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Species Composition and Distribution of Mollusca in Relation to Water Quality

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Abstract

Lake Eğirdir is an “A class wetland” according to international criteria and in terms of the protection of biological diversity. The lake connects to Lake Kovada via a regulator and channel system. Lake Kovada is one of the important Nature Conservation Areas in Turkey. In this study, the possibility of using Mollusca for assessment of water quality in lakes Eğirdir and Kovada, study-area water quality according to physico-chemical parameters, variety and distribution of Mollusca, and ecological aspects were investigated from July 2010 to June 2011. Mollusk fauna in the working field was represented by 11 taxa of Gastropoda and 2 taxa of Bivalvia. *Radix auricularia* at E1 station; *Theodoxus heldreichi heldreichi, Falsipyrgula pfeiferi, Radix labiata, Planorbis planorbis* and *Hippeutis complanatus* at E2 station; *Gyraulus albus* at K1 station; *Physella acuta* at K2 station; *Bithynia pseudemmericia* and *Graecoanatolica lacustristurca* at E3 station; *Borysthenia naticina* at C3 station and *Pisidium casertanum* at C2 station reached to the highest dominance. Water quality was determined using by physicochemical parameters. Three different classes of water quality were determined. Based on the assessments, the stations on Lake Eğirdir (E1, E2, E3) were unpolluted, those on Kovada channel (C1, C2, C3) moderately polluted, while those on Lake Kovada (K1, K2, K3) slightly polluted. The relationships between the total number of individuals and environmental measurements were determined by Pearson correlation index. The results of analysis suggest a significant correlation between the total number of individuals and some environmental measurements such as dissolved oxygen, pH, total hardness, anions and cations. Additionally, *Hippeutis complanatus* was firstly recorded from the Lake Eğirdir.

Keywords: Environmental parameters, Lake Eğirdir, Lake Kovada.

Mollusca Türlerinin Su Kalitesine Bağlı Olarak Dağılımı ve Kompozisyonu

Özet

Uluslararası kriterlere göre A sınıfı sulak alan olarak kabul edilen Eğirdir Gölü, bir regülatör ve kanal sistemi ile Kovada Gölü’ne bağlanır. Kovada Gölü, Türkiye’nin önemli doğa koruma alanlarından biridir. Temmuz 2010-Haziran 2011 tarihleri arasında gerçekleştirilen bu çalışmada, Eğirdir ve Kovada Gölleri ile Kovada kanalının su kalitesi fizikokimyasal parametreler kullanılarak belirlenmiş, su kalitesini belirlemede Mollusklarin kullanılabilirliği araştırılmıştır. Ayrıca bu canlıların ekolojik özellikleri, dağılım ve çeşitlilikleri incelenmiştir. Çalışma sonunda 11’i Gastropoda ve 2’si Bivalvia sınıflarına ait olmak üzere 11 takson tespit edilmiştir. *Radix auricularia* E1 istasyonunda; *Theodoxus heldreichi heldreichi, Falsipyrgula pfeiferi, Radix labiata, Planorbis planorbis* ve *Hippeutis complanatus* E2 istasyonunda; *Gyraulus albus* K1 istasyonunda; *Physella acuta* K2 istasyonunda; *Bithynia pseudemmericia* ve *Graecoanatolica lacustristurca* E3 istasyonunda; *Borysthenia naticina* C3, *Pisidium casertanum* ise C2 istasyonunda en yüksek baskınlığına ulaşmıştır. Fizikokimyasal parametrelere göre 3 farklı su kalitesi sınıfı belirlenmiş, Eğirdir Gölü (E1, E2, E3) kirlenmemiş, Kovada kanalı (C1, C2, C3) orta derecede kirlenmiş, Kovada Gölü (K1, K2, K3) ise az kirlenmiş olarak tespit edilmiştir. Çevresel faktörler ile canlılar arasındaki ilişki Pearson korelasyon indeksi kullanılarak belirlenmiştir. Analiz sonuçları, bireylerin toplam sayısı ile bazı çevresel faktörler (çözünmüş oksijen, pH, toplam sertlik, anyonlar ve katyonlar gibi) arasında önemli korelasyon olduğunu göstermiştir. Ayrıca çalışmada tespit edilen *Hippeutis complanatus* Eğirdir Gölü için yeni kayıt niteliğindedir.

Anahtar Kelimeler: Çevresel faktörler, Eğirdir Gölü, Kovada Gölü.

Introduction

Lakes and rivers have important multi-usage components, such as sources of drinking water, irrigation, fishery and energy production. These considerably depend on water quality and thus water quality should be kept at a certain level. The pollution of surface water with toxic chemicals and the eutrophication of rivers and lakes with excess nutrients are areas of great environmental concern worldwide. Agricultural, industrial and urban activities are considered to be major sources of the addition of chemicals and nutrients to aquatic ecosystems. Concentrations of toxic chemicals and biologically available nutrients in excess can lead to such diverse problems as toxic algal blooms, loss of oxygen, fish kills, loss of biodiversity, and loss of aquatic plants beds and coal reefs (Ouyang *et al*., 2006; İscen *et al*., 2008).

