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RESEARCH PAPER

Freshwater Snails (Mollusca, Gastropoda) of the Kizilirmak Delta (Samsun, Türkiye)

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Abstract

The Kızılırmak Delta was declared as a Ramsar Site because of its location on the birds' migration routes and high exposure to anthropogenic pressures on the delta. There are recent comprehensive studies conducted to determine the trophic levels of the lakes in the delta, together with faunal studies to assess its biodiversity. However, there are limited preliminary studies on the freshwater snail fauna. In this study, we determined 15 species, including two from Neritimorpha, three from Caenogastropoda, and ten from Heterobranchia, at 25 stations in the research area. *Gyraulus piscinarum* (N: 462) was abundant at most stations, while *Acroloxus lacustris* (N: 1) was determined at one station. We recorded *Armiger crista*, *G. piscinarum*, and *A. lacustris* for the first time from the study area and in the Black Sea Region. *Theodoxus major* and *Ecrobia maritima*, which are Ponto-Caspian species, are classified as "Data Deficient" (DD) according to International Union for the Conservation of Nature (IUCN) Red List of Threatened Species Data (2022). In addition, the populations of *Valvata macrostoma* (LC-Decreasing) are declining, and there is no information about the population status of *Ecrobia ventrosa* (LC), *Planorbis planorbis* (LC), and *G. piscinarum* (LC). Detailed fauna studies should be completed in our country urgently to determine the factors that threaten freshwater snails and to take the necessary protective measures. This is the first comprehensive study to determine the freshwater snail fauna of the Kızılırmak Delta to close the malacofaunal gap in the region.

Introduction

We can consider wetlands, which are the ecosystems with the most biodiversity after tropical areas, as "biological supermarkets" (Sandilyan et al., 2009). In addition to being areas where inorganic nutrients and primary production rates are high, they also have a regulatory function for the hydrological cycle, edaphic structure and climate. Unfortunately, climate change has wiped out many wetlands that support human life and its social, cultural and economic value in recent years. Wetlands are under intense anthropogenic pressure due to drying for agricultural or residential use, pollution from industry, agriculture and settlement, introduction of foreign fish species, overfishing, habitat destruction and management problems. Wetlands, which are both ecologically essential and economically important, must be protected and used rationally for sustainable development (World Wide Fund for Nature-Turkey, 2008).

Kızılırmak Delta is on the border of the provinces of Bafra, Alaçam and 19 Mayıs of Samsun. The delta of 6110 hectares is at sea level and consists of sea, river, lake, reeds, swamp, meadow, pasture, forest, dunes and agricultural areas. Due to ideal climate conditions, the delta has a rich biodiversity and high biological production rate, where different ecological habitats coexist. To the west of the Kızılırmak River, there are the Karaboğaz and Mülk Lakes; to the east, Balık, Uzun, Gıcı, Tatlı, Cernek, Liman, Alımlı, Paralı, Tuzlu and Sülüklü Lakes. The delta is located on an important bird migration route and is under human pressure through fishing, agriculture and livestock, tourism, hunting, grazing and reed farming activities. It was declared a Ramsar Site in 1998 (Republic of Türkiye-Ministry of Environment and Urbanization, 2019).

A large amount of nutrients in wetlands creates optimum habitat conditions for aquatic and terrestrial animals. Among these animals are molluscs, the most abundant group of invertebrates in the world, behind arthropods. Gastropods are in the Mollusca phylum, which includes more than half of all living mollusc species. They are adapted to living in all kinds of habitats (Demirsoy, 2005). Freshwater snails serve as ecosystem engineers because they feed on organic residues accumulated in the benthic zone. They are used in biological monitoring studies to determine heavy metal contamination and water quality as pollution indicators (Lee et al., 2002; Wadaan, 2005; Fortunato, 2015; Gümüş et al., 2022). Furthermore, their shells shelter them from predators, in addition to physical and physiological stress and form a substrate for epibiont organisms (Gutiérrez et al., 2003).

