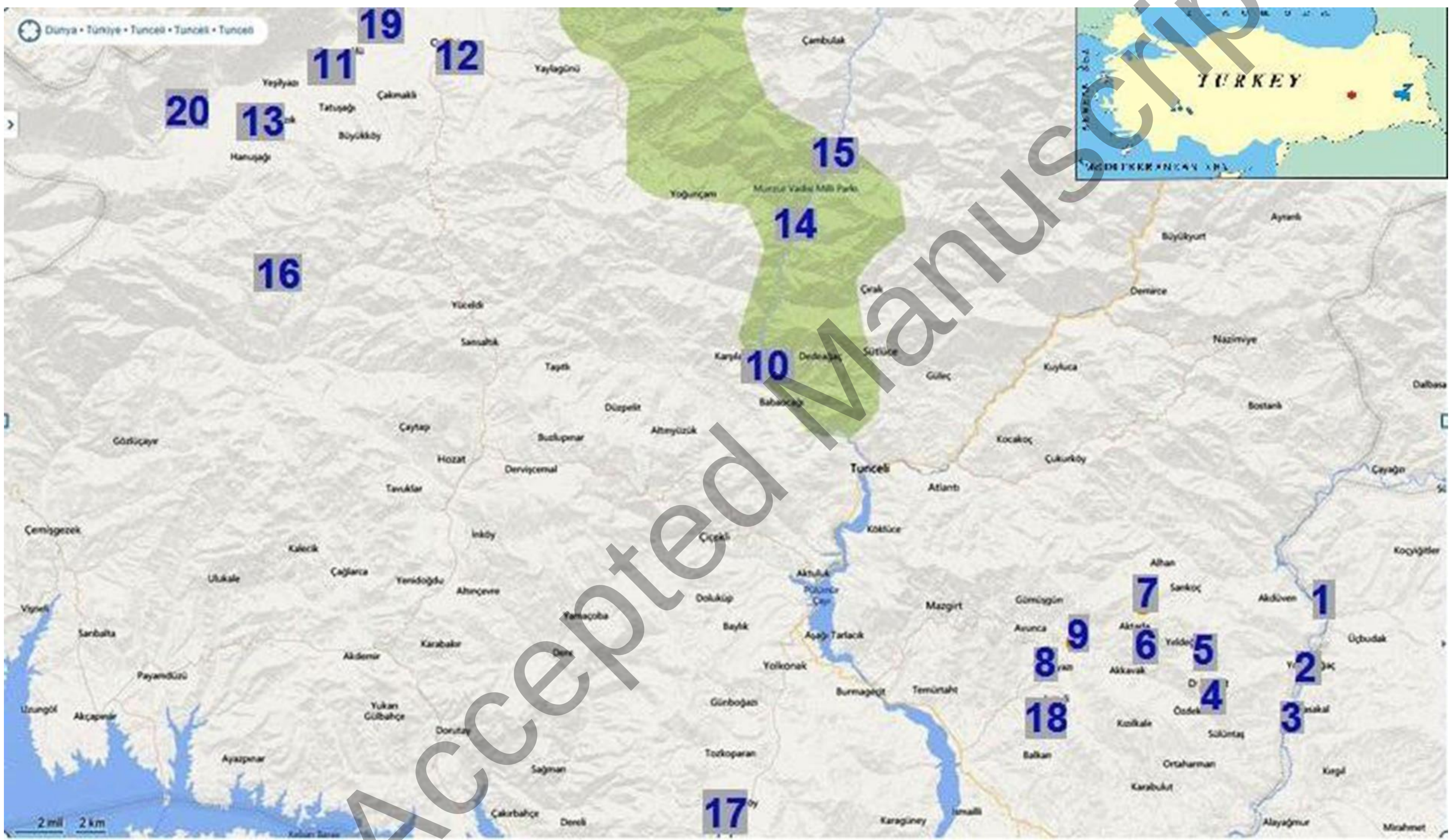

Figure 1. The map of study area