In the determining of water quality should be assessed by the use of physical, chemical and biological parameters in order to provide a complete spectrum of information (Rosenberg and Resh, 1993). Benthic macroinvertebrates constitute an important part of aquatic organisms in aquatic environments. The aquatic organisms are exposed to anthropogenic disturbance as well as natural changes in their habitats which are to be responded in various ways. Therefore, aquatic organisms also have an important role in biomonitoring (Rosenberg and Resh, 1993; Mooraki *et al*., 2009). Benthic macroinvertebrates are currently used in lake monitoring and diferent indexes were proposed to assess the ecological status of lentic ecosystems (Wiederholm, 1980). Gastropoda and Bivalvia are likely to be a common group of macrobenthic fauna in aquatic ecosystems. Molluscs occupy a prominent place among aquatic organisms suitable for biological monitoring (Goldberg, 1986; Salánki, 1989). They react strongly to environmental changes. This makes them suitable for studies of the relationship between organisms and environment (Ustaoğlu *et al*., 2001). The distribution of freshwater snails depend on water quality, e.g. pH, DO, calcium etc. and temperature. It has been reported that the toxicity of most substances is influenced by such factors as temperature, turbidity, DO, pH, CO_2 and water hardness (Okland, 1969; Williams, 1970). Researchers have studied the ecology of different groups of invertebrates, little information is available about the ecology of aquatic gastropods in inland water bodies of Turkey (Çabuk *et al*., 2004; Kalyoncu *et al*., 2008; Kalyoncu and Yıldırım, 2009). In this study, Mollusca fauna were determined in Lakes of Eğirdir, Kovada and Kovada Channel which have qualitatively and quantitatively rich malacofauna.

Materials and Methods

Description of Study Area

Lake Eğirdir has a tectonic origin and is 929 m above sea level. It is located at latitude 38°15′ N and longitude 30°52′ E in The Lake District, southwest Turkey (Figure 1). It has a surface area of approximately 482 km^2 and maximum depth of the lake ranges from 9 m to15 m. Northern part of the lake is also called as Lake Hoyran. Main water sources of the lake are under ground springs, small streams and rain waters. Especially, most of the streams (e.g. Pupa Stream, Aksu Stream) transport domestic, agricultural and industrial wastes to the lake. Lake Eğirdir is the fourth largest lake in surface area size (48,800 ha) in Turkey. It is located in the southwestern part of Turkey (40°10'N, 28°35'E) at an

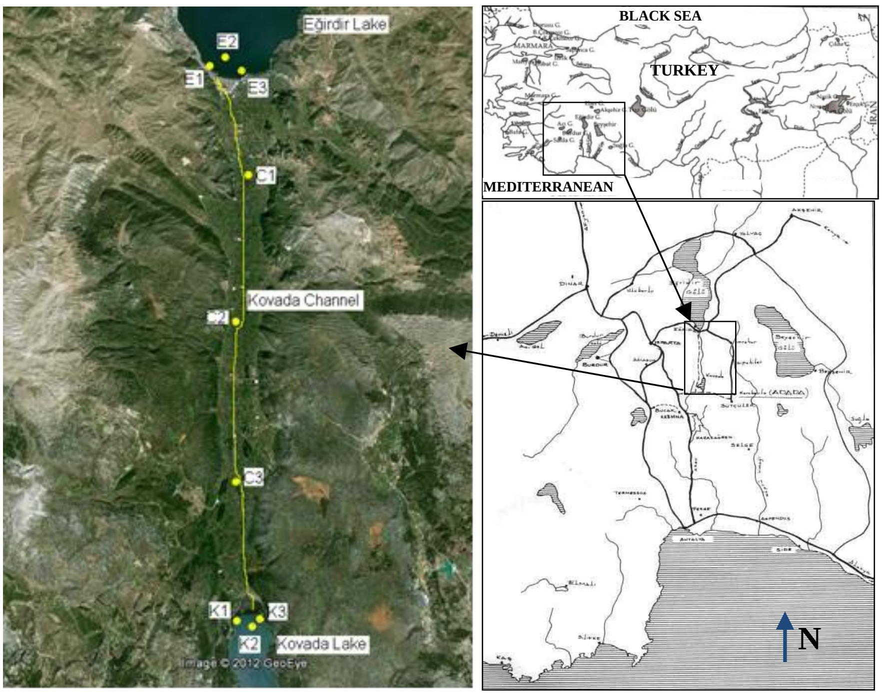

Figure 1. Study area and stations.

altitude of 918 m above sea level, and is a mesotrophic lake of tectonic origin (Zeybek, 2012). Lake is fed by three major streams (which largely dry up in summer) and a number of springs. Lake water is used for irrigation and as drinking water for Isparta and Eğirdir. The only outlet is in the south where water flows the Kovada Lake (Magnin and Yarar, 1997). Lake Eğirdir connects to Lake Kovada via a regulator and channel system and water of the lake flows to the Lake Kovada. Because of domestic, agricultural and industrial wastes and the purified wastewater is discharged into the Kovada channel, the stations on the Kovada Channel were under pressure of organic and inorganic pollution (Anonymous, 2010).