The study of freshwater snails in Anatolia began in Izmir with Roth (1839) and spread throughout the country with local and foreign researchers. These studies concentrated on the Mediterranean, the Aegean and the Marmara regions (Yıldırım, 1999; Yıldırım et al., 2006a, 2006b; Gürlek et al., 2019; Yıldırım ve Gürlek, 2019). Gözler and Baytaşoğlu (2020) studied the mollusc fauna of the Çoruh River in the eastern Black Sea region of the Black Sea. Other studies were preliminary studies (Gözler and Baytaşoğlu, 2020; Öktener, 2004; Özbek et al., 2004; Kabak et al., 2021; Yıldırım et al., 2022). This study is the first comprehensive study to determine the freshwater snails in the Kızılırmak Delta and aims to close the malacofaunistic gap in the region.

Materials and Methods

***Study area*:** Gastropod samples were collected from Balık Lake, Cernek Lake, Karaboğaz Lake, Liman Lake and Uzun Lake in the Kızılırmak Delta during field studies carried out on 18-21 September 2012. Table 1 includes information about the stations in the research area, and Figure 1 displays the locations of the stations.

Tablo 1. Station code, coordinates, depth and sediment structure of the stations in the research area

Lake Name	Station code	Coordinates	Depth (cm)	Sediment structure
Balık Lake	B1	41°35'56.6"N 36°05'59.3"E	180	Very sandy, gravelly, clayey, gray
	B2	41°36'06.3"N 36°05'09.7"E	190	Sandy, gravelly, silty, low clay, gray
	B3	41°34'31.6"N 36°04'19.5"E	185	Silty, clayey, gray
	B4	41°33'29.8"N 36°04'46.4"E	200	Very little silty, very clayey, dark gray
	B5	41°35'11.2"N 36°05'41.4"E	135	Sandy, very little pebble, gray
Cernek Lake	C1	41°39'27.8"N 36°03'42.7"E	150	Silty, clayey, light gray
	C2	41°38'16.4"N 36°03'59.3"E	160	Clayey, light gray
	C3	41°38'11.3"N 36°04'36.4"E	130	Silty, clayey, light gray
	C4	41°38'23.8"N 36°04'52.0"E	140	Silty, clayey, light gray
	C5	41°38'41.3"N 36°04'47.2"E	150	Sandy, slightly silty, light brown
Karaboğaz Lake	K1	41°40'17.6"N 35°47'47.3"E	130	Silty, clayey, light gray
	K2	41°40'39.5"N 35°48'22.7"E	97	Silty, clayey, light gray
	K3	41°40'24.7"N 35°48'10.1"E	131	Silty, clayey, light gray
	K4	41°39'57.6"N 35°47'36.8"E	113	Silty, clayey, dark gray
	K5	41°39'40.4"N 35°46'44.7"E	163	Silty, clayey, dark gray
Liman Lake	L1	41°41'45.5"N 36°00'48.2"E	95	Silty, clayey, light beige
	L2	41°42'21.6"N 36°00'28.4"E	210	Silty, clayey, light beige
	L3	41°42'03.2"N 36°01'22.8"E	280	Sandy, slightly silty, gray
	L4	41°41'26.4"N 36°01'33.4"E	113	Silty, clayey, gray
	L5	41°41'21.4"N 36°01'20.7"E	0	Sandy, silty, clayey, gravelly, light gray
Uzun Lake	U1	41°33'21.9"N 36°05'19.9"E	110	Clayey-silty, light gray
	U2	41°33'46.0"N 36°05'30.1"E	155	Clayey, dark gray
	U3	41°34'41.7"N 36°06'01.6"E	170	Clayey, light gray
	U4	41°35'19.0"N 36°06'23.3"E	150	Clayey, light gray
	U5	41°35'37.1"N 36°06'40.7"E	105	Sandy, clayey, light gray

