Research Article

ACTA ZOOLOGICA BULGARICA
Acta zool. bulg., Suppl. 9, 2017: 93-98

The Non-indigenous and Ponto-Caspian Gastropoda Fauna of Lake Sapanca (Turkey), with Notes on the Ponto-Caspian Clitellata Species in the Lake

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Abstract: Many Ponto-Caspian invertebrate species have been introduced to new areas in Europe, Baltic Sea and North America. In Turkey, the Ponto-Caspian fauna has spread in the inland waters, following different patterns and in different geological periods. Lake Sapanca is located on a tectonic hole in the Marmara region in the north-western part of Turkey. Except for a few studies, there has been no detailed information about the non-indigenous and Ponto-Caspian species in the lake. In the present study (from June 2011 to December 2013), the benthic macroinvertebrate fauna of Lake Sapanca was determined. The following Gastropoda species, which originate from the Ponto-Caspian area, were detected: *Lithoglyphus naticoides*, *Esperiana esperi*, and *Borysthenia naticina*. The presence of these species in different parts of Turkey suggests that the main routes of migration might be the rivers flowing into the Black Sea. Some notes on the Ponto-Caspian and invasive Clitellata species in the lake were made.

Key words: Ponto-Caspian, non-indigenous, Gastropoda, Clitellata, Lake Sapanca

Introduction

It is known that the Ponto-Caspian area is a remnant basin left after the regression of the Paratethys Sea (Dumont 2000). During the Miocene time (11.6-5.3 million years ago), not only Turkey but also Eastern Europe were covered by the Paratethys Sea. In Mio-Pliocene time, about 7.5-5.0 million years ago, this sea shrank in size and divided into a number of brackish water basins, one of them being the Sarmatian Sea, currently included in the modern regions of the Black, Azov, Aral and Caspian Seas. The Ponto-Caspian area, which is accepted as one of the most significant hotspots of benthic macroinvertebrate diversity in the Palearctic region (Väinölä et al. 2008), consists of the basins of the Black, Caspian and Azov Seas. The Black Sea, which has an area of 436,400 km^2 and the longest east-west extent of about 1,175 km, is located between Eastern Europe and Western Asia. Its basin includes several big rivers: the Sakarya, Kızılırmak, Yeşilırmak, and Çoruh (from Turkey) and the Danube, Dnieper, Rioni, Southern Bug, and Dniester, as well as many coastal lagoons, marshes and lakes. These different water bodies contain important breeding grounds for a large number of fish, amphibians and invertebrate species.

Several studies have been done on the occurrence and distribution of the Ponto-Caspian Gastropoda species in Turkey (Yildirim 1999, Yildirim et al. 2006a, b, Yildirim & Kebapçi 2012). Although, several studies reported benthic macroinvertebrates from Lake Sapanca (Schütt 1989, Altinsaçli 1997, Şahin & Yildirim 2007,

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Şahin & Yildiz 2011, Arslan et al. 2016), except a few studies, there has been no data on the Ponto-Caspian or Ponto-Baltic macroinvertebrate species in the lake.

In this paper, Lake Sapanca was evaluated in terms of: 1) the benthic macroinvertebrate community structure and diversity, with focus on the Gastropoda species; 2) the presence and distribution of the non-indigenous and Ponto-Caspian Gastropoda species in the lake; and 3) the presence of other Ponto-Caspian and invasive species in the lake.

Materials and Methods

Study Area

Lake Sapanca is one of the most important freshwater lakes in the north-western part of Turkey. It is located between the Gulf of İzmit and Adapazarı meadow (Fig. 1), in a tectonic hole, at an altitude of 30 m a.s.l. It has an area of 46.8 km^2 and a maximum depth of 55 m. There are 13 rivers flowing into the lake and one outflowing river.