Lake Kovada is one of the important national parks in Turkey. It is a continuation of Lake Eğirdir to the south, was formed through the blocking of the narrow valley over a long time. Lake Kovada, lying to the east of Isparta and to the south of Lake Eğirdir, is the result of the overflowing of Lake Eğirdir. There are known to be Karstic patterns between both of these lakes, as well as all around Lake Kovada. The deepest part of the lake is about 7 m. It is located at an altitude of 900 m and has a 40 km^2 surface area. The length of the lake is roughly 9 km and the average width is about 2-3 km (Magnin *et al*., 2000). Sampling was carried out at 9 stations, the locations of which are shown in the Figure 1, from July 2009 to June 2010.

Sampling of Mollusca and Physical and Chemical Analysis

Physical and Chemical Analysis

Water samples for chemical analyses were collected monthly from each station, using prewashed polyethylene bottles. All samples were analyzed within 24 hours after collection. Water temperature, pH, dissolved oxygen (DO) and conductivity were measured during sampling in the field. Mg^{+2}, Ca^{+2}, Cl^-, NH_4^+-N, NO_2^--N, NO_3^--N, PO_4^--P, ∑P, COD, BOD and total hardness determined in the laboratory according to Standard methods (Anonymous, 1988). Classification of water quality was performed according to Klee (1991) and Turkish Water Pollution Control Regulation (SKKY, 2008).

Samping of Mollusca

Samples were collected per site monthly (July 2010-June 2011) from 9 stations on study area. The gastropods and bivalves were caught by an Ekman-Birge grab and the sediments were sieved using a sieve-mesh of 0.5 mm. Two hauls of bottom sediment were taken from each sampling site with an Ekman-Birge grab, which covered a surface area of 225 cm^2. Only living organisms were considered. The materials were preserved in 70% ethyl alcohol. In the laboratory, they were identified and counted under a 10x magnification binoculer microscope. Samples were identified to species level using taxonomic keys (Schütt, 1964;1965; Geldiay and Bilgin, 1969; Macan, 1977; Bilgin, 1980; Schütt and Şeşen, 1989; Yıldırım, 1999; 2004). All collected materials were kept in the Hydrobiology Laboratory of Art and Sciences Faculty, Süleyman Demirel University. Dominance and frequency were used for the numerical analysis. Correlations between environmental parameters and mollusca were determined by Pearson's correlation coefficients.

Results and Discussions

According to physical and chemical parameters, three different water quality levels were observed in the study area. E1, E2 and E3 stations were unpolluted or slightly polluted, C1, C2 and C3 moderately polluted, K1, K2 and K3 slightly polluted according to Klee (1991) and SKKY (2008). According to physicochemical parameters, the results obtained seem to support each other. Because of domestic, agricultural and industrial wastes and the purified wastewater is discharged into the Kovada channel, the stations on the Kovada channel were under pressure of organic and inorganic pollution (Anonymous, 2010). So, most of the physicochemical parameters were recorded to be high relatively other stations (Table 1).

In the present of Mollusca were identified, 11 taxa belonging to Gastropoda and 2 taxa belonging to Bivalvia. *Dreissena polymorpha anatolica* (Bourguignat, 1884) was determined as only valva. So, they were not evaluated in relation to water quality. A total of 17305 in per square meter (ind.m^{-2}) mollusca species were collected in this study. The dominant species of the mollusca community in the study area are shown in Table 2. Of the gastropods, *T.h. heldreichi* (Martens 1879), *B. naticina* (Menke 1845), *G. lacustristurca* Radoman 1973, *F. pfeiferi* (Weber, 1927), *B. pseudemmericia (*Schütt 1964) are belonging to Prosobranchia; while *R. auricularia* (Linnaeus 1758), *R. labiata* (O. F. Müller 1774), *H. complanatus* (Linnaeus 1758), *G. albus* (O. F. Müller 1774), *P. planorbis* (Linnaeus, 1758), *P. acuta* (Draparnaud, 1805) to order Pulmonata. *P. casertanum* (Poli 1791) to Sphaeriidae and *D. polymorpha anatolica* (Bourguignat 1884) to Dreissenidae family of Bivalvia.