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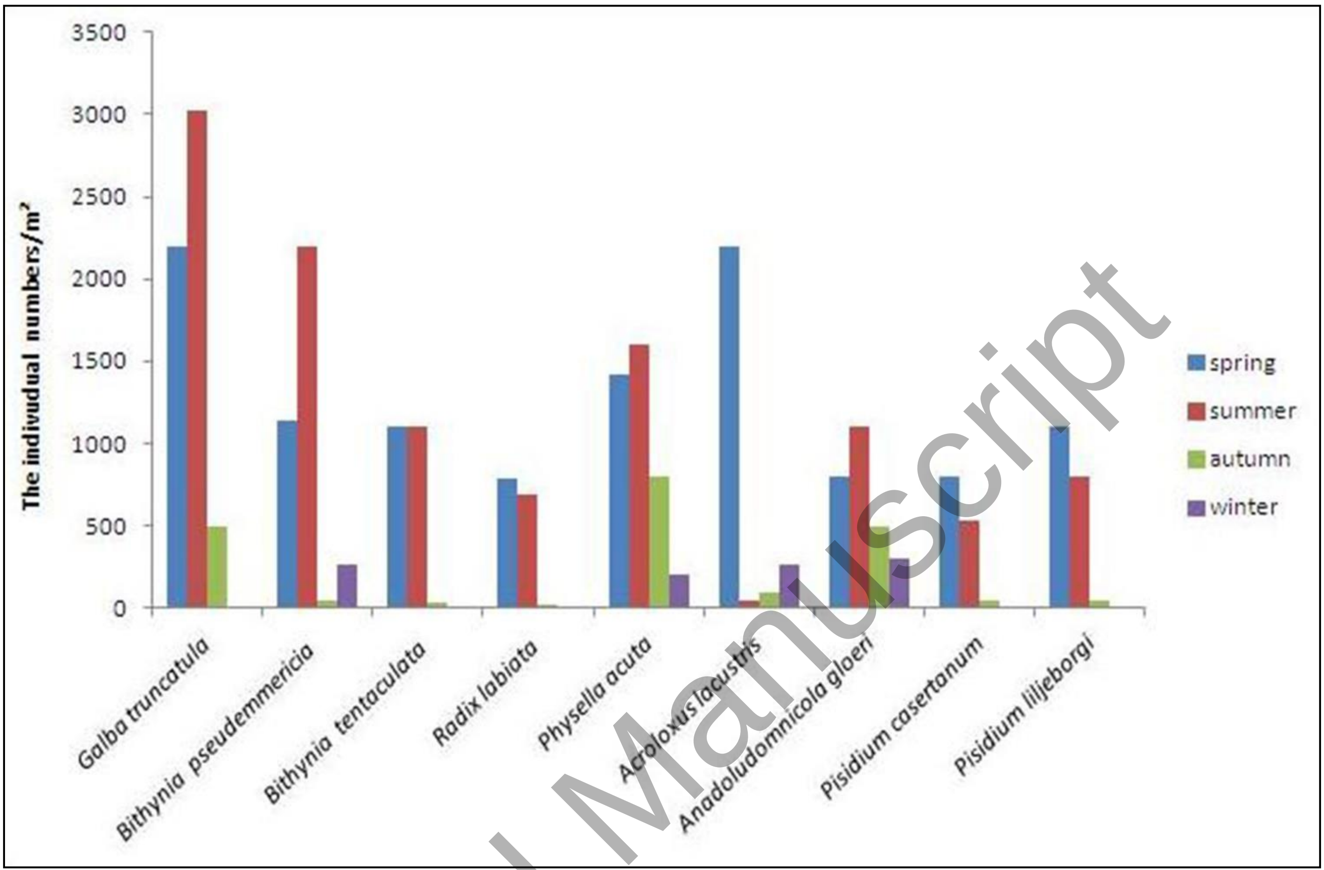