Sampling

The benthic macroinvertebrates were collected seasonally from different dephts at nine stations in Lake Sapanca (Fig. 1), using an Ekman grab (225 cm^2, two hauls per station) and a hand dredge, in the period from June 2011 to December 2013 (TS 6469 EN 27828). The samples were washed with a series of sieves and all samples collected were immediately fixed with 70% ethyl alcohol in the field. At the laboratory, the samples collected were sorted and counted by using a stereomicroscope and then identified to the lowest possible taxon, following Macan (1977a, b) and Bouchard (2004).

Data analyses

The benthic macroinvertebrate community at each sampling station was studied, using the number of taxa, number of specimens, and relative abundance (percentage, %). For each sampling station, the Shannon-Weaver's index of diversity (H'), Margalef's index of diversity (d), and Pielou's eveness (E) index were calculated, using PAST 1.75b software (Hammer et al. 2001).

Fig. 1. Geographical location of the studied area and sampling stations in Lake Sapanca, Turkey

Results

Community and diversity structure of benthic macroinvertebrates

The greatest part of the benthic macroinvertebrate community was represented by Clitellata (39.24%) and Gastropoda (22.72%). Apart from these dominant groups, Bivalvia comprised 10.68 % and Diptera: Chironomidae 8.86%, while the other taxonomic groups (Hirudinea, Copepoda, Gammaridae, Ephemeroptera, and Diptera: Ceratapogonidae and Simuliidae) together reached about 18.5% (Table 1).

Gastropoda consisted of 13 taxa. Of them the following species, which originate from the Ponto-Caspian area, were detected: *Lithoglyphus naticoides*, *Esperiana esperi*, and *Borysthenia naticina*.

Borysthenia naticina was the dominant species among all taxa. It was found at eight stations out of nine. In winter, the abundance of *B. naticina* showed a distinct peak, with 55.5%. In the north-eastern part of the lake (Stations 5 and 6), *B. naticina* was the most abundant species (65.33% and 55.84%, respectively). These stations were characterised with abundant macrophytes and silty-sand substratum. However, at Stations 3, 4 and 8, *B. naticina* was represented only by sub-recent empty shells and probably was extinct in the area a short time ago.

The values of the Shannon-Weaver's index of diversity, Margalef's index of diversity and Pielou's eveness index varied in the following ranges: H' – from 1.00 to 2.99; d – from 1.25 to 3.42; and E – from 0.23 to 0.36. The lowest values were recorded at Station 4, while the highest values - at Station 1, for all three diversity indices.

Discussion

Benthic macroinvertebrate community

Şahin & Yildirim (2007) who studied the mollusc fauna of Lake Sapanca, found that the most dominant species was *Esperiana esperi*, with a maximum abundance of 2,266 ind./m^2, which together with *B. naticina* was the most widespread species. Our results showed that the dominant species composition of the lake has changed over

Table 1. Occurrence and relative abundance (percentage, %) of benthic macroinvertebrates at different sampling stations in Lake Sapanca, Turkey (2011-2013). Gastropoda species recorded for the first time in the lake are marked by an asterisk (*)