The mean densities of Mollusca at nine sampling sites were differed from each other. The highest mean densities of Mollusca were observed at E1, E3 and E2 stations (Table 3). The most abundant species in the sampling area through out the study period were *B. naticina*, *G. albus* and *P. acuta*.

Temperature ranged between 3.6-27.1°C, and no significant correlation with mollusca species in this study area. *B. pseudemmericia*, *F. pfeiferi*, *H. complanatus*, *R. auricularia* were positively

Table 1. Average values of water quality parameters and classes corresponding to levels (Average±SE; min-max)

Parameter	E1	E2	E3	C1	C2	C3	K1	K2	K3
Temp. (°C)	15.9±2.38	15.8±2.34	15.8±2.34	16.2±2.08	16.2±2.13	16.3±2.16	15.2±2.13	15.2±2.09	15.3±2.12
	4.5-27.1	4.5-26.7	4.7-26.7	6.3-25.1	6.3-25.6	5.9-25.3	3.6-24.4	3.7-23.9	3.9-24.1
DO (mg/L)	7.80±0.28	7.58±0.28	7.54±0.23	3.87±0.26	4.59±0.30	5.23±0.33	7.61±0.21	8.18±0.39	7.96±0.21
	6.76-9.5	6.1-8.98	6.5-8.79	2.63-4.80	3.27-6.8	3.92-7.3	6.57-8.66	7.09-11.38	7.19-9.15
pH	8.87±0.11	9.07±0.12	9.2±0.14	8.41±0.12	8.49±0.15	8.56±0.13	8.72±0.14	8.88±0.14	8.65±0.15
	8.3-9.66	8.51-9.71	8.6-9.95	7.62-9.10	7.98-9.3	7.97-9.23	7.72-9.58	8.26-9.60	7.9-9.46
EC (µS/cm)	309.3±8.61	312.0±9.47	310.8±8.76	428.7±26.20	386.0±5.18	378.1±9.47	259.4±5.89	250.8±8.55	264.5±6.63
	261.7-343.7	261.7-357.5	261.1-345.9	363.9-644	359.0-422.5	322.1-422.7	230.6-290.2	204.9-290.4	231.1-291.8
Ca^{++} (mg/L)	28.37±1.41	28.38±1.75	28.3±1.18	53.11±5.77	52.58±4.34	51.47±4.60	31.59±2.64	29.34±3.09	31.92±2.69
	23.56-40.64	23.24-44.20	24.54-38.44	26.75-87.28	28.24-68.57	28.41-67.55	16.46-42.07	16.22-43.11	15.87-43.73
Mg^{++} (mg/L)	31.93±0.30	32.04±0.27	31.86±0.27	29.20±1.19	27.41±1.62	26.94±1.52	19.98±0.54	19.60±0.62	20.63±0.65
	30.32-33.46	30.92-34.07	30.75-33.2	19.00-32.22	18.40-32.14	18.90-33.18	17.46-23.96	15.76-23.49	18.26-24.66
Cl^- (mg/L)	8.42±0.53	8.47±0.90	8.01±0.48	13.75±0.99	12.11±0.69	11.15±0.64	7.75±0.41	8.27±0.49	8.13±0.49
	6.33-11.80	5.80-16.30	6.38-11.2	7.62-18.00	7.89-16.30	8.34-14.60	6.08-10.70	6.15-11.20	6.12-12.10
NH_4-N (mg/L)	0.08±0.01	0.09±0.01	0.06±0.01	1.20±0.31	0.92±0.21	0.77±0.17	0.13±0.02	0.13±0.02	0.13±0.02
	UDL-0.13	UDL-0.18	UDL-0.11	0.17-3.00	0.17-2.09	0.10-1.53	0.07-0.23	0.06-0.28	UDL-0.22
NO_2-N (mg/L)	UDL*	UDL *	UDL *	0.02±0.01	0.02±0.00	0.03±0.01	0.01±0.00	UDL *	0.01±0.00
				UDL-0.07	UDL-0.05	UDL-0.05	UDL-0.02		UDL-0.02
NO_3-N (mg/L)	1.15±0.12	1.22±0.13	1.28±0.19	1.95±0.73	1.47±0.40	1.55±0.29	1.16±0.12	1.25±0.17	1.22±0.15
	UDL-2.10	UDL-2.10	UDL-2.6	UDL-9.20	UDL-5.40	UDL-4.20	UDL-2.20	UDL-2.80	UDL-2.30
PO_4-P (mg/L)	0.05±0.01	0.06±0.02	0.05±0.00	0.33±0.10	0.19±0.04	0.24±0.12	0.11±0.03	0.16±0.06	0.29±0.21
	UDL-0.10	UDL-0.22	UDL-0.05	UDL-0.99	UDL-0.45	UDL-1.42	UDL -0.37	UDL -0.73	UDL-2.42
∑P (mg/L)	0.06±0.01	0.07±0.01	0.06±0.02	0.44±0.11	0.28±0.04	0.29±0.13	0.13±0.04	0.13±0.03	0.32±0.21
	UDL-0.10	UDL-0.15	UDL-0.21	0.05-1.07	0.12-0.57	0.09-1.54	UDL-0.42	UDL-0.31	UDL-2.45
COD (mg/L)	21.27±2.04	25.09±2.37	20.18±2.28	32.36±3.25	25.64±2.26	21.91±3.15	23.64±2.59	26.45±3.86	22.27±2.80
	10.0-36.0	13.0-41.0	10.0-30.0	10.0-42.0	10.0-38.0	10.0-39.0	13.0-41.0	10.0-52.0	10.0-43.0
BOD (mg/L)	1.64±0.31	1.55±0.25	1.36±0.24	3.45±0.79	2.73±0.54	3.00±0.43	2.45±0.41	2.36±0.24	2.18±0.30
	1.0-4.0	1.0-3.0	1.0-3.0	1.0-9.0	1.0-7.0	1.0-5.0	1.0-5.0	2.0-4.0	1.0-4.0
TH (°dH)	12.00±0.21	12.37±0.20	12.00±0.16	15.76±0.84	14.66±0.55	14.75±0.58	9.71±0.53	9.26±0.63	9.90±0.47
	11.09-13.10	11.09-13.10	11.09-13.10	12.10-20.16	12.10-17.14	12.10-18.14	7.06-12.10	6.05-12.10	7.06-12.10
Water Quality Classes: SKKY (2008)	II-slightly polluted			III-polluted			II-slightly polluted		
Water Quality Classes: Klee (1990)	I-oligosaprob			II-betamesosaprob			I-II oligo/betamesosaprob		