Figure 2. The seasonal density of species (ind.m^2)

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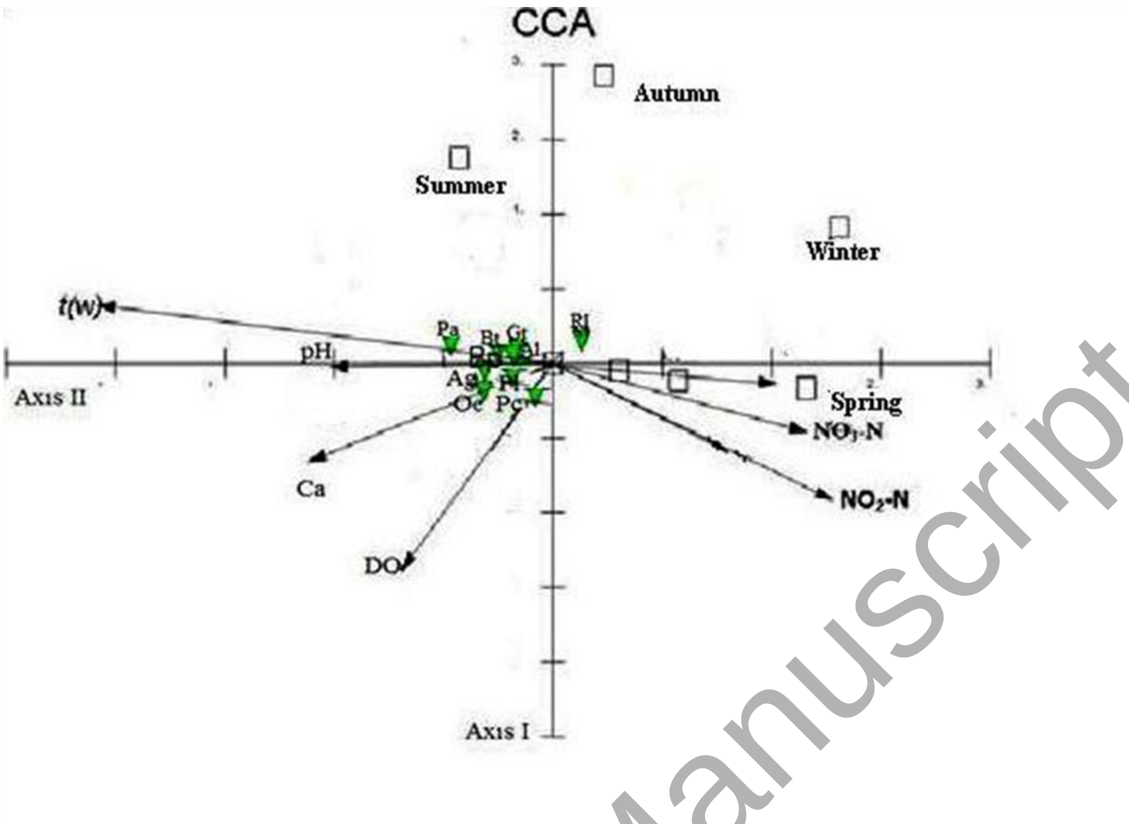

Figure 3. According to CCA, The relationships between Mollusc species and environmental parameters (*Bithynia pseudemmericia* (Bp), *Bithynia tentaculata* (Bt), *Anadoludamnicola glöeri* (Ag), (*Galba truncatula (Gt)*, *Radix labiata* (Rl), *Physella acuta* (Pa), *Acroloxus lacustris* (Al), *Pisidium casertanum* (Pc), *Pisidium lilljeborgii* (Pl), DO : Dissolved oxygen, Ca : Ca^{+2} ion, t : Water temperature, NO_2^--N : Nitrite nitrogen, NO_3^--N : Nitrate nitrogen.