	Sampling Stations								
Taxa	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Gastropoda									
Theodoxus fluviatilis fluviatilis (Linnaeus, 1758)	-	-	-	-	3.36	3.55	0.59	-	-
**Viviparus viviparus* (Linnaeus, 1758)	0.41	-	-	-	0.09	-	0.20	-	0.30
**Melanopsis praemorsa* (Linnaeus, 1758)	-	0.33	-	-	0.09	-	0.20	-	-
Esperiana esperi (Fèrussac, 1823)	0.27	-	-	0.21	2.33	3.17	1.96	-	-
*Bithynia sp.	2.05	-	-	-	2.70	2.33	0.20	-	-
Radix labiata (Rossmassler, 1835)	2.05	-	-	-	0.37	1.03	-	-	-
Lymnaea stagnalis (Linnaeus, 1758)	1.10	-	1.11	-	0.09	-	-	-	0.30
**Physella acuta* (Draparnaud, 1805)	5.07	-	2.22	-	0.37	2.99	1.17	-	0.30
**Planorbis intermixtus* Mousson, 1874	0.27	-	-	-	-	-	-	-	-
**Gyraulus piscinarum* (Bourguignat, 1852)	2.60		1.11		3.63	2.43	2.15		0.89
Borysthenia naticina (Menke, 1845)	12.60	1.66		0.21	65.33	55.84	11.15	0.37	3.27
**Anisus* sp.	0.14	-	-	-	-	-	-	-	-
Lithoglyphus naticoides (Pfeiffer, 1828)	0.14	-	-	-	2.52	-	0.98	-	0.30
Bivalvia g. sp.	5.34	-	2.44	-	12.95	14.38	15.07	-	47.92
Nematoda g. sp.	-	15.23	-	1.68	-	-	-	5.19	-
Oligochaeta g. sp.	81.82	72.18	60.89	38.95	5.03	6.91	57.74	46.29	33.64
Hirudinea g. sp.	-	-	-	-	0.09	-	-	-	1.79
Copepoda g. sp.	6.16	-	27.11	58.74	-	0.09	-	45.93	-
Gammaridae g. sp.	1.37			0.21	-	-	-		0.60
Ephemeroptera: Baetidae	-	-	0.67	-	-	0.19	-	0.74	-
Diptera: Chironomidae	18.07	10.59	4.21	-	1.04	7.09	8.62	0.74	10.43
Diptera: Ceratapogonidae	1.10	-	0.22	-	-	-	-	-	-
Diptera: Simuliidae		-	-	-	-	-	-	0.74	-

a decade. Furthermore, on comparing with these two studies, we can conclude that probably changes in the environmental conditions of the lake have caused alterations in species richness, composition and diversity. The most important and influential cause of species composition and trophic changes in an aquatic ecosystem are the high loads of organic nutrients (such as nitrogen and phosphorus).

Our results on the diversity of benthic macroinvertebrates in Lake Sapanca confirmed the presence of five Gastropoda species reported earlier by Şahin & Yildirim (2007). At the same time, although the samples were collected during the four seasons, seven of the previously reported Gastropoda species were not found: *Bithnynia tentaculata* (Linnaeus, 1758), *Viviparus acerosus costae, Esperiana accicularis situssineri, Radix labiata* (Rossmässler, 1835), *Galba truncatula* (Müller, 1774), *Planorbis planorbis* (Linnaeus, 1758), and *Oxyloma elegans* (Risso, 1826). On the other hand, we found seven Gastropoda species, which have not been reported previously (Şahin & Yildirim 2007), namely: *Viviparus viviparus*, *Melanopsis praemorsa, Planorbis intermixtus, Gyraulus piscinarum, Physella acuta, Bithynia* sp. (probably new species), and *Anisus* sp. (Table 1). Among Clitellata, the presence of all six species mentioned in an earlier study (Şahin & Yildiz 2011) was confirmed by Arslan et al. (2016); however the authors reported 14 different taxa not recorded in the survey by Şahİn & Yildiz (2011), these are: *Aulodrillus pluriseta* (Piquet, 1906), *Dero digitata* Müller, 1773, *Limnodrilus cervix* Brinkhurst, 1963, *L. claperadeanus* Claparède, 1862, *L. udekemianus* Claparède, 1862, *Nais elinguis* Müller, 1774, *Ophidonais serpentina* Müller, 1773, *Potamothrix heuscheri* (Bretscher, 1900), *Psammoryctides albicola* (Michaelsen, 1901), *P. moravicus* (Hrabe, 1934), *Quistadrillus multisetosus* (Hrabě, 1934), *Trichodrillus* sp., *Rhynchelmis* sp., and *Enchtyraidae* spp. These different results between similiar studies at different time may be explained not only with the different sampling methods but also with the changing environmental parameters.