*The measured values for all analysis are under the limits of analysis (UDL: under the limits of analysis)

Table 2. Dominancy of Mollusca species in stations

	Taxa	STATIONS								
		E1	E2	E3	C1	C2	C3	K1	K2	K3
Gastropoda	Prosobranchia									
	Neritinimorpha									
	Theodoxus h.heldreichi (Martens 1879)	6.19	6.80	6.62	4.54	3.70	3.85	-	-	3.22
	Caenogastropoda									
	Bithynia pseudemmericia Schütt 1964	14.2	11.5	14.5	-	3.70	-	-	-	8.06
	G. lacustristurca Radoman 1973	10.9	8.16	16.5	-	7.40	12.82	-	-	-
	Neotaenioglossa									
	Falsipyrgula pfeiferi (Weber 1927)	12.8	13.6	11.9	-	-	1.28	-	-	4.83
	Allogastropoda									
	Borysthenia naticina (Menke 1845)	13.8	11.5	11.2	22.72	31.48	34.62	30.7	9.6	19.35
	Pulmonata									
	Radix auricularia (Linnaeus 1758)	15.7	10.2	10.6	4.54	-	1.28	-	-	1.61
	Radix labiata (O. F. Müller 1774)	6.67	6.80	5.30	-	-	-	-	3.23	-
	Physella acuta (Draparnaud 1805)	1.90	4.76	4.64	40.90	31.48	20.23	19.2	51.6	30.64
	Planorbis planorbis (Linnaeus 1758)	2.86	3.40	0.66	-	1.85	1.28	-	-	-
	Gyraulus albus (O. F. Müller 1774)	2.38	7.48	4.64	27.27	12.96	25.64	50.0	35.4	32.25
	Hippeutis complanatus (Linnaeus 1758)	11.4	14.9	11.9	-	-	-	-	-	-
Bivalvia	Sphaeriidae									
	Pisidium casertanum (Poli 1791)	0.95	0.68	1.32	-	7.40	1.28	-	-	-

correlated with DO values (P<0.01). *B. pseudemmericia*, *G. lacustristurca*, *F. pfeiferi*, *H. complanatus*, *R. auricularia* (P<0.01) and *T.h. heldreichi* (P<0.05) were positively correlated with pH values. *B. pseudemmericia*, *F. pfeiferi R. auricularia*, *R. labiata* and *H. complanatus* were negatively correlated with Ca^{+2} values (P<0.01). All taxa, except *P. acuta* and *P. casertanum*, evidenced correlations with Mg^{+2}, only *Gyraulus albus* was negatively correlated (P<0.05). *F. pfeiferi*, *R. auricularia*, *R. labiata*, *H. complanatus* were negatively correlated with Cl^-, NH_4^+-N, NO_2^--N values. *R. auricularia*, *R. labiata*, *H. complanatus*, were negatively correlated with PO_4^- -P values