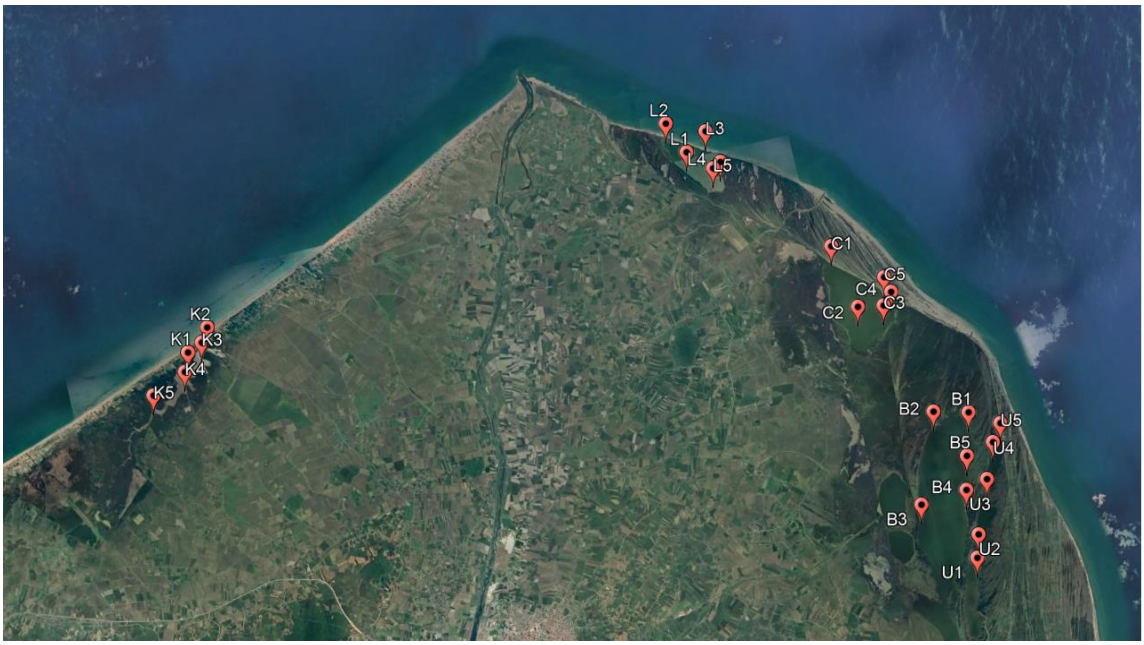

Figure 1. Stations in the Kızılırmak Delta (Balık Lake: B; Cernek Lake: C; Karaboğaz Lake: K; Liman Lake: L and Uzun Lake: U; prepared by Şaban Kabak with the Google Earth Pro, V 7.3.6.9345, 2022).

***Collection, identification and counting of gastropods*:** Sampling was carried out from 25 stations, five each of the lakes, using a sediment scoop (15cm x 15cm) from the littoral zone of the lakes. Sediment samples were labelled, placed in storage bags, and taken to Hacettepe University Paleontological Laboratory. The dry sediment samples were treated overnight with 5% H_2O_2 to separate them from the soil. After the sediment was sieved with a griddle (mesh size 0.25 cm), it was dried in porcelain containers at room temperature. Gastropod samples were separated from the sediment using an Olympus SZX7 stereo microscope (Tokyo, Japan), and species identifications were performed by the method of Glöer (2019), Welter-Schultes (2012), Yıldırım et al. (2006a, 2006b). Photographs of identified species were recorded using an Olympus SZX7 stereo microscope and LCmicro Image Analysis Software (Olympus Soft Imaging Solutions GmbH, Version 510_UMA_Install-LCmicro21_Quesnel_en_00_13092016, Münster, Germany).

Results

A total of 15 species from 1621 specimens, including two species from the subclass Neritimorpha (*Theodoxus fluviatilis* and *Theodoxus major*), three species from the subclass Caenogastropoda (*Bithynia* sp., *Ecrobia maritima*, and *Ecrobia ventrosa)* and ten species from the subclass Heterobranchia (*Valvata macrostoma*, *Galba* cf. *truncatula*, *Peregriana labiata*, *Physella acuta*, *Physa fontinalis*, *Planorbis planorbis*, *Armiger crista*, *Gyraulus piscinarum*, *Acroloxus lacustris*, and *Oxyloma elegans*) were collected from 25 stations in the research area as given in Table 2. The species names in Table 2 are the authoritative molluscan names approved by the scientific community in the editorial board of MolluscaBase (Mollusca Base, 2023). Photographs of some species are presented in Figure 2.