Ponto-Caspian Gastropoda species in Lake Sapanca

The Ponto-Caspian fauna, especially the euryhalin genera and species, which have been living in both freshwater and brackish water, have become specialised and dispersed both throughout this region and outside. The euryhalinity of the Ponto-Caspian biota makes them ideally pre-adapted to invade (and survive in) new environments (Dumont 2000).

The Gastropoda *L. naticoides* originates from the western Black Sea, and it is considered to be a species of slowly flowing waters as those in the downstream parts of rivers, canals and lakes (Gittenberger et al. 1998). It has been reported from different parts of Europe. The genera *Lithoglyphus* is represented by only one species in Turkey, *L. naticoides*, inhabiting only Lake Sapanca (Soylu 1990, Yildirim 1999, Şahin & Yildirim 2007). This inference supports the immigration way of the Ponto-Caspian snails from the Black Sea to Turkish inland lakes along the Sakarya rift valley suggested by Şeşen & Schütt (2009).

The freshwater prosobranch snail *E. esperi* has a Pontian origin. This species was recorded in Lake Sapanca as the most abundant species by Şahin & Yildirim (2007). In our study the species was not very abundant and found at five stations. *E. esperi* is distributed in the upper and central parts of the Danube River and localities in other rivers that drain towards the west of the Black Sea (Schütt 1989). The way of immigration from the Danube River into the Turkish highland became enlightened by the discovery of a third species in Turkey: *F. sangarica* from the main spring Sakaryabaşı near Çifteler, 60 km SE Eskişehir in the Turkish province of the same name (Şeşen & Schütt 2009). The authors emphasised that the Sakarya River (also Sakaryabaşı) is connected with the mouth into the Black Sea at Sakarya Ağzı near Adapazari. Also, they suggested immigration way of Ponto-Caspian snails from the Black Sea to Turkish inland lakes along the Sakarya rift valley.

It is known that *B. naticina* has Ponto-Baltic distribution in lakes and its distribution in Turkey includes the Mediterranean Sea (Yildirim 1999). This species is listed as rare and zoogeographically restricted species in Germany and endangered in some other European countries (Poland); it is primarily confined to eastern and central Europe and Turkey. Zettler (2012) indicated that contrary to the IUCN European Red List of Non-marine Molluscs where *B. naticina* is categorised as LC (least concern), the species is at least endangered in some parts of its distribution area. High densities of *B. naticina* were observed at only two of the studied stations in Lake Sapanca. At the other sampling stations, especially in the southern part of the lake, *B. naticina* had very low density (Stations 2, 4, 8, and 9) or was represented only by sub-recent empty shells (Station 3).

Notes on Ponto-Caspian and invasive Clitellata species in Lake Sapanca

In the study which was performed by Şahin & Yildiz (2011) in Lake Sapanca, 13 Clitellata species were found, of which 11 tubificids and 2 naidid species. After five years Arslan et al. (2016) reported 20 Clitellata species, among them the presence of all six species mentioned by Şahin & Yildiz (2011), and 14 new taxa not recorded in the survey by Şahin & Yildiz (2011). Two of the Clitellata species, *Potamothrix hammoniensis* and *Potamothrix heuscheri*, found in Lake Sapanca are known to originate from the Ponto-Caspian area. Some species of the genera *Potamothrix,* together with *Psammoryctides* and *Paranais,* as well as two tubificids: *Isochaetides michaelseni* and *Tubifex newaensis,* were reported as invasive oligochaetes by Timm (2010, 2013). Species belonging to these three genera have been reported from different parts of Turkey. Another oligochaete species, representative of the Ponto-Caspian fauna, *Isochaetides* sp., was recorded by Taş et al. (2012) in the Turkish Trace region. *Tubifex newaensis* was reported from the Black Sea lagoons (Yildiz et al. 2007a) and from south-western Turkey (Yildiz et al. 2007b).