Table 3. Mean density of individuals (ind. m^{-2}) of Mollusca samples in the study area

Station	Mean density of total Mollusca (ind. m^{-2})	*T.h. heldreichi*	*B. pseudemmericia*	*F. pfeiferi*	*G. lacustristurca*	*B. naticina*	*R..auricularia*	*R.. labiata*	*P. acuta*	*P. planorbis*	*G.albus*	*H. complanatus*	*P. casertanum*
E1	4662	288	666	600	511	644	733	311	88	133	111	533	44
E2	3261	222	377	444	266	377	333	222	155	111	244	488	22
E3	3350	222	488	400.	555	377	355	177	155	22	155	400	44
C1	488	22	-	-	-	111	22	-	200	-	133	-	-
C	1175	44	44	-	88	377	-	-	377	2	155	-	88
C3	1731	66	-	22	222	600	22	-	311	22	444	-	22
K1	576	-	-	-	-	177	-	-	111	-	288	-	-
K2	687	-	-	-	-	66	-	22	355	-	244	-	-
K3	1375	44	111	66	-	266	22	-	422	-	444	-	-
Total	17305	908	1686	1532	1642	2995	1487	732	2174	290	2218	1421	220

($P<0.05$). *F. pfeiferi, Radix auricularia* ($P<0.01$), *R. labiata, H. complanatus* ($P<0.05$) were negatively correlated ∑P values. *B. pseudemmericia, F. pfeiferi R. labiata* and *H. complanatus,* were negatively correlated with COD values ($P<0.05$). *F. pfeiferi, B. pseudemmericia, R. auricularia, H. complanatus,* ($P<0.01$) and *G. lacustristurca, R. labiata* ($P<0.05$) were negatively correlated with BOD values. Water hardness showed a significant positive correlation with only *T. h. heldreichi* ($P<0.05$) (Table 4).

Prosobranchs are often sensitive indicators of water quality because of widespread geographic distribution and obligate contact with aquatic environment (Aldridge, 1983; Duft *et al*., 2007). Dissolved oxygen levels of the water were a significant parameter for the abundance of especially Prosobranchia species (Hart and Fuller, 1974; Ertan *et al*., 1996; Yıldırım, 1999). Some Prosobranchia species could be found in waters also with low DO levels (Hart and Fuller, 1974). This information supported our result (Table 1 and Table 2).

The Palearctic genus *Theodoxus* lives in running waters of turbulent ecosystems includes taxa living in springs, rivers, lakes and even in low-salinity waters (Yıldırım *et al*., 2006b). They often live, in large groups, on the benthic zones of running or turbulent waters, on the solid banks and sometimes on the vegetation (Roth, 1987; Yıldırım, 1999; Yıldırım, 2004). *T. heldreichi heldreichi* is endemic to Lakes Beyşehir and Eğirdir (Kebapçı and Yıldırım, 2010). In our study, *Theodoxus* specimens were collected from the gravel and muddy bottom. *T. heldreichi heldreichi* showed positive correlation with pH, water hardness ($P<0.05$), and Mg^{+2} ($P<0.01$). The highest dominancy observed at E1, E2 and E3 stations (Table 2).

Bithynia is represented a Bithyniid genus of euryoecious characteristic (Hart and Fuller, 1974). Except for *B. tentaculata*, all *Bithynia* species are generally distributed in averagely polluted freshwater sections, and spring waters (Meyer, 1987). Members of the single genus *Bythinella* in Turkey are generally stenoecious species with limited distributions (Zhadin, 1952). *B. pseudemmericia* is endemic to Anatolia. In this study, *B. pseudemmericia* reached the highest frequency at unpolluted sites (E1, E2, E3), while the lowest frequency was observed of *B. pseudemmericia* at C2 and K3 stations. Also, they were not sampled at the C1, C3, K1, K2 stations (Table 5). *B. pseudemmericia* was negatively correlated with Ca^{+2}, NH_4^+-N, BOD ($P<0.01$) and NO_2^--N, COD ($P<0.05$).

Another prosobranch in the field, *F. pfeiferi* is a local endemic and its distribution matches the oligotrophic character of the species. Another species belonging to the same genus, *F. beysehirana*, lives in Lake Beyşehir. Both were previously regarded as subspecies by some researchers, though they have been considered allopatric species recently (Weber, 1927; Schütt, 1990; 1991; Yıldırım and Şeşen, 1994; Yıldırım 1999). In our study *F. pfeiferi* were frequently observed at the unpolluted stations (E1, E2, E3) (Table 5). Also, *F. pfeiferi* was positively correlated with DO, pH, Mg^{+2} ($P<0.01$), but was negatively correlated with Ca^{+2}, Cl^-, NH_4^+-N, NO_2^--N, BOD ($P<0.01$) and ∑P, COD ($P<0.05$).

As two Balkan species undergone extinction, all recent Graecoanatolicinae taxa are endemic to Lakes Region. Two Anatolian species, *G. conica* and *G. brevis*, have also gone extinct. Remaining taxa are distributed in the provinces Denizli, Burdur, Afyonkarahisar, Isparta, and Antalya (Schütt, 1964; 1990; Radoman, 1973; Yıldırım and Schütt, 1996). *G. lacustristurca* was positively correlated with pH, Mg^{+2} ($P<0.01$) and DO ($P<0.05$) while negatively correlated with BOD ($P<0.05$). Especially, *G. lacustristurca* intensely found unpolluted stations (E1, E2, E3).

T. heldreichi heldreichi and *G. lacustristurca* are endemic to Lakes Eğirdir and Beyşehir, while *F. pfeiferi* only to Lake Eğirdir. However, we found them also in Lake Kovada and its channel. We think that these species were dragged to Lake Kovada with

Table 4. Correlation between Mollusca species and water quality parameters

	°C	DO	pH	EC	Ca^{++}	Mg^{++}	Cl^{-}	NH_4-N	NO_2-N	NO_3-N	PO_4-P	∑P	COD	BOD	TH
T.h. heldreichi	NS	NS	.222*	NS	NS	.323**	NS	NS	NS	NS	NS	NS	NS	NS	.213*
B. pseudemmercia	NS	.269**	.299**	NS	-.312**	.458**	NS	-.274**	-.202*	NS	NS	NS	-.242*	-.272**	NS
F. feifferi	NS	.345**	.353**	NS	-.357**	.532**	-.301**	-.321**	-.259**	NS	NS	-.199*	-.214*	-.274**	NS
G. lacustriturca	NS	.220*	.290**	NS	NS	.382**	NS	NS	NS	NS	NS	NS	NS	-.239*	NS
B. naticina	NS	NS	NS	NS	NS	.236*	NS	NS	NS	NS	NS	NS	NS	NS	NS
R. auricularia	NS	.320**	.271**	NS	-.329**	.523**	-.288**	-.297**	-.241*	NS	-.238*	-.264**	NS	-.288**	NS
R. labiata	NS	.209*	NS	NS	-.282**	.445**	-.236*	-.282**	-.215*	NS	-.207*	-.252*	-.203*	-.201*	NS
H. complanatus	NS	.356**	.363**	NS	-.338**	.532**	-.235*	-.295**	-.231*	NS	-.222*	-.252*	-.204*	-.348**	NS
G. albus	NS	NS	NS	NS	NS	-.207*	NS	NS	NS	NS	NS	NS	NS	NS	NS
P. planorbis	NS	NS	NS	NS	NS	.227*	NS	NS	NS	NS	NS	NS	NS	NS	NS
P. acuta	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P. casertanum	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

**. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed) N: 108; NS: Not significant

Table 5. Frequency levels for each station (%)

	Taxa	Frequency levels for each station (%)								
		E1	E2	E3	C1	C2	C3	K1	K2	K3
Gastropoda	Prosobranchia									
	Neritinimorpha									
	Theodoxus h. heldreichi	91.67	91.67	66.67	8.33	16.67	25.00	-	-	16.67
	Caenogastropoda									
	Bithynia pseudemmericia	91.67	91.67	100.00	-	8.33	-	-	-	8.33
	G. lacustristurca	91.67	83.33	100.00	-	16.67	41.67	-	-	-
	Neotaenioglossa									
	Falsipyrgula pfeiferi	91.67	91.67	100.00	-	-	8.33	-	-	16.67
	Allogastropoda									
	Borysthenia naticina	83.33	83.33	83.33	33.33	58.33	91.67	25.00	33.33	33.33
	Pulmonata									
	Radix auricularia	100.00	91.67	100.00	8.33	-	8.33	-	-	8.33
	Radix labiata	83.33	83.33	66.67	-	-	-	-	8.33	-
	Hippeutis complanatus	83.33	91.67	91.67	-	-	-	-	-	-
	Gyraulus albus	25.00	66.67	50.00	25.00	33.33	41.67	50.00	66.67	66.67
	Planorbis planorbis	41.67	16.67	8.33	-	8.33	8.33	-	-	-
	Physella acuta	33.33	16.67	41.67	41.67	66.67	83.33	25.00	83.33	66.67
Bivalvia	Sphaeriidae									
	Pisidium casertanum	16.67	8.33	16.67	-	33.33	8.33	-	-	-

flow.

*B. naticina***,** has Pontic-Baltic distribution in lakes (Glöer, 2002) and its distribution in Turkey includes the Mediterranean (Yıldırım, 1999). *B. naticina showed a significant correlation with only* Mg^{+2} (P<0.05). In this study, it determined at all stations of Lakes Eğirdir, Kovada and Kovada Channel.

Pulmonata species normally belong to eurytopic species spreading especially on shallow and muddy bottoms (Hart and Fuller, 1974; Ertan *et al*., 1996). They are widely distributed in different aquatic systems, even those with high trophic content (Zhadin, 1965; Hart and Fuller, 1974). The Pulmonate fauna of Turkey, under these paleozoogeographic conditions, have an ordinary composition. Owing to this, their distribution in Turkey can be evaluated in consideration of these ordinary dimensions (Yıldırım *et al*., 2006a).

R. auricularia and *R. labiata* is common in Europe, northern Africa, as well as central, northern and eastern Asia (Zhadin, 1965; Schütt, 1993; Glöer and Meier-Brook, 1998; Pfleger, 1999), and in Turkey, except southeast of Turkey (Yıldırım *et al*., 2006a). In this study, the highest abundance of *R. auricularia* and *R. labiata* were found unpolluted sites (E1, E2, E3). This species were found only one time at the C1, C3, K2 and K3 stations.

According to Capitulo *et al*. (2001), the family Physidae is very tolerant to pollution. *P. acuta* in most studies has been shown as an indicator of organic pollution to critical degrees (Meyer, 1987; Gallordo *et al*., 1994; Ertan *et al*., 1996; Çabuk *et al*., 2004; Kalyoncu and Yıldırım, 2009). In this study, although it was found in all quality classes, the lowest abundance was in unpolluted parts (E1, E2, E3).

P. planorbis is a widespread species and does not have zoogeographic importance, there is a linear balance between high trophic levels of a lake and abundance of the species (Zhadin, 1965; Hart and Fuller, 1974). In this study, *P. planorbis* showed positive correlation with Mg^{+2} values (P<0.05). Also, It wasn't determined at the K1, K2, K3 and C1 stations.

G. albus is known to be a widespread and euryoecious species (Ertan *et al*., 1996; Yıldırım and

Karaşahin, 2004; Yıldırım *et al*., 2006a). Çabuk *et al*. (2004) and Gallordo *et al*. (1994) determined *G. albus* in polluted waters. In this study, *G. albus* was found at all stations.

According to Çabuk *et al*. (2004) and Kalyoncu *et al*. (2009), *G. albus* and *P. acuta* are the most tolerant taxon and can be found in all the determined water quality classes. Our findings support this knowledge. In this study, *G. albus, P. acuta* and addiatonally *B. naticina was observed in all the stations.*

H. complanatus was found only at stations of Lake Eğirdir (E1, E2, E3) and showed positive correlation with DO, pH, Mg, (P<0.01) and negative correlation with Ca^{+2}, NH_4^+-N, BOD (P<0.01), and Cl^-, NO_2^--N, PO_4^--P, ∑P, COD (P<0.05). *H. complanatus* reported from Turkey by some researchers (Ustaoğlu *et al*., 2001; Yıldırım *et al*., 2003, 2006a). The presence of *H. complanatus* in Lake Eğirdir was reported for the first time in this study.

P. casertanum belongs to Sphaeriidae. They are easily recognized by conchological characteristics. This clam lives in a wide variety of habitats, including ponds, swamps, creeks, and rivers (Herrington, 1962). According to Thorp and Covich (2001), this taxon, prefering mud biotopes but also can live in lakes and rivers. *P. casertanum* is one of the most widely distributed species of freshwater mollusca in the world. It is widely known from Palaearctic and Nearctic region including some parts of South America, Africa and Australia and Asia. It is a cosmopolitan and euryoecious species (Subba Rao, 1989; Ramakrishna and Dey, 2007). It reached to the highest abundance at C2 station. According to Meyer (1987), *Pisidium* genus predominantly located in areas with oligo/ betamesosaprobic water quality. In the present study,it was the most dominant in betamesosaprobic area (C2 station) (Table 2).

Conclusions

Molluscs are used to biological evaluation of the quality of freshwaters in Europe for many years. However, similar studies are very limited number in Turkey. In this study, the possibility of using Mollusca for assessment of water quality in Turkish freshwaters, working-area water quality according to physico-chemical parameters, variety and distribution of Mollusca, and ecological aspects were investigated. According to the results obtained in this study, there is hormony between the distribution of Mollusca and water quality. *T. heldreichi heldreichi* and *G. lacustriturca* are endemic to Lakes Eğirdir and Beyşehir, while *F. pfeiferi* only to Lake Eğirdir. However, we found them also to live in Lake Kovada and its channel. We think that these species were dragged to Lake Kovada with a flow. On the other hand, the presence of *H. complanatus* in Lake Eğirdir was reported for the first time in this study. This study is important in providing some useful information can be used in a biotic index for Turkey in the future.

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