Tablo 2. The distribution of the species collected from the research area according to the stations, the number of individuals of the species at the stations (N; number of individuals/$m+^{2}$), the total number of individuals of each species in the research area (ΣN), the total number of taxa at the stations (ΣT) and the number of identified individuals at the stations (NI).

	Theodoxus fluviatilis (Linnaeus, 1758)	*Theodoxus major* Issel, 1865	*Bithynia* sp.	*Ecrobia maritima* (Milaschewitsch, 1916)	*Ecrobia ventrosa* (Montagu, 1803)	*Valvata macrostoma* Mörch, 1864	*Galba* cf. *truncatula* (O. F. Müller, 1774)	*Peregriana labiata* (Rossmässler, 1835)	*Physella acuta* (Draparnaud, 1805)	*Physa fontinalis* (Linnaeus, 1758)	*Planorbis planorbis* (Linnaeus, 1758)	*Armiger crista* (Linnaeus, 1758)	*Gyraulus piscinarum* (Bourguignat, 1852)	*Acroloxus lacustris* (Linnaeus, 1758)	*Oxyloma elegans* (Risso, 1826)	ΣN	ΣT
B1	9	-	1	-	-	93	-	-	-	1	-	2	27	-	2	135	7
B2	2	-	-	2	-	126	-	3	-	-	-	13	73	-	4	223	7
B3	1	-	-	4	14	7	-	-	-	-	-	-	13	-	-	39	5
B4	-	-	-	-	-	-	-	-	-	-	-	-	11	-	-	11	1
B5	1	-	-	-	-	-	-	-	-	-	-	-	5	-	1	7	3
C1	-	1	-	-	18	8	-	4	1	-	-	6	24	-	-	62	7
C2	-	3	-	-	80	3	2	1	-	-	-	-	84	-	1	174	7
C3	10	3	-	9	23	-	-	-	1	-	-	1	22	-	1	70	8
C4	-	-	1	-	31	-	-	2	-	-	3	-	39	-	-	76	5
C5	-	1	-	-	6	-	-	-	-	1	-	-	-	-	-	8	3
K1	3	-	-	-	5	-	-	-	-	-	-	1	17	-	2	28	5
K2	-	-	-	-	4	59	-	4	-	-	-	-	51	-	7	125	5
K3	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	5	1
K4	1	-	3	-	5	3	-	-	-	-	-	-	12	-	-	24	5
K5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
L1	6	9	-	39	14	2	-	-	-	-	-	-	-	-	-	70	5
L2	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	1
L3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
L4	6	30	-	13	33	-	-	-	-	-	-	-	-	-	-	82	4
L5	121	11	10	5	-	82	2	-	-	2	-	23	28	-	12	296	10
U1	-	1	-	-	-	1	-	-	-	-	-	-	5	-	-	7	3
U2	-	-	-	-	-	1	-	-	-	-	-	-	3	-	1	5	3
U3	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	1
U4	1	-	-	-	-	17	-	-	-	-	-	-	17	1	3	39	5
U5	-	1	-	61	40	1	-	-	-	-	-	1	29	-	-	133	6
NI	161	60	15	133	278	403	4	14	2	4	3	47	462	1	34	1621	

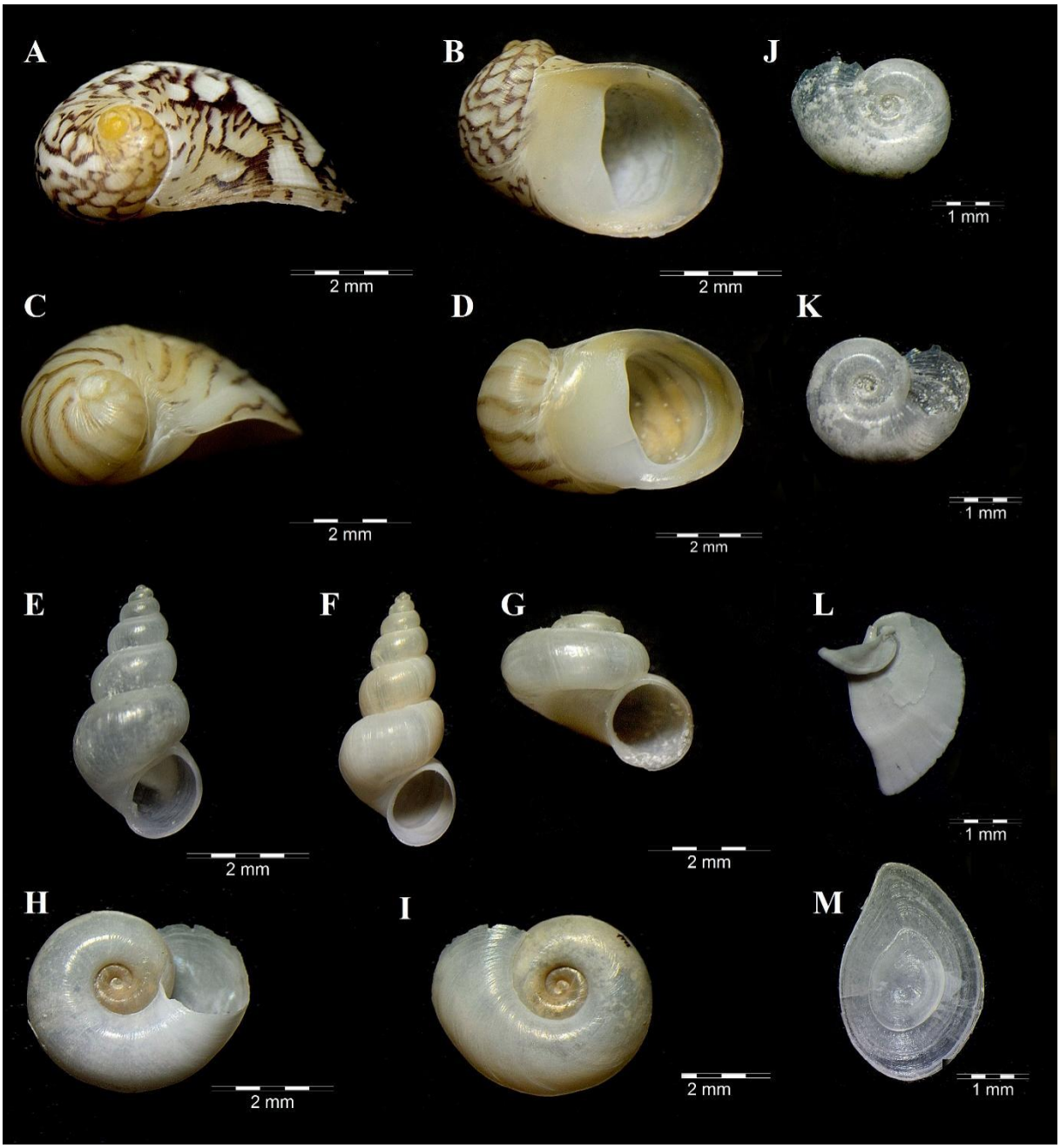

Figure 2. A-B. *Theodoxus fluviatilis*, C-D. *T. major*, E. *Ecrobia maritima*, F. *E. ventrosa*, G. *Valvata macrostoma*, H-I. *Gyraulus piscinarum*, J-K. *Armiger crista*, L. operculum (*T. fluviatilis*), M. operculum (*Bithynia* sp.) (Photographed by Şaban Kabak, 2023).

Discussion

The trophic characteristics of the lakes in the delta vary between eutrophic and hypertrophic. Demirkalp et al. (2010) determined that Liman Lake is eutrophic with a value of chlorophyll a 5-50 µg/L., while Cernek Lake (chlorophyll a: 4.12-541.5 mg/m^3), Uzun Lake (chlorophyll a: 6,83- 40.75 µg/L), and Balık Lake (chlorophyll a: 10,24-85,62 mg/m^3) are eutrophic with a hypereutrophic tendency (Demirkalp et al., 2004; Gündüz et al., 2013; Özdemir, 2019). Özdemir et al. (2021) determined eutrophication-representative zooplankton growth in Karaboğaz Lake.

In this study we observed the possibility of the connections between Cernek and Balık lakes during rainy periods. Balık Lake is connected to Uzun Lake, and also has a connection to the sea through a short channel. Liman and Karaboğaz lakes are

close to the sea and partly isolated from the sea by dunes formed due to sea waves (Figure 3).

Figure 3. A-B. Connection of Karaboğaz Lake and Liman Lake with the sea; C. Livestock activities (buffalo farming) carried out in the research area; D. Liman Lake-4 station from the research area (Photographed by Alaettin Tuncer, 2012).

As can be seen in Table 2, Liman Lake (N: 449) and Balık Lake (N: 415) have the highest number of individuals among all the lakes in the research area due to swamp areas with dense macrophytes despite the agricultural lands surrounding both lakes. The station with the highest number of individuals was L5 (N: 296), which connects to the irrigation canals and swamps in Liman Lake. Cernek (N: 390), Uzun (N: 185), and Karaboğaz (N: 182) lakes have fewer individuals than other lakes. The lowest number of individuals was at stations L2 (Liman Lake, N: 1) and U3 (Uzun Lake, N: 1), and no samples were detected at station L3 (Liman Lake) and K5 (Karaboğaz Lake), possibly due to intensive agriculture, animal husbandry and reed farming in the region (Figure 3).

In the study area, the dominant species were *G. piscinarum* (N: 462) and *V. macrostoma* (N: 403), distributed in nineteen and thirteen stations, respectively. *A. lacustris* existed with one individual at one station (U4). The Pulmonata and Prosobranchia (Valvatidae) species members of Heterobranchia, which dominated the research area, prefer lentic ecosystems with rich vegetation in freshwater (Hubenov, 2007). This information from the literature is consistent with the eutrophic-hypertrophic structures and hydromorphological characteristics of the lakes in the delta.

T. major and *E. maritima* are adaptive to brackish waters and members of the Ponto-Caspian fauna. *E. maritima* is present in the Aegean islands (Baba, 2002; Welter-Schultes, 2012; Georgiev and Hubenov, 2013; Örstan and Haase, 2014). Fossils of both species were found in the geological formations of the Boğaziçi and the Marmara

Sea, indicating that these species entered our country in the Late Quaternary (Holocene) period (Meriç et al., 2000; Büyükmeriç, 2016). In this study, *T. major* and *E. maritima* reached the highest individual numbers in Liman Gölü (N: 50, 57 respectively), which directly connects to the sea.

P. labiata prefers waters with rich macrophytes and lives in muddy substrate, adaptable to changes in trophic conditions (Georgiev and Hubenov, 2013; Welter-Schultes, 2012). However, some studies indicated that *P. labiata* is vulnerable to pollution, similar to *T. fluviatilis* (Borja et al., 2000). We found 14 specimens from five stations: B2 (N: 3), C1 (N: 4), C2 (N: 1), C4 (N: 2), and K2 (N: 4). The presence of this species in small numbers of individuals in the research area, despite its tolerance to eutrophication, led us to evaluate its distribution with the water's physicochemical characteristics.

E. ventrosa is highly tolerant to the changes in ecological conditions (Borja et al., 2000). It lives in coastal waters, quiet estuaries, and drainage ditches in coastal marshes, more or less permanently submerged in mud or aquatic vegetation (Welter-Schultes, 2012). This species was present in thirteen stations in the research area (N: 278). The highest number of *E. ventrosa* individuals were in the swamps of Cernek Lake (N: 158). On the other hand, the lowest number of *E. ventrosa* individuals were in the supralittoral zones of Balık Lake (N: 14), under high exposure to anthropogenic activities.

P. acuta is an alien species native to North America (Lydeard et al., 2016; Spyra et al., 2019). This species has a high reproductive success and tolerance to environmental pollution. Vinarski (2017) suggested that this New World snail invaded the Old World (Europe, Transcaucasia, and Central Asia) firstly by natural processes such as long-distance dispersal from the Americas to Europe, secondly by sociocultural factors such as canal building in industrial countries of Europe, aquarium trade, and anthropogenic modification of natural habitats. Bilgin (1980) recorded *P. acuta* from Antalya (Türkiye) for the first time. It has a wide distribution in Türkiye from natural and modified freshwater habitats (Gürlek et al., 2019; Gümüş et al., 2022; Yıldırım et al., 2022). Its invasive features are not apparent in all the sites of its occurrence in Türkiye. We determined two specimens of *P. acuta* from Cernek Lake (C1, C3). Biomonitoring of this species in our research area and Türkiye will provide further information.

We recorded *A. crista*, *G. piscinarum* and *A. lacustris* for the Kızılırmak Delta, and the Black Sea region for the first time. However, we did not find *Viviparus contectus*, *V. viviparus*, *Stagnicola palustris*, *Radix auricularia*, *Peregrina peregra*, *Gyraulus ehrenbergi*, *G. elenae*, *G. parvus*, and *Succinea putris* which were reported in Öktener (2004) and Yıldırım et al. (2022). The malacofauna information of the Black Sea Region has been enriched with the studies carried out in the region. Additionally, new species have been described in the region (Vinarski et al., 2013).

According to IUCN Red List (2022) Data, 13 of the 15 species collected from the delta are at "Low Risk" (LC) category. In contrast, *T. major* and *E. maritima* are in the "Data Deficient" (DD) category. The population of *P. acuta* is increasing. The populations of *T. fluviatilis*, *P. fontinalis*, *A. crista*, *A. lacustris*, and *O. elegans* are stable. Unfortunately, the population of *V. macrostoma* is decreasing, and no information is available on the population status of *E. ventrosa*, *G. truncatula*, *P. planorbis*, and *G. piscinarum* (IUCN Red List, 2022).

Conclusions

As a result of this research, we identified 15 freshwater snail taxa (N: 1621), 14 at the species level and one at the genus level. While the highest number of individuals was in Liman Lake (N: 449), the lowest

number was in Karaboğaz Lake (N: 180). Cernek Lake showed the highest species diversity (14 species), while Karaboğaz Lake (8 species) had the lowest. *G. piscinarum* (N: 462), *V. macrostoma* (N: 403), and *E. ventrosa* (N: 278) had the highest number of individuals, while *A. lacustris* (N: 1), *P. acuta* (N: 2), and *P. planorbis* (N: 3) had the lowest number of individuals. We also recorded *A. crista*, *G. piscinarum* and *A. lacustris* for the first time in the Black Sea Region. We observed that the delta is under exposure to anthropogenic pressures consistent with the results of the management plan (Republic of Türkiye-Ministry of Environment and Urbanization, 2019). Besides, the lakes in our research area had a rich malacological diversity compared to previous malacological studies in the region.

Our study aimed to serve as a crucial data source for future biological observations and conservation studies. With the more comprehensive malacological study of the Black Sea Region, we think more species, especially Ponto-Caspic species, will be encountered. To obtain information on species in a specific region of our country not listed on the IUCN Red List and sensitive species on the list with declining populations, conducting fauna studies is necessary.

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Ethical approval

The author declares that this study complies with research and publication ethics.

Informed consent

Not available.

Conflicts of interest

There is no conflict of interests for publishing their study.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Funding organizations

No funding available.

Author contributions

Şaban Kabak: Data curation, Preparation, identification, counting, photographing and cataloging gastropod samples, Conceptualization, Writing the original draft.

Burçin Aşkım Gümüş: Validation, Conceptualization, Writing the original draft.

Cemal Tunoğlu, Alaettin Tuncer, and Cüneyt Bilen: Review, Funding acquisition, field studies.

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