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Diversity, spatiotemporal distribution, abundance, species composition and habitat preferences of Ostracoda in Akbük and Akdeniz coastal mesosaline lagoons (Muğla, the South Aegean Region, Turkey)

by

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Abstract

Akdeniz and Akbük lagoons are part of a shallow coastal ecosystem of great aesthetic and ecological importance, located in Muğla Province in the southern Aegean region of Turkey. In the present study, four expeditions to collect ostracods from these lagoons were conducted in May, July, October, and November of 2008. Benthic samples were obtained monthly and several environmental factors were recorded simultaneously in situ. The ecological preferences of the ostracods were monitored, and qualitative and quantitative samples were collected from three sites in Akdeniz lagoon and two sites in Akbük lagoon. Three ostracod taxa (*Cyprideis torosa*, *Loxoconcha elliptica* and *Cytheris fischeri*) were identified from the Akdeniz lagoon sampling sites and one species (*Cyprideis torosa*) from the Akbük lagoon sampling sites. We present and analyze the dominance and distribution of ostracod assemblages and their relationships to environmental factors: temperature, dissolved oxygen, percentage oxygen saturation, pH, redox potential, salinity, and electrical conductivity) using classification and ordination techniques. Canonical correspondence analysis (CCA) is used to characterize the relationship between ostracods and the environmental variables. Approximately 82% of the correlation between the community composition and environmental variables was explained by the first axis of the CCA ordination for the Akdeniz lagoon. The study revealed that the distribution and population density of ostracod species depends on the physicochemical properties of the environment. The reason for this is that *Cyprideis torosa* and *Loxoconcha elliptica* are euryhaline species.

Key words: Ostracoda, fauna, ecology, Akbük lagoon, Akdeniz lagoon, Turkey

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Introduction

Wetland areas and the lands around lakes, lagoons, ponds, rivers and brooks are important life spaces (biotopes) for species. Since these areas represent a natural habitat for many forms of life, they need to be protected and used in a way that does not affect the ecological balance. In order to protect them, we need information gathered through limnological, zoological, ecological, and hydrological studies. Some current and former scientific studies provide detailed information on the flora, fauna and ecology of some of these areas. Nevertheless, as a result of much research, the importance of these areas and the threats they are facing is understood and they have been taken under legal protection.

Along the 8333 km Turkish coastline, there are 14 lagoons at the Black Sea, 12 at the Marmara Sea, 128 at the Aegean, and 17 at the Mediterranean, comprising a total of 171 lagoons. Among these lagoons, three are national parks, three special protected areas, two nature conservation areas, six wildlife conservation areas, and five sites designated by local authorities for the protection as natural and cultural heritage sites (Deniz & Çelebi 2008).

The brief inventory of the existing data for Turkish lagoons shows that traditional fishing is carried out in 43 lagoons, representing 64% of the total surface area of these waters. Different types of nature and wildlife protection have been declared for outstanding 83% of the lagoons, amounting to 23 water bodies. However, the bans on fishing and related activities in 44 protected areas are not fully enforced by the fisheries management of the Turkish lagoons (Deniz & Çelebi 2008). Studies conducted on lagoons in Turkey by Uyguner and Gözenalp (1959), STM (consultancy firm) and the Ministry of Agriculture and Rural Affairs (STM & MARA 1996), Yerli & Bayrak (1992) and Yerli (1999) revealed important scientific information. The ecological characteristics and faunal components of the lagoons in Turkey are, however, still poorly researched.

Ostracods are amongst the most important aquatic organisms for modern and paleo-environmental studies (Frenzel & Boomer 2005, Ruiz et al. 2005), and are good indicators of organic pollution (Rosenfeld & Ortal 1983), because they are sensitive to changes in environmental factors and useful as indicators of water quality (Mezquita et al. 1999 a, b, c; 2000). Moreover, ostracod species are abundant worldwide in aquatic environments and some of them have a high tolerance to changes in water quality (Zarikian et al. 2000). Out of these species, *Cyprideis torosa* (Jones, 1850) has been used as a salinity paleoindicator (e.g. Vesper 1972, Van Harten 1975, Boomer 1993, Boomer et al. 1996, Roca & Julia 1997, Frenzel & Boomer 2005, Marco-Barba et al. 2013), from the perspective of morphometric variability and ornamentation (Kilenyi 1972; Vesper 1975; Van Harten 1975, 1996, 2000; Carbonel 1983; Frenzel et al. 2011), genetics (Tetart 1983; Sywula et al. 1995), geochemistry (Bodergat et al. 1991; Anadón et al. 1994; Wansard 1997; Wansard et al. 1998; Marco-Barba et al. 2012) and physiology (Herman & Heip 1982, Jahn et al. 1996). Faunal (Kubanç & Altınsaçlı 1990, Külköylüoğlu et al. 1993, Kaleli 1993), paleoecological, (Nazik et al. 1999, Meriç et al. 2010, Mischke et al. 2012), and ecological (Altınsaçlı 2004, Perçin-Paçal 2011) studies have contributed to determine ostracod fauna of the lagoons in Turkey. The present study aims to analyze in detail the distribution and abundance of ostracod species in Akdeniz and Akbük lagoons and to investigate the key environmental factors affecting the ostracoda community structure. This will enable us to estimate the past, current, and future habitat conditions, according to the ecological preferences and the tolerance level of ostracod species in Akdeniz and Akbük lagoons, now threatened by pollution.

The objectives of this study are: (1) to describe the diversity and distribution of ostracods found in two lagoons of Milas and Bodrum Districts in Muğla province, Turkey; (2) to describe the impact of anthropogenic and agricultural activities on these two lagoons; (3) to understand the ecological characteristics of ostracods found in these lagoons; (4) to examine whether lagoon protection provides any benefits for aquatic biodiversity, and (5) to discuss the conservation status of these two lagoons.

Materials and methods

The Akbük and Akdeniz lagoons are situated on the western coast of Turkey adjacent to the Aegean Sea (Fig. 1). The Akbük lagoon is situated on the north coast of the Gulf of Gökova, while the Akdeniz lagoon is on the north coast of Türkbükü Bay.

Figure 1

Akdeniz and Akbük Lagoons with sampling sites

The Akdeniz Lagoon (Lake Akdeniz): With a maximum depth of 2 m, the Akdeniz lagoon covers an area of 1.4 ha and is connected with Türkbükü Bay (Aegean Sea) by two narrow channels, one natural and the other artificial. Some parts of the lagoon were used for fish farming in the 1990s. In 1990, two drainage channels were excavated by business administrators of a fish farm to drain water from the lagoon into Türkbükü Bay on the Aegean, which dried up the shallow section (9.5 ha) of the lake. The Akdeniz lagoon and Gölköy Important Plant Area represent an important and rare natural habitat of *Phoenix theophrasti* Greuter which grows only in three areas: Crete, Antalya's Karaöz harbor, and the Datça peninsula (Boydak & Barrow 1995). Theophrastus or Cretean palm (*Phoenix theophrasti*), together with the dwarf palm *Chamaerops humilis* L. are the only indigenous palms in Europe. They grow in Crete and south-west Turkey, in coastal areas (usually on sandy and soaked soils). Around the lagoon, there are reeds, rushes, tamarisk and Cretan palm trees, as well as olive tree plantations, while on the rocks and elevated places – pine trees. There are date trees in the wetland to the west of the lagoon, around the natural outlet (canal); the brackish water that runs through this canal is quite important to the growth of trees. In the past, the Cretan Date Palm grew in a 6.5 ha section of the wetland area but this has now declined to 3 ha due to damage caused by anthropogenic activity such as tourism and holiday cottage construction. Despite the classification of this lagoon as a first degree (SIT) protected site, it is still exposed to many threats. There are few brackish water resources on the southern side of the lagoon and rather little rain water feeds the lagoon.

The Akbük Lagoon: The Akbük lagoon is located in the province of Muğla in the southern Aegean region of Turkey. It is a shallow coastal ecosystem of great aesthetic and ecological importance, included in the Gökova Special Environmental Protection Area (SEPA), designated in 1988. The Akbük Lagoon covers an area of 9.6 ha with a maximum depth of 3 m. It is an open water brackish lagoon with seawater entering through a small channel on its western side. In this region, such brackish wetland areas, with outflows directly into the sea for most of the year, are called 'azmak'. These azmaks have quite different characteristics compared to those of hypersaline lagoons. Most of the lagoon is covered with reed and rushes, with small areas of Tamarix and glasswort (Salicornia). The region of Akdeniz and Akbük lagoons has a typical Mediterranean climate, with hot and dry summers and mild, wet winters (Fig. 2). In the greater part of the Akbük lagoon is covered with the reeds, and the water at the bottom of the reeds dries out during the summer and autumn months. The lagoon is fed by high-flow underground water sources and rain. Thus, with subterranean water feeding the lagoon, water flows into the sea all year round. The surrounding higher ground is covered with pine trees as are the surrounding areas rented to the private sector for the use as picnic areas by the Forest and Environmental Ministries.