Potamothrix hammoniensis has been recorded from different regions of Turkey several times. According to the studies carried out to date, this species is very common in freshwater and brackish water of Turkey (except in the eastern and south-eastern parts). The study of the fauna of Oligochaeta in the eastern and south-eastern parts of Turkey is very limited. Only a limited number of *P. hammoniensis* individuals were found in Lake Nemrut (Caldera) in eastern Turkey (unpublished data of the first author). The Ponto-Caspian species of the genus *Potamothrix* have been divided into four groups in terms of their distribution and dispersing ability by Timm (2013). The first of them includes *P. hammoniensis*, which has a large area in the Western Palaeartic, is also distributed in the Ponto-Caspian area. The second group consists of *P. moldaviensis* Vejdovský & Mrázek, 1903, *P. vejdovskyi* (Hrabě, 1941), *P. bavaricus* (Oschmann, 1913), *P. heuscheri*, and *P. bedoti* (Piguet, 1913), which have distributed over the last two centuries with human aid in

Europe and on some other continents. The third group of *P. caspicus* (Lastockin, 1937), *P. mrazeki* (Hrabě, 1941), *P. moldaviensis mitropolskiji* (Hrabě, 1950), *P. cekanovskajae* Finogenova, 1972, *P. a. alatus* (Timm, 2013), and *P. grimmi* (Hrabe, 1950) are still restricted to the Ponto-Caspian basin. The last group includes species with very limited distribution in ancient lakes. A new subspecies (*P. alatus hazaricus*) has been described from the profundal of Lake Hazar in south-eastern Anatolia (Timm et al. 2013), while the distribution of *P. alatus* Finogenova, 1972, is known to be still limited to the Ponto-Caspian basin. The presence of subspecies in Lake Hazar may indicate a connection between the lakes and rivers in south-eastern Anatolia and the Ponto-Caspian region.

In conclusion, the occurrence of the Ponto-Caspian species of Gastropoda and Clitellata in Lake Sapanca shows a relationship with the invertebrate fauna of the Black Sea. In the aspect of the distribution and dispersing ability, we can conclude that the species of Ponto-Caspian origin have successfully distributed throughout Turkey by natural expansion of their ranges or by human aid.

Özbek (2011), who has studied the distribution of the Ponto-Caspian amphipoda species in Turkey, indicated that the Ponto-Caspian fauna representatives may have used the three main waterways (the Bosporus, Sakarya and Kızılırmak-Yeşilırmak rivers) to reach the Anatolian lakes and rivers in the past geological time. Not only the distribution of the Ponto-Caspian amphipoda species, but also the distribution of the Gastropoda and Oligochaeta species supported this view. But only these three waterways are inadequate to explain the distribution of the Ponto-Caspian species (or subspecies) in south-eastern and eastern Turkey as there is not any freshwater connection between the western and the south-eastern and eastern parts of Turkey. In addition, Turkey is divided by massive mountains called the Anatolian Diagonal (extending from the Amonos Mountains to the Erzurum-Kars Plateau) from the north-east towards the south-west, as well as from the east to the west. Therefore, the connection of the Ponto-Caspian region with the rivers and lakes in the eastern Turkey (e.g. Çoruh and Aras rivers, Çıldır Lake) may be the fourth water connection. Since the Oligochaeta fauna of the eastern Black Sea region is not yet known in detail, it is impossible to speculate about its zoogeography. Another possibility is the existence of a lake in the past geological period, extending as uninterrupted from the today modern Lake Sapanca to Lake Van in Anatolia (Demirsoy 2008). This lake might have created the connection between the east and the west regions of Anatolia until the Anatolian Diagonal was formed. Thus, the Ponto-Caspian species reaching Anatolia through the Black Sea connection had spread to Anatolia and after the formation of the Anatolian Diagonal, the isolation mechanisms may have begun speciation or subspeciation. The existence of a subspecies of *P. alatus*, which distribution is limited to the Ponto-Caspian region, in Lake Hazar in the south-eastern part of Anatolia, supports this view.

Acknowledgements: This study was supported by the Scientific and Technological Research Council of Turkey (TUBİTAK), Project No 113Y030.

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