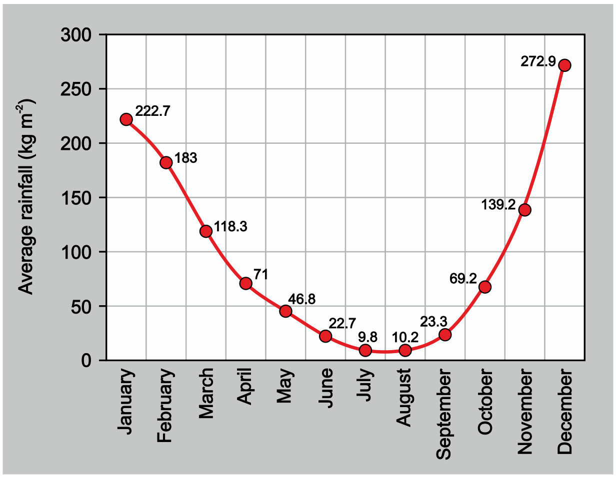

Figure 2

Monthly average rainfall data of the Muğla province between 1960 and 2012. (Turkish State Meteorological Service: Devlet Meteoroloji İşleri Genel Müdürlüğü or DMİ, 2013)

Both lagoons are isolated from the sea by a wide barrier, with seawater entering through a narrow and shallow inlet, depending on prevailing weather conditions and the state of the road constructed on the natural barrier.

The collected subfossil shells of *Cyprideis torosa* together with adult and juvenile ostracod individuals within the same surface sediments were also evaluated and investigated. Noded and unnoded shells of *Cyprideis torosa* from the surface sediments were used as indicators of salinity variation.

Ostracods and surface sediments were collected from the shallow littoral zone (<1 m) using a hand net (250 µm mesh size) at each sampling site. Two hundred milliliters of sediment (with submerge aquatic plants) were collected from a depth of 10 to 60 cm (ca. 1 sq. meter (m^2) of area) using a standard hand net (250 µm mesh size). Sediment samples were kept in polyethylene jars (250 ml bottles) containing 4% formaldehyde solution and fixed in situ. Seasonal sampling (May, July, October and December) was conducted in both Lake Akdeniz and Akbük Lagoons. Samples were collected from the shallow littoral zone (<1 m). In the laboratory, these samples were washed with pressurized tap water, and separated from sediment using four standardized sieves (2.0, 1.5, 0.5, 0.25 mm mesh size, respectively). The samples were then fixed again in 70% ethanol. The retained material was transferred to a Petri dish. The number of adult and juvenile individuals of each ostracod species was counted under a stereomicroscope. Ostracod specimens were stored in 1:1 70% ethanol to glycerin. Species were identified using both soft parts and carapace-based characters, using standard identification keys (Bronshtein 1947, Mordukhai & Boltovskoi 1969, Barbeito-Gonzales 1971, Hartmann & Puri 1974, Bonaduce et al. 1975, Breman 1975, Athersuch 1977, Yassini 1979, Stambolidis 1985, Meisch 2000). Various invertebrate and vertebrate animal species, and macrophyte species other than ostracod species were identified to the lowest possible taxon (Table 1). Vertebrate and invertebrate animal species and macrophytic plant species in the same sediment samples have also been documented (Table 1). Non-ostracod invertebrates were not used in statistical analysis.

Physicochemical variables were measured through the seasons at all three sampling sites in Akdeniz and two sampling sites in the Akbük lagoon through 2008. At each site, several physicochemical parameters, such as temperature (°C), salinity (PSU), pH, dissolved oxygen (mg l^{-1}), electrical conductivity (mS cm^{-1}), and reduction potential (Eh; mV) were measured before sediment sampling with the handheld model WTW 340i multimeter equipment in situ. The data on physicochemical environmental parameters, ostracod species determined in the two lagoons, and the numbers of individuals for each ostracod species are presented in Table 2. Each site was monitored at seasonal intervals. Seasonal variations in the salinity of Akdeniz and Akbük lagoons are presented in Figure 3.

Geographical data (latitude and longitude) were obtained with a global positioning system (Garmin GPS eTrex H) unit (Table 2). The

Table 1

Invertebrate, vertebrata and plant species list that determined along with ostracod species in Akdeniz and Akbük lagoons

AKDENİZ LAGOON	AKBÜK LAGOON
FAUNA	
POLYCHAETA	
Capitella capitata (Fabricius, 1780) *Hediste diversicolor* (O.F. Müller, 1776) *Heteromastus filiformis* (Claparède, 1864) *Perinereis cultrifera* (Grube, 1840) *Capitella capitata* (Fabricius, 1780) *Heteromastus filiformis* (Claparède, 1864) *Perinereis cultrifera* (Grube, 1840)	*Hediste diversicolor* (O.F. Müller, 1776) *Heteromastus filiformis* (Claparède, 1864) *Perinereis cultrifera* (Grube, 1840)
CRUSTACEA	
Mysidacea	
Mesodopsis slabberi van Beneden 1861	*Mesodopsis slabberi* van Beneden 1861 *Siriella armata* (Milne-Edwards, 1837)
Amphipoda	
Corophium orientale Schellenberg, 1928 *Gammarus aequicauda* (Martynov, 1931) *Gammarus crinicornis* Stock, 1966	*Corophium orientale* Schellenberg, 1928 *Gammarus aequicauda* (Martynov, 1931) *Gammarus crinicornis* Stock, 1966 *Gammarus subtypicus* Stock, 1966
Isopoda	
Idotea baltica (Pallas, 1772) *Sphaeroma serratum* (Fabricius, 1787)	
Tanaidecea	
Leptochelia savignyi (Krøyer, 1842) *Tanais cavolini* Milne-Edwards, 1829 *Tanais filiformis* Lilljeborg, 1864	
Decapoda	
Carcinus aestuarii Nardo, 1847	
MOLLUSCA	
Bivalvia	
Abra ovata Philippi, 1836 *Cerastoderma glaucum* (Poiret, 1789)	*Cerastoderma glaucum* (Poiret, 1789)
Gastropoda	
Hydrobia acuta (Draparnaud, 1805) *Myosotella myosotis* (Draparnaud, 1801) *Nassarius incrassatus* (Strom, 1768) *Planorbis planorbis* (Linnaeus, 1758)	*Bittium reticulatum* (da Costa, 1778) *Theodoxus fluviatilis* (Linnaeus, 1758) *Hydrobia acuta* (Draparnaud, 1805) *Hydrobia ventrosa* (Montagu, 1803) *Myosotella myosotis* (Draparnaud, 1801) *Nassarius reticulatus* (Linnaeus, 1758)
PISCES	
Chelon labrosus (Risso, 1826) *Liza ramada* (Risso, 1826) *Liza saliens* (Risso, 1810) *Mugil cephalus* (Linneaus, 1758)	*Chelon labrosus* (Risso, 1826) *Gambusia affinis* (Baird & Girard, 1853) *Liza ramada* (Risso, 1826) *Liza saliens* (Risso, 1810) *Mugil cephalus* (Linnaeus, 1758)
REPTILIA	
Emys orbicularis (Linnaeus, 1758) *Natrix natrix* (Linnaeus, 1758)	
FLORA	
Chaetomorpha crassa (C. Agardh) Kützing 1845 *Carex riparia* Curtis *Juncus littoralis* C.A. Mey. *Enteromorpha* sp. *Phragmites australis* (Cav.) Trin. ex Steudel *Tamarix hampeana* L. *Phoenix theophrasti* Reuter *Salicornia* sp.	*Chaetomorpha crassa* (C. Agardh) Kützing 1845 *Chara aspera* C.L. Willdenow 1809 *Carex riparia* Curtis *Juncus littoralis* C.A. Mey. *Enteromorpha* sp. *Phragmites australis* (Cav.) Trin. ex Steudel *Potamogeton pectinatus* L. *Ruppia maritima* L. *Tamarix hampeana* L. *Salicornia* sp.

coordinates of sampling sites are given in Table 3. Water transparency was determined with a 25 cm diameter Secchi disc. The coordinates of the Akdeniz and Akbük sampling sites, biotope types and water transparency values are given in Table 3.

Ostracoda community structure was analyzed using the total number of individuals (n), the number of species (S), and the Shannon-Wiener species diversity (H') (Zar 1984). The Shannon-Weaver diversity index was estimated using Biodiversity Pro version 2.0 (McAleece 1997).

Sorensen's Similarity Index was used to compare ostracod fauna similarities of the two lagoons based on species presence following the formula:

$$\textit{Sørensen Similarity Index} = \left(\frac{2c}{a+b}\right) \times 100$$

where c - the number of species common to both sites A and B, a - the number of species found at site A, and b = the number of species found at site B (Magurran 1988).

Table 2

The data on physico-chemical environmental variables, ostracod species and number of ostracod specimens of each lagoon

Date	Station	pH	Eh	EC	Sal.	DO	%S	T (w)	Depth (m)		CT	LE	CF
		Akdeniz Lagoon											
03.05.08	Station 1	7.62	-39	25.6	15.7	3.50	41.0	19.0	0.5		287	78	6
03.05.08	Station 2	7.86	-53	25.5	15.5	4.44	52.3	23.0	0.5		1160	500	4
03.05.08	Station 3	7.89	-54	25.7	15.8	4.38	51.3	22.8	0.5		150	8	0
	Mean	7.79	-48.6	25.6	15.6	4.10	48.2	21.6	0.5	Total (n)	1597	586	10
25.07.08	Station 1	7.07	-41	27.7	17.2	4.33	57.0	21.5	0.4		245	60	12
25.07.08	Station 2	7.45	- 26	26.3	16.2	5.90	70.1	29.0	0.4		1900	1120	8
25.07.08	Station 3	7.50	- 28	26.6	16.5	4.70	59.4	28.7	0.4		16	19	0
	Mean	7.34	-31.6	26.8	16.63	4.97	62.1	26.4	0.4	Total (n)	2161	1199	20
09.10.08	Station 1	7.07	-4	33.2	20.5	3.30	44.0	19.7	0.4		170	25	5
09.10.08	Station 2	7.45	- 26	27.1	17.2	4.90	59.5	25.7	0.4		1123	870	4
09.10.08	Station 3	7.50	- 28	28.2	16.6	4.50	57.3	25.4	0.4		120	11	0
	Mean	7.34	-19.3	29.5	18.1	4.23	53.6	23.6	0.4	St.Total (n)	1413	906	9
20.12.08	Station 1	7.62	-39	26.6	16.2	3.50	41.0	17.0	0.5		137	110	4
20.12.08	Station 2	7.86	-53	25.9	16.5	5.21	69.3	16.0	0.5		655	340	3
20.12.08	Station 3	7.89	-54	26.4	16.8	5.38	72.5	15.6	0.5		98	9	0
	Mean	7.79	-48.6	26.3	16.5	4.69	60.9	16.2	0.5	St.Total (n)	890	459	7
	Max:	7.89	-54	33.2	20.5	5.9	72.5	28.7	0.5	Total Sum	6061	3150	46
	Min.	7.07	-54	25.5	15.5	3.3	41	15.6	0.4				
		Akbük Lagoon											
04.05.08	Station 1	8.02	-62	16.85	9.9	4.35	50.4	22.0	0.5		200	-	-
04.05.08	Station 2	7.97	-59	13.81	8.0	4.35	51.2	21.8	0.5		112	-	-
	Mean	7.99	-60	15.33	8.95	4.35	50.8	21.9	0.5	St.Total (n)	312	-	-
26.07.08	Station 1	8.50	-66	15.28	9.0	4.10	51.5	24.6	0.5		680	-	-
26.07.08	Station 2	7.81	- 61	14.20	8.3	4.87	54.3	22.0	0.5		700	-	-
	Mean	8.15	-63.5	14.74	8.65	4.48	52.9	23.3	0.5	St.Total (n)	1380	-	-
10.10.08	Station 1	8.31	-59	13.92	8.1	4.79	59.0	24.2	0.5		560	-	-
10.10.08	Station 2	7.87	- 53	12.70	7.6	4.50	54.5	22.3	0.5		624	-	-
	Mean	8.09	-56	13.31	7.85	4.64	56.7	23.2	0.5	St.total (n)	1184	-	-
21.12.08	Station 1	7.75	-48	12.2	7.1	5.40	75.0	14.0	0.5		80	-	-
21.12.08	Station 2	7.65	-41	10.7	6.6	4.53	55.2	13.0	0.5		54	-	-
	Mean	7.70	-44.5	11.45	6.85	4.96	65.1	13.5	0.5	St.Total (n)	134	-	-
	Max.	8.5	-66	16.85	9.9	5.4	75	24.6	0.5			-	-
	Min.	7.65	-41	10.7	6.6	4.1	50.4	13	0.5	Total Sum	3010	-	-

Abbreviations: pH; Eh - redox potential (mV); DO - dissolved oxygen (mg l^{-1}); $T_{(w)}$ - water temperature (°C); EC - electrical conductivity (mS cm^{-1}); S - oxygen saturation (%); Sal. - salinity (PSU); n - number of individuals; Max - maximum; Min - minimum; CT - *Cyprideis torosa*, LE - *Loxoconcha elliptica* and CF - *Cytherois fischeri*

Canonical Correspondence Analysis (CCA) (ter Braak 1986, 1987; ter Braak & Barendregt 1986) was used to show relationships between three species and six selected environmental variables (EC, DO, Temp, pH, Sal. and %Sat.) in Akdeniz lagoon. Only one ostracod species was identified in Akbük lagoon, so CCA was not used to analyze relationships with environmental variables. To provide congruity with CCA analyses, we also preferred to use the same environmental variables in correlation analysis. We used Spearman correlation analyses to outline correlations among variables and species. Correlations between species and environmental variables were analyzed with a two-tailed nonparametric Spearman correlation analysis performed with the SPSS 10.0 software program (SPSS 1999). These results are significant at the 0.01 level and/or 0.05.

Table 3

Coordinates, substrate type and water transparency values of each station in the Akdeniz and Akbük lagoons

Station No	Coordinates	Secchi Disc depth (cm)	Type of substrate
Akdeniz Lagoon			
1	37° 06' 49.08" N 27° 24' 00.48" E	Bottom 50 cm	Sandy -gravel
2	37° 06' 49.28" N 27° 24' 01.03" E	Bottom 50 cm	Sandy mud
3	37° 07' 09.09" N 27° 23' 50.30" E	Bottom 50 cm	Sandy mud
Akbük Lagoon			
1	37° 01' 55.19" N 28° 05' 53.26" E	Bottom 50 cm	Sandy mud
2	37° 02' 00.17" N 28° 05' 44.66" E	Bottom 50 cm	Muddy sand

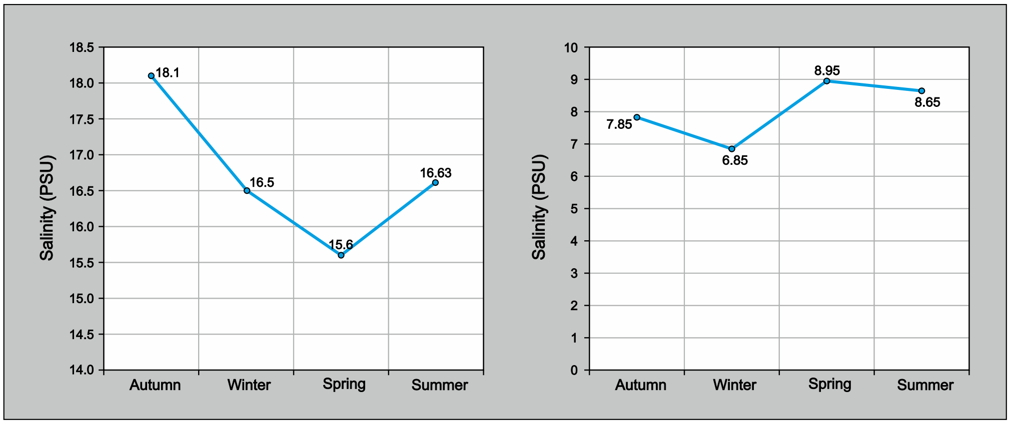

Figure 3

Seasonal variations in the salinity of Akdeniz and Akbük lagoons

Results

Three ostracod species (*Cyprideis torosa* (Jones, 1850), *Loxoconcha elliptica* and *Cytherois fischeri*) were found in the Akdeniz lagoon (Table 1). In the Akbük lagoon, only one species (*Cyprideis torosa*) was found. The most common species in the Akdeniz lagoon was *Cyprideis torosa*, which was present at all three sites, (6061 specimens, i.e. 65% of the total specimens counted), followed by *Loxoconcha elliptica* Brady, 1868 (also at all sites; 3150 individuals – 34%) and then *Cytherois fischeri* (Sars 1866) (sites 1 and 2 only; 46 specimens – 1%). Only *Cyprideis torosa* was found in the Akbük lagoon (present at both sites) (see Fig. 4).

Seasonal changes in the number of ostracods found in the Akdeniz lagoon are presented in Figure

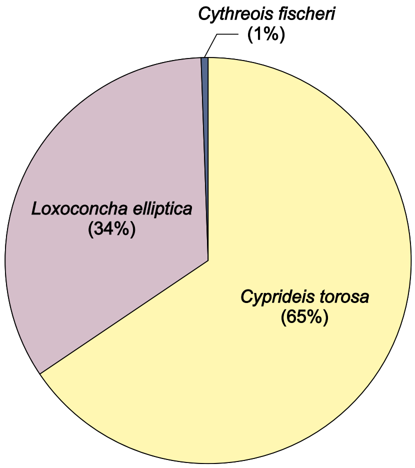

Figure 4

The number of specimens and the relative abundance rate of ostracod species found in Akdeniz lagoon

5, and for *Cyprideis torosa* in the Akbük lagoon in Figure 6, and the seasonal changes in the number and relative abundance (%) of *Cyprideis torosa* in Akbük lagoon in Figure 7.

In Akbük lagoon, approximately half (1520 specimens) of the total number of 3010 *Cyprideis torosa* specimens were found at the first site and most of the rest (1490 specimens) at the second site. The two sites at the Akbük lagoon had a similar number of species: the source water forming a stream towards the sea that affects both sites similarly. The highest abundance was observed in the summer (1380 specimens, 46%).

According to the Shannon-Weaver index, the highest level of diversity was found at Site 2 (*H'*=1.007) and the lowest at Site 3 (*H'*=0.289) in Akdeniz lagoon (Table 4, Fig. 8). The highest diversity for all sites was found in the summer months. The second site represents the lagoonal habitat, so this site has the highest biodiversity. The first site represents the lagoon's resource habitat, and the third site, by the canal to the sea, represents the slow flowing canal habitat (Fig. 6).

According to Sorensen's similarity coefficient, the ostracod fauna of Akdeniz lagoon is in 50% similar to Akbük (Table 5). According to the Spearman correlations analyses for the Akdeniz lagoon, *Cyprideis torosa* was positively correlated with *Loxoconcha elliptica* (r: 0.839, $p < 0.01$), while *Cytherois fischeri* was positively correlated with *Cyprideis torosa* (r: 0.649, $p < 0.05$) and *Loxoconcha elliptica* (r: 0.610, $p < 0.05$). These three species clearly show significant correlation (Table 5). There is a weak negative correlation between salinity and *Cyprideis torosa* and *Loxoconcha elliptica*. *Cytherois fischeri* is negatively correlated with pH ($p < 0.01$). Depth is positively correlated with pH ($p < 0.01$), but negatively correlated with electrical conductivity ($p < 0.01$), salinity ($p < 0.05$) and temperature ($p < 0.05$).

For the Akbük lagoon (Table 5), *Cyprideis torosa* shows a high positive correlation with temperature ($p < 0.05$), but is weakly (positively) correlated with pH, electrical conductivity, and salinity. *C. torosa* is weakly negatively correlated with DO and oxygen saturation (see Table 5). The pH was highly positively correlated with temperature ($p < 0.01$), electrical conductivity ($p < 0.05$), and salinity ($p < 0.05$) (see Table 5).

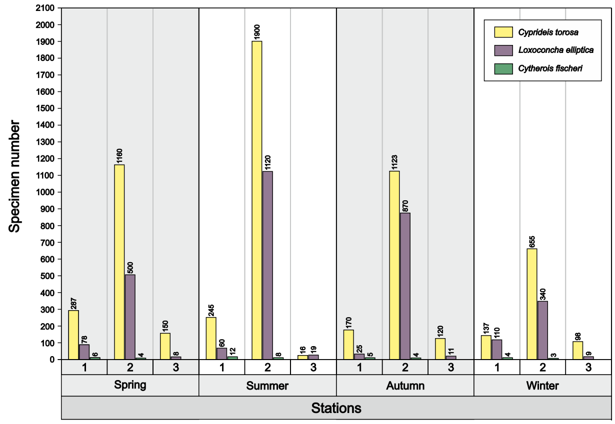

Figure 5

Seasonal changes in the number of ostracod species at the sampling sites in Akdeniz lagoon

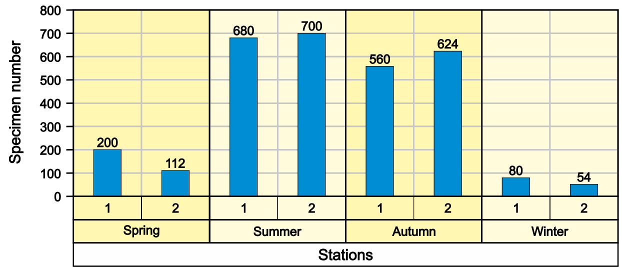

Figure 6

Seasonal changes in the number of specimens of *Cyprideis torosa* at the sampling sites in Akbük lagoon

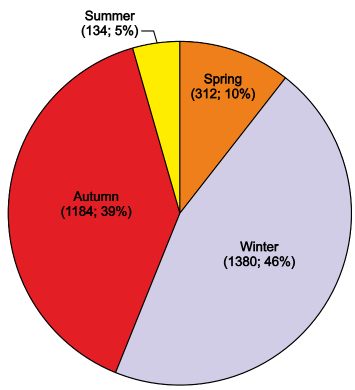

Figure 7

Seasonal changes in the absolute and relative abundance (%) of *Cyprideis torosa* in Akbük lagoon

Results from the salinity analysis shows that Akdeniz lagoon has either a mesosaline (Gasse et al. 1987) or α- mesosaline (Venice System 1958) character (Table 1). On the other hand, Akbük

Table 4

Shannon Weaver Diversity index values in spring, summer, autumn and winter

Station	number of species	number of specimens	Shannon-Weaver diversity index
		Spring	
1	3	371	0.856
2	3	1664	0.905
3	2	158	0.289
		Summer	
1	3	317	0.921
2	3	3028	0.975
3	2	35	0.995
		Autumn	
1	3	200	0.707
2	3	1997	1.007
3	2	131	0.416
		Winter	
1	3	251	1.094
2	3	998	0.953
3	2	108	0.417

lagoon has both mesosaline and β-mesosaline characteristics (Table 1). The pH of the two lagoons is alkaline. Water transparency is related to the type and concentration of suspended matter in the water body. The Secchi disk was seen at the bottom of both lagoons in all seasons (Table 2, 3). Because only one ostracod species was found in Akbük lagoon, CCA analysis was not appropriate or possible, but to offer consistency with the CCA analysis for Akdeniz, we used the same environmental variables but in a Pearson correlation analysis (Table 6). Neither CCA (Akdeniz) nor Pearson correlation analysis (Akbük) indicated a relationship between physicochemical conditions and species occurrence and spatial distribution, because neither of the two lagoons conforms to typical specifications (shallowness, high evaporation in the summer period, and low water flow) as do most other lagoons. Moreover, these three species are able to tolerate a wide range of fluctuating ecological conditions. *Cyprideis torosa* and *Loxoconcha elliptica* can be found closer to the center of the CCA diagram due to euryhaline characteristics, whereas *C. fischeri* is a better discriminant in its selection of brackish water conditions (Fig. 9).

See figure 10 for photographs of *Cyprideis torosa* and *Loxoconcha elliptica*.

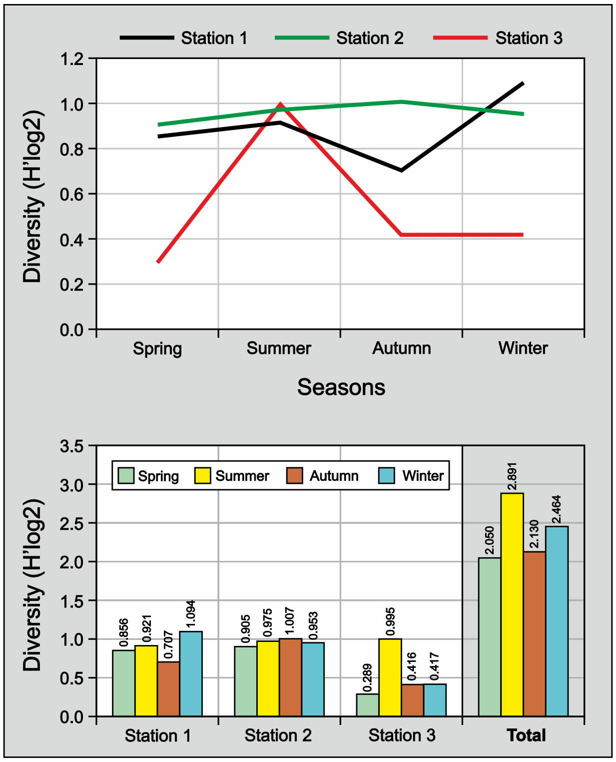

Figure 8

Seasonal Shannon-Weaver diversity index values for Akdeniz lagoon

Discussion

The mean salinity level in the Akdeniz lagoon was 16.5 PSU in winter, 15.6 PSU in spring and increased from 16.63 PSU to 18.1 PSU in the summer months, most probably because of the decreased

Table 5

Spearman correlations between the environmental variables and ostracod species. Codes are the same as in Tables 2. High correlations (P<0.05) and (P<0.01) are indicated in bold.

Variables	pH	EC	SAL	DO	%S	T	Depth	CT	LE	CF
	Akdeniz Lagoon									
pH	1									
EC	-0.534	1								
SAL	-0.446	0.870(**)	1							
DO	0.127	-0.165	0.042	1						
%S	0.021	0.056	0.316	0.951(**)	1					
T(w)	-0.468	0.126	-0.063	0.266	0.189	1				
Depth	0.778(**)	-0.750(**)	-0.631(*)	-0.097	-0.241	-0.676(*)	1			
CT	-0.306	-0.382	-0.250	0.147	0.063	0.238	0.000	1		
LE	-0.472	-0.210	-0.176	0.231	0.133	0.266	-0.097	0.839(**)	1	
CF	-0.719(**)	0.052	0.052	-0.319	-0.269	0.065	-0.248	0.649(*)	0.610(*)	1
	Akbük Lagoon									
pH	1									
EC	0.762(*)	1								
SAL	0.762(*)	1.000(**)	1							
DO	-0.635	-0.479	-0.479	1						
S	-0.452	-0.690	-0.690	0.778(*)	1					
T(w)	0.850(**)	0.647	0.647	-0.404	-0.204	1				
Depth	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	1			
CT	0.500	0.643	0.643	-0.156	-0.286	0.790(*)	N.S.	1		

** p<0.01 level (2-tailed) * p<0.05 level (2-tailed) N.S. not significant;

Table 6

The main results of Canonical Correspondence Analyses for Akdeniz Lagoon

Axis	1	2	3	4	Total inertia
Eigenvalues	0.026	0.007	0.015	0.001	0.049
Species-environment correlations	0.816	0.844	0.000	0.000	
Cumulative percentage variance of species data	52.7	67.6	97.9	100.0	
Cumulative percentage variance of species-environment relation	77.9	100.0	0.0	0.0	
Sum of all eigenvalues					0.040
Sum of all canonical eigenvalues					0.033

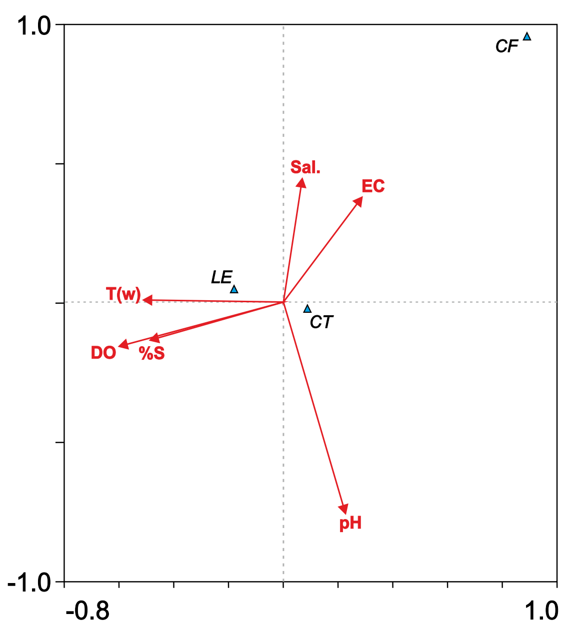

Figure 9

Diagram of Canonical Correspondence Analysis (CCA) shows relationships between 3 species (triangular) and six selected environmental variables (EC, DO, Temp., pH, Salinity and percentage oxygen saturation) (arrows) in Akdeniz Lake. Abbreviations are the same as in Table 2.

precipitation and evaporative losses at the end of the spring and summer months (Table 7). We also observed the highest salinity rate at site 1 in October (20.5) and the lowest at site 2 in May (15.5). The Akdeniz lagoon is fed by water sources from the foot of a south-facing slope. This water has a mesosaline character and a flow rate that rises in the winter and spring months. The brackish water sources are supplemented by surface drainage from small hill slopes on the southern side of the lagoon and seawater drainage from the aquifers at

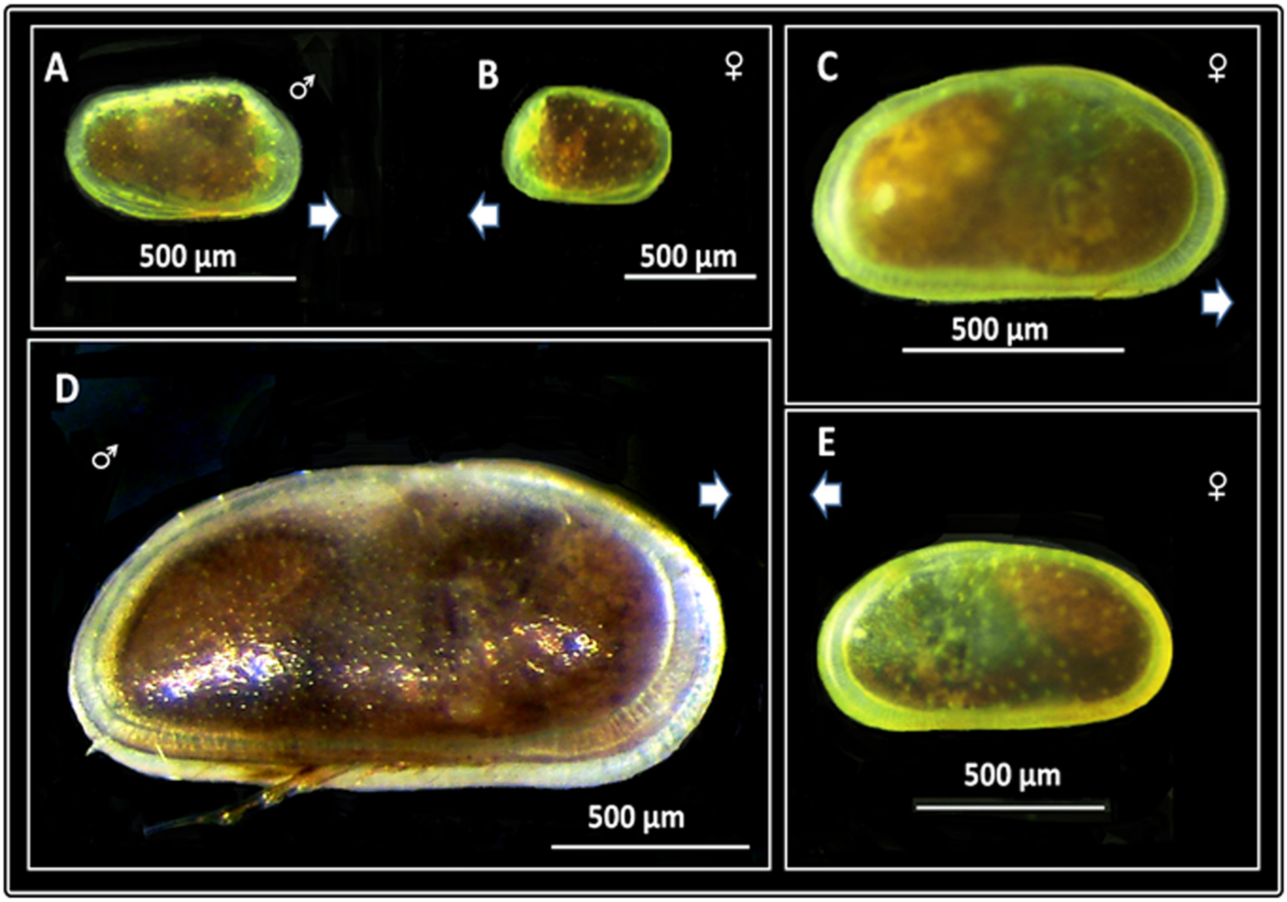

Figure 10

A - *Loxoconcha elliptica* (Male); B - *Loxoconcha elliptica* (Female); C - *Cyprideis torosa* (Female); D,E - *Cyprideis torosa* (scale 500 µm). White arrows: Anterior side

the base of the lagoon. The reason for the brackish character of the water sources is that they are mainly composed of the sea water sources. The permanent water sources around the lagoon are not apparent and visible due to the raised water level in rainy years, but they become evident when the rain decreases and the water level falls in the summer and autumn months. There is definitely no water entry from the channels which connect the lagoon with the sea, as the flow is always outward.

Table 7

The precipitation level of the Muğla province between the 1960-2012 (DMİ 2013). http://dmi.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=MUGLA

Winter months	Spring months	Summer months	Autumn months
kg m^{-2}			
183-227.9	46.8-118	9.8-22.7	23-139.2

Around the Akbük lagoon, there are no supplementary surface water sources. This lagoon is fed internally, from the bottom. High flow water resources exist on contact line of terrestrial and coastal strata at northern side of the Akbük lagoon. Aquifers located at the bottom of the lagoon are regularly fed by the seawater and rain water. The lagoon water is therefore brackish. Akbük lagoon water is less salty than Akdeniz, because it receives relatively more fresh water. Salinity levels decrease further during rainy seasons. Like the Akdeniz lagoon, Akbük also has no water supply whatsoever from the narrow channels which connect it with the sea, again with the water from this canal running seaward throughout the year. The clarity and blue coloration of the water in both lagoons indicate very low levels of nutrients and algae. Secchi disc measurements and physical specifications (always clear and blue waters) confirm this. The fact that both lagoons are supplied by underground water and rain, and flow outward into the sea, and also the small amounts of nitrogen and phosphorus that enter due to the negligible use of fertilizers in the surrounding olive plantations, suggest that both lagoons have oligotrophic characters.

Low diversity values could be natural or a result of anthropogenic stress – in other words, low values of Shannon's diversity may not necessarily be a sign of degradation (Rullet & Duavin 2007). The majority of *Cyprideis* species inhabit brackish (oligo-, meso-, meta-, and hypersaline) environments (Van Morkhoven 1963). *Cyprideis torosa* (Jones 1850) is a member of the brackish biocenosis in European coastal waters and is often very abundant in hypo- as well as in hypersaline waters (Meisch 2000). It is also one of the commonest marginal marine ostracod species in the northern hemisphere (Frenzel et al. 2012). It is a holoeuryhaline and strongly eurythermic species, but its main distribution is in the sediments of shallow brackish water habitats where large amounts of organic detritus are present (Heip 1976). As well as being a detritus feeder, *Cyprideis torosa* also lives on algae, diatoms, and bacteria (Meisch 2000). The substrates of both lagoons are composed of sand or gravel and do not include rich detritus. Any detrital material would be transported out of the lagoons through the seawater channels. This probably explains why high densities of populations containing large number of individuals of *Cyprideis torosa* were not observed in the present study.

Cyprideis torosa has been recorded in 14 (some oligohaline, some hypersaline) coastal wetland areas of Turkey examined by Altınsaçlı (2004). This species was identified at the Ayvalık saltpan, Badavut lagoon, Yenişakran saltpan (Kubanç & Altınsaçlı 1990), Küçükçekmece lake (lagoon) (Külköylüoğlu et al. 1993), Karaboğaz lagoon (Kaleli 1993), Akyatan lagoon (Nazik et al. 1999), Çamaltı saltpan (Meriç et al. 2010), and Hersek lagoon (Mischke et al. 2012). It was also found in the spring water which feeds hypersaline Lake Acıgöl by Altınsaçlı and Mezquita (2008). The Akdeniz and Akbük mesosaline lagoons are therefore preferred habitats for *Cyprideis torosa*.

The surface sediments taken from the Akbük lagoon contained some subfossil valves of *Cyprideis torosa* in noded forms. *Cyprideis torosa* develops phenotypic tubercles on one or both valves when moving to less saline environments (Van Morkhoven 1963, Keyser & Aladin 2004). In water with low salinity (< 5 PSU), the valves often have nodes (Sandberg 1964; Vesper 1972, 1975; Neale 198). We suggest that from time to time the salinity level in the lagoon falls below < 5 PSU (or 7 PSU) in rainy seasons of very wet years. Although the Akbük lagoon is a lagoon, it is fed by very large karstic brackish water springs. In the Akdeniz lagoon sediments, only subfossil valves without nodes (*Cyprideis torosa* forma *littoralis*) are found. The physicochemical conditions in Akdeniz and Akbük provide a very suitable habitat for this form of the species. This account for the fact that 65% of the ostracod samples collected in Akdeniz belonged to this species (*C. torosa*), a percentage that rises to 100% in Akbük.

In both lagoons, females exceed male in number. *C. torosa* produces eggs all year round and show a bivoltine reproductive pattern (Mezquita et al. 2000). The first generation of *Cyprideis torosa*, from eggs produced in spring, reaches the adult size after approximately 154 days (Mezquita et al. 2000). The second generation, starting in autumn, develops more slowly, reaching adulthood after 196 days on average. Maximum counts for *C. torosa* in both lagoons in the summer months confirm this reproductive pattern (Table 2), these results therefore match those of Mezquita et al. (2000).

Loxoconcha elliptica (Brady 1868) is another frequent and ubiquitous species found in brackish coastal waters (mesohaline) with salinity levels between 18–30 PSU. It thrives in shallow waters (20 m or less) in lagoons, gulfs, estuaries, river mouths, and tidal plains, commonly associated with algae and mud (Bonaduce et al. 1975, Carbonel et al. 1975, Athersuch et al. 1989, Pascual & Carbonel 1992, Besonen 1997). *Loxoconcha elliptica* tolerates a wide range of salinities and is frequent in coastal swamps, estuaries and lagoons (Ghetti & McKenzie 1981, Athersuch et al. 1989); it even tolerates high salinities (up to 65 PSU) in Mediterranean saltpans (Zaninetti 1982, 1984) where it is found together with *C. torosa*. This euryhaline species was found together with *Cyhterois fischeri* in the lower section of the Huelva Estuary (Ruiz 1995) and has been recorded from similar wetland areas like Mecidiye lagoon, Vakıf lagoon, Lake Köyceğiz, Güllük lagoon (Altınsaçlı 2004) and the Tuzla saltpan (Kubanç & Altınsaçlı 1990) together with *Cyprideis torosa*. In this study, it was recorded in sandy mud and sandy substrate with rock in the Akdeniz lagoon, again together with *C. torosa*. The water quality at this site is strongly influenced by a freshwater inflow and does not become strongly hypersaline in summer. Two of the recorded species: *Cyprideis torosa* and *Loxoconcha elliptica* occur normally with rather even populations through the year, while the third one (*Cytherois fischeri*) was found only during the warm season. *Loxoconcha elliptica* begins reproduction in spring, producing two or three generations through the summer, the last surviving through the following winter (Athersuch et al. 1989). Our data is therefore consistent with data of Athersuch et al. (1989). *Loxoconcha elliptica* is used as an indicator organism in ecological and paleoecological studies, along with *Cyprideis torosa.* It is always subordinate to *Cyprideis torosa* when found in the same habitat (Altınsaçlı, unpublished data). Our observations indicate that as the ostracod population density increases, its species diversity decreases.

Cytherois fischeri (Sars 1866) was found at sites 1 and 2 in the Akdeniz lagoon. Like *L. elliptica* and *C. torosa*, *C. fischeri* is a euryhaline species (Rodriguez & Pascual 1985; Ruiz et al. 1996; Ruiz et al. 1997a, b). It has been found in estuaries (Rodriguez et al. 1985, Ruiz et al. 1996) and lagoons (Ruiz et al. 2006). *C. fischeri* has been recorded at the Güllük lagoon, Köyceğiz Lake (lagoon), and Sülüngür Lake (lagoon) by Altınsaçlı (2004). It was found together *C. torosa* and *L. elliptica* at the Güllük lagoon and Köyceğiz Lake (lagoon) (Altınsaçlı 2004). *Cyhterois fischeri* populations develop from overwintering eggs that hatch in spring and may produce three or even four generations before late autumn (Athersuch et al. 1989).

The reason why *C. torosa* is the only ostracod found in the Akbük lagoon is that the saline level in this lagoon is much lower (6.6–9.9 PSU) and the water flow rate is much higher than in many other lagoons. Akbük lagoon has an even lower salinity than Akdeniz (15.5–20.5 PSU). The high flow rate through the exit channels at Akdeniz prevents seawater access. The high osmoregulatory capacity of *C. torosa* allows this species to adapt easily to both high and low salinity levels. According to the data collected in this study, it might be inferred that *C. fischeri* and *L. elliptica* do not prefer very low salinity environments, because large populations of both species have been observed in the sections of seawater inflow (Altınsaçlı 2004).

C. fischeri and *L. elliptica* are positively correlated in the Akdeniz lagoon (Table 5). Both occupy similar habitats and interact with each other (Ruiz et al. 1997a, Ruiz et al. 2000, Ruiz et al. 2004). Mazzini et al. (1999) have also observed *C. torosa* and *L. elliptica* together in similar environments. Montenegro (1995) had determined them as dominant species in Marano and Grado lagoons in Italy. As well as ostracod species, many species of plants and animals that characterize lagoon habitats and are found in these lagoons (Table 1). According to these results, and similarly other Aegean Sea coast lagoons (Kevrekidis 1997, 2004; Kevrekidis et al. 2000; Sylaios & Theocharis 2002; Mogias & Kevrekidis 2005; Sabancı 2012), Akdeniz and Akbük have rich biodiversity. However, because brackish water is too salty for most freshwater species and too fresh for most marine species, brackish water lagoons are distinguished for their reduced biodiversity compared to either fully marine, or completely freshwater systems.

If anthropogenic activities (rapid population growth, tourism, holiday cottages, inadequate waste disposal systems) intensify around these two lagoons, overall species diversity, its functional significance, and habitat quality will all be threatened. In addition to these problems, several other threats are foreseeable in Turkey, for example: increasingly intensive land use, water extraction, regulation of waters, non-sustainable water management practices and climate change. The intensive use of fertilizers and pesticides in agriculture, the discharge of sewage and industrial waste waters are major threats to natural aquatic ecosystems. The detection of gamma Protobacteria in the Gulf of Güllük (adjacent to Akbük and Akdeniz lagoons) indicates the discharge of domestic waste water (Altuğ et al. 2013).

The presence of sandy-gravel substrates and high water flow explains the reduced number of ostracod species in these two lagoons. Without these influences, the ostracod community would show a lower diversity and smaller numbers of individuals. Our hypothesis is that the lowest abundance and dominance of just three species is accounted for by the high water outflows rates of lagoons.

In the present study, the relationship between the water and surface sediments characteristics of Akbük and Akdeniz lagoons and their ostracoda assemblages has been established. *Cyprideis torosa* dominates in both sediments and water, followed by *Loxoconcha elliptica* as the second most abundant and common species in Akdeniz lagoon. These two species are nowadays commonly found together in permanent brackish waters of coastal Aegean wetlands, but *C. torosa* is more widely distributed and more tolerant to different salinities from freshwater to hypersaline environments. The diversity is considerably reduced at Akbük and Akdeniz lagoons because of the increased dominance of *Cyprideis torosa*, as a result of the changing conditions that favor the growth of this euryhaline species.

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References

Anadón, P., Utrilla, R. & Julia, R. (1994). Palaeoenvironmental reconstruction of a Pleistocene lacustrine sequence from faunal assem blages and ostracode shell geochemistry, Baza Basin, SE Spain. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 111: 191–205.

Altınsaçlı, S. (2004). Investigation on Ostracoda (Crustacea) Fauna of Some Important Wetlands of Turkey. *Pak. J. Biol. Sci.* 7: 2130–2134. DOI: 10.3923/pjbs.2004.2130.2134

Altınsaçlı, S.& Mezquita, F. (2008). Ostracod fauna of salt Lake Acıgöl (Acı Tuz) (Turkey), *J. of Nat. Hist.*. 42, 1013 – 1025. *DOI*: 10.1080/00222930701851735.

Altuğ, G., Mine Çardak, M., Çiftçi Türetken, P.S., Gürün, S. & Kalkan, S. (2013). Bacteriological Diversity in Güllük Gulf, Bacteriology of the Güllük Gulf. TÜBITAK Project Workshop, 10 May 2013 Güllük Muğla, 3-6.

Athersuch, J. (1977). The genus *Urocythereis* (Crustacea; Ostracoda) in Europe, with particular reference to Recent Mediterranean species. *Bull. Br. Mus. of Nat. Hist.,* 32(7), 247-283.

Athersuch, J., Horne, D.J. and Whittaker, J.E. (1989). *Marine and Brackish Water Ostracods. (In: Kermack DM, Barnes RSK. (eds.), Synopses of the British Fauna* (New Series), no. 43. E.J. Brill, Leiden (for the Linnean Society of London and the Estuarine and Brackish Water Sciences Association) pp. 343.

Barbeito-Gonzales, J.P. (1971). Die ostracoden des künstenbereiches von Naxos (Griechenland) und ihre lebensbereiche. *Mitt. Zool. St. und Zool. Mus. in Hamburg,* 67: 255-326.

Besonen, M.R. (1997). *The Middle and Late Holocene Geology and Landscape Evolution of the Lower Acheron River Valley, Epirus, Greece*. [dissertation], University of Minnesota, Faculty of the Graduate School, p.161.

Bodergat, A.M., Rio, M. & Andreani, A.M. (1991). Composition chimique et ornamentation de *Cyprideis torosa* (Crustacea, Ostracoda) dans le domaine paralique. *Oceanologica Acta* 14: 505-514.

Breman, B. (1975). The distribution of ostracodes in the bottom sediments of the Adriatic Sea. *Krips Repro, Meppel*, 50-165.

Boomer, I. (1993). Palaeoenvironmental indicators from Late Holocene and contemporary ostracoda of the Aral Sea. -*Palaeogeogr. Palaeoclimatol. Palaeoecol.* 103: 141-153.

Boomer, I., Whatley, and Aladin, N.V. (1996). Aral Sea Ostracoda as environmental indicators. - *Lethaia* 29:77- 85. DOI: 10.1111/j.1502-3931.1996.tb01840.x

Bonaduce, G., Ciampo, G & Masoli, M. (1975). Distribution of Ostracoda in the Adriatic Sea. *Publicazioni Della Stazione Zoologica di Napoli*, 40: 1-154.

Boydak, M. and Barrow; S. (1995). A new Locality of Phoenix in Turkey; Gölköy- Bodrum. *Principes*, 39: 117-122.

Bronshtein, Z. S. (1947). Fresh-water Ostracoda. Fauna of the USSR Crustaceans, Vol. 2, No.1. *Russian Translation Series* 64, Oconian Press, New Delhi.

Carbonnel, G. (1983). Morphometrie et hypersalinite chez *Cyprideis torosa* (Jones) (Ostracoda, Actuel) dans les Salines de Santa-Pola (Alicante, Espagne). -*Sciences Geologiques, Bulletin* 36: 211-219.

Carbonel, P., Moyes, J. & Peypouquet, J. P. (1975). Utilisation des Ostracodes pour la mise en evidence et l'evolution d'une lagune holocene a l'ouest de la Gironde, Golfe de Biscay. *Bull Am. Paleontol*. 65: 445-462.

Deniz, H. & Çelebi, R. (2008). Fisheries management in Turkish lagoons. Proceedings of the symposium on "Interactions between social, economic and ecological objectives of inland commercial and recreational fisheries and aquaculture, Antalya, Turkey, 21-24 May 2008. *EIFAC Occasional Paper* No.44. Rome, FAO. 2010, 275 pp. 188-200.

DMİ, (2013) The precipitation level of the Muğla province between the 1960-2012 [Internet]. [cited 2013 Dec 07]. Available from: http://dmi.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=MUGLA.

Frenzel, P. & Boomer, I. (2005). The use of ostracods from marginal marine, brackish waters as bioindicators of modern and Quaternary environmental change. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 225: 68–92. *DOI*: 10.1016/j.palaeo.2004.02.051.

Frenzel, P., Schulze, I., Pint, A., Boomer, I.& Feike, M. (2011). Salinity dependant morphological variation in *Cyprideis* *torosa*. *Joannea Geol. und Palaontol.*11: 59.

Frenzel, P., Schulze, I. and Pint, A. (2012). Noding of *Cyprideis torosa* valves (Ostracoda) – a proxy for salinity' New data from field observations and a long-term microcosm experiment International Review of *Hydrobiol.*, 97, 314–329.

Gasse, F., Fontes, J.C., Plaziat, J.C., Carbonel, P., Maczmarska, I., De Deckker, P., Soulie-Marsche, I., Callot, Y and Depeuple, P.A. (1987). Biological remains Geochemistry and stable isotopes for the Recontructions of environmental and hydrological changes in the Holocene lakes from North Sahara. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 60, 1-146.

Ghetti, P.F. and McKenzie, K.G. (1981). Ostracodi (Crustacea, Ostracoda). Guide per il riconoscimento delle specie animali delle acque interne italiane. *Consiglio Nazionale delle Ricerche* AQ/1/108, 1- 83 pp.

Hartmann, G. & Puri, S.H. (1974). Summary of neontological and paleontological classification of Ostracoda. *Mitt. Zool. St. und Zool. Mus. in Hamburg,* Band 70, 7-73.

Heip, C. (1976). The life-cycle of *Cyprideis torosa* (Crustacea, Ostracoda). *Oecologia*, 24, 229-245.

Herman, P.M.J. & Heip, C. (1982). Growth and respiration of *Cyprideis torosa* Jones 1850 (Crustacea Ostracoda), *Oecologia* 54, 300-303.

Jahn, A., Gamenick, I. & Theede, H. (1996). Physiological adaptations of *Cyprideis torosa* (Crustacea, Ostracoda) to hydrogen sulphide. Mar. Ecol. Prog. Ser., 142, 215–223. DOİ:10.3354/meps142215.

Kaleli, A. (1993). Orta Karadeniz Sahil Ostrakod Faunası [Ostracoda fauna of the mid BlackSea coasts] Deniz Bilimleri ve İşletmeciliği Enstitüsü [Institute of marine sciences and management [dissertation] Istanbul University. Turkish.

Keyser, D. & Aladin, N. (2004). Noding in *Cyprideis torosa* and its causes, Studia Quaternaria, 21: 19–24.

Kevrekidis, T. (1997). Seasonal variation of the macrobenthic fauna in an isolated area of the Evros Delta (North Aegean Sea). – *Israel J. Zool.* 43: 243–255. *DOI*: 10.1080/00212210.1997.10688909

Kevrekidis, T., Mogias, A. & Gouvis, N. (2000). Interannual changes in the composition of the macrobenthic fauna of Drana lagoon (Evros Delta, N. Aegean Sea): preliminary note *Belg. J. Zool.* 130: 105-111.

Kevrekidis, T.(2004). Seasonal Variation of the Macrozoobenthic Community Structure at Low Salinities in a Mediterranean Lagoon (Monolimni Lagoon, Northern Aegean). *Internat. Rev. Hydrobiol.* 89: 407-425.

Kilenyi, T.L. (1972). Transient and balanced genetic polymorphism as an explanation of variable noding in the ostracode *Cyprideis torosa*. - *Micropaleontology* 18: 47-63.

Kubanç, C. & Altınsaçlı, S. (1990). Ayvalık- Bergama Lagün Ostrakod Faunası.[The Ostracoda fauna of the Ayvalık-Bergama Lagoon] X.Ulusal Biyoloji Kongresi Tebliğleri, [Papers of X. National Biological Congress Erzurum] pp.37-46.

Külköylüoğlu, O., Altınsaçlı, S. & Kubanç, C. (1993). The Ostracoda (Crustacea) fauna of Küçükçekmece Lake (İstanbul) and seasonal distributions. Doğa-*Tr.J. Zool.* 17: 19-27

Magurran, A.E. (1988). *Ecological diversity and its measurement*. Princeton University Press, Princeton, NJ. pp. 179.

Marco-Barba, J., Ito, E., & Mesquita-Joanes, F.(2012). Empirical calibration of shell chemistry of *Cyprideis torosa* (Jones, 1850) (Crustacea: Ostracoda) *Geochimica et Cosmochimica Acta* 93: 143-163. DOI: 10.1016/j.gca.2012.06.019

Marco-Barba, J., Mesquita-Joanes, F. and Miracle, M.R. (2013**).** Ostracod palaeolimnological analysis reveals drastic historical changes in salinity, eutrophication and biodiversity loss in a coastal Mediterranean lake. *The Holocene* 23: 556–567.

Mazzini, I., Anadon, P., Barbieri, M., Castorina, F., Ferreli, L., Gliozzi, E., Mola, M. &Vittori, E. (1999). Late Quaternary sea level changes along the Tyrrhenian coast near Orbetello (Tuscany, central Italy): palaeoenvironmental reconstruction using ostracods. *Mar. Micropaleontol.*, 37:289-311. *DOI*: 10.1016/S0377-8398(99)00023-7.

McAleece, N. (1997). Biodiversity professional beta version. *The Nat. Hist. Museum and Scot. Assoc. Mar. Sci*

Meisch C. 2000. Freshwater Ostracoda of Western and Central Europe. In Schwoerbel, J. & P. Zwick (eds) Süsswasserfauna von Mitteleuropa 8/3. Spektrum Akademischer Verlag, Heidelberg.

Mezquita, F., Griffiths, I., Sanz, S., Soria, J.M. & Piñón, A. (1999a). Ecology and distribution of ostracods associated with flowing waters in the eastern Iberian Peninsula. *J. Crust. Biol.* 19: 344–354.

Mezquita, F., Hernandez, R. & Rueda, J. (1999b). Ecology and distribution of ostracods in a polluted Mediterranean river. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 148: 87–103. DOI: 10.1016/S0031-0182(98)00177-1.

Mezquita, F., Tapia, G. & Roca, J.R. (1999c). Ostracoda from springs on the eastern Iberian Peninsula: ecology, biogeography and palaeolimnological implications. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 148: 65–85. DOI: 10.1016/S0031-0182(98)00176-X

Mezquita, F., Olmos, V. & Oltra, R. (2000). Population ecology of *Cyprideis torosa* (Jones, 1850) in a hypersaline environment of the Western Mediterranean (Santa Pola, Alacant) (Crustacea: Ostracoda). *Ophelia*, 53: 119-130.DOİ: 10.1080/00785236.2000.10409442

Meriç, E., Avşar, N., Nazik, A., Barut, I.F., Bergin, F., Balkıs, N., Öncel, M.S. & Kapan-Yeşilyurt, S. (2010). The response of benthic foraminifer, ostracod and mollusc assemblages to environmental conditions: a case study from the Çamaltı Saltpan (Izmir-Western Turkey) *Mediter. Mar. Sci.* 11:05-32. DOI: 10.12681/mms.88.

Mischke, S., Schudack, U., Bertrand, S. & Leroy, S. (2012). Ostracods from a Marmara Sea lagoon (Turkey) as tsunami indicators. *Quatern. Int.*, 261: 156-161. DOI:10.1016/j.quaint.2010.11.013.

Mogias, A. & Kevrekidis, T. (2005). Macrozoobenthic community structure in a poikilohaline Mediterranean lagoon (Laki Lagoon, northern Aegean) *Helgol. Mar. Res*. 59: 167–176. DOI 10.1007/S10152-004-0215-1

Montenegro, M.E. (1995). *Distribution of the Ostracods in the Marano and Grado lagoons (northern Adriatic sea, Italy) and their tolerability to environmental fluctiations*. Ostracoda and Biostratigraphy, (Ed. Riha) Balkema, Rotterdam, 377-379.

Mordukhai-Boltovskoi (ed.) F.D.(1969). *A key to fauna of Black Sea and Azov Sea*. 536 pp.

Nazik, A., Evans, G. & Gürbüz, K. (1999). Sedimentology and paleontology with special reference to the ostracoda fauna of Akyatan Lagoon (Adana-SE Turkey), *Geosound*, 35:127-147.

Neale, J.V. (1988). *Ostracods and paleosalinity reconstruction*. In: De Deckker, P., Colin, J.P.& Peypouquet JP. (eds), Ostracoda in the Earth Sciences. Amsterdam, Elsevier: 125–155.

Pascual, A. & Carbonel, P. (1992). Distribution and annual variations of *Loxoconcha elliptica* in the Gernika Estuary (Bay of Biscay). *Geobios*, 25: 495-503.

Perçin-Paçal, F. (2011). The ecology of the Ostracoda (Crustacea) species obtained from the coasts of Iskenderun Bay (Eastern Mediterranean Sea) *J. Black Sea/Mediterr. Environ*. 17(2): 127-144.

Roca, J.R. & Julia, R. (1997). Late-glacial and holocene lacustrine evolution based on ostracode assemblages in southeastern Spain. - *Geobios* 30: 823-830. DOI:10.1016/S0016-6995(97)80183-0

Rodriguez Lazaro J, Pascual A. 1985. Estudio preliminar de los ostracodos de1 estuario de la ria de Bilbao. Actas Reunion Cuaternario Iberico;1: 229-240.

Rosenfeld, A. & Ortal, R. (1983). *Ostracodes as indicators of water pollution in Nahal Harod, Northern Israel*. In: Maddocks, R.F. (Ed.), Applications of Ostracoda. University of Houston, Geosciences, Houston, Texas.

Rullet, T. & Duavin, J.C. (2007). Benthic indicators: analysis of the threshold values of ecological quality classifications for transitional waters. *Mar. Pollut. Bull.,* 54:1707-1714. DOI:10.1016/j.marpolbul.2007.07.003

Ruiz Munoz, F. (1995). Los ostracodos del litoral de la provincia de Huelva (SW de Espania). Servicio de Publicaciones de la Universidad de Huelva, Libro electronico no. 1 1995:275.

Ruiz, F., Gonzalez-Regalado, M.L. & Morales, J.A. (1996). *Distribución y ecología* de los foraminiferos y ostracodos actuales del estuario mesomareal del rio Guadiana (S.0. Espania). *Geobios*. 29.:513-529.

Ruiz, F., Gonzalez-Regalado, M.L. & Munoz, J.M. (1997a). Multivariate analysis applied to total and living fauna: ecology of recent benthic Ostracoda of the North Cadiz Gulf coast (Southwestern Spain). *Mar. Micropaleontol.* 31: 183-203. DOI:10.1016/S0377-8398(96)00060-6

Ruiz, F., Gonzalez-Regalado, M.L., Borrego Flores, J. & Morales, J.A. (1997b). The response of ostracod assemblages to recent pollution and sedimentary processes in the Huelva Estuary, SW Spain. *Sci Total Environ*. 207: 91 –103. DOI:10.1016/S0048-9697(97)00275-1

Ruiz, F., Gonzalez-Regalado, M.L., Baceta, J.I. & Munoz, J.M. (2000). Comparative ecological analysis of the ostracod faunas from low- and high-polluted southwestern Spanish estuaries: a multivariate approach. *Mar. Micropaleontol*., 40: 345-376. DOI:10.1016/S0377-8398(00)00048-7

Ruiz, F., Gonzalez-Regalado, M.L., Borrego, J., Abad, M. & Pendon, J.G.(2004). Ostracoda and Foraminifera as short-term tracers of environmental changes in very polluted areas: the Odiel Estuary (SW Spain). *Environ. Pollut.* 129: 49-61. DOI:10.1016/j.envpol.2003.09.024

Ruiz, F., Abad, M., Bodergat, A.M., Carbonel, P., Rodríguez-Lázaro, J. & Yasuhara, M. (2005). Marine and brackish-water ostracods as sentinels of anthropogenic impacts. *Earth–Sci. Rev*. 72: 89–111.

Ruiz, F., Abad, M., Galán, E., González, I., Aguilá, I., Olías, M., Gómez Ariza, J.L. & Cantano, M. (2006). The present environmental scenario of El Melah Lagoon (NE Tunisia) and its evolution to a future sabkha. *J. Afr. Earth Sci*., 44: 289-302. DOI:10.1016/j.jafrearsci.2005.11.023

Sabancı, F.Ç. (2012). Taxonomic Survey of Benthic Diatoms on Natural Substrata From Coastal Lagoon (Aegean Sea, Turkey) *Turk. J. Fish. and Aquat. Sci.* 12: 841-849. DOI: 10.4194/1303-2712-v12_4_12

Sandberg, P.A. (1964). The ostracod genus *Cyprideis* in the Americas. Stockholm Contrib. *Geol.* 12: 1–178.

Sorensen, T.A. (1948). Method of establishing groups of equal amplitude in plant sociology based on similarity of species content // *Kongelige Danske Videnskabernes Selskab. Biol. krifter. Bd* V. № 4 . P. 1-34.

SPSS, (1999). SPSS 10.0 for Windows.,1999, SPSS Inc.

Stambolidis, A.E. (1985). Zur kenntnis Der Ostracodes des Evros-Delta (North-Agaisches Meer) Griechland. *Mitt. Zool. St. und Zool. Mus. in Hamburg*, 82:155-254.

STM & MARA, 1996. *A study on management and development strategies for lagoons along the Turkish coastline and their rehabilitation*. Draft Final Report, TUGEM, MARA, Ankara.

Sylaios, G. & Theocharis, V. (2002). Hydrology and Nutrient Enrichment at Two Coastal Lagoon Systems in Northern Greece, *Water Resources Management* 16: 171–196.

Sywula, T., Glazewska, I., Whatley, R.C. & Moguilevsky, A. (1995). Genetic differentiation in the brackish-water ostracod *Cyprideis torosa*. *Mar. Biol.* 121:647–653.

Ter-Braak, J.F. (1986). Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis, *Ecol.* 67:1167–1179.

Ter-Braak, C.J.F. (1987). The analysis of vegetation-environment relationships by correspondence analysis. *Vegetatio* 69: 69–77.

Ter-Braak, C.J.F. & Barendregt, L.G. (1986). Weighted averaging of species indicator values: its efficiency in environmental calibration. *Math. Bio*. 78: 57–72.

Tetart, J. (1983). Les charactéristiques chromosomiques de *Cyprideis littoralis* Brady. *Sci. Géol., Bull.* 36: 221-222.

Uyguner & Gözenalp, (1959). Turkish Coastal Lagoons. GFCM, Proc. *Gen. Fish. Coun. Medit.* 5:241-245pp.

Van Harten, D. (1975). Size and environmental salinity in the modern euryhaline ostracod *Cyprideis torosa* (Jones, 1850), a biometrical study. - *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 17: 35-48.

Van Harten, D. (1996). *Cyprideis torosa* (Ostracoda) revisited. Of salinity, nodes and shell size. - In Keen C.M. (ed.): Proceedings of 2nd European Ostracodologists Meeting, British Micropalaeontological. - Society, pp. 191-194, London.

Van Harten D.(2000). Variable noding in *Cyprideis torosa* (Ostracoda, Crustacea): an overview, experimental results and a model from Catastrophe Theory, *Hydrobiol.,* 419,: 131-139. DOI:10.1023/A:1003935419364

Van Morkhoven, F.P.C.M. (1963). *Post-Palaeozoic Ostracoda. Vol. II Generic Descriptions*; Amsterdam – London - New York (Elsevier). 478 p., 763 figs.

Venice system, (1959). The final resolution of the symposium on the classification of brackish waters. *Archo Oceanogr. Limnol.*, 11:, 243–248.

Vesper, B. (1972). Zum Problem der Buckelbildung bei *Cyprideis torosa* (Jones, 1850) (Crustacea, Ostracoda, Cytheridae). *Mitt. Zool. St. und Zool. Mus. in Hamburg* 68: 79–94.

Vesper, B. (1975). To the problem of noding on *Cyprideis torosa* (Jones, 1850). *B. Am. Paleontol*. 65: 205–216.

Wansard, G. (1997). *Reconstruction paleoenvironmentale des derniers 30.000 ans de la sequence de La Draga (Banyoles, Espagne), deduite des rapports (Sr/Ca) et (Mg/Ca) des valves d'ostracodes lacustres*. – Annales de la Societe Geologique de

Wansard, G., De Deckker, P & Juliàc, R. (1998). Variability in ostracod partition coefficients D(Sr) and D(Mg): Implications for lacustrine palaeoenvironmental reconstructions. *Chem. Geol.*, 146:39–54. DOI: 10.1016/S0009-2541(97)00165-4

Yassini, I. (1979). The littoral system ostracodes from the Bay of Bou-İsmail, Algiers, Algeria. *Revista Espanola De Micropaleontol.*, *3*, 353-416.

Yerli, S.V. & Bayrak, M. (1992). The brief inventory of existent data for Turkish lagoons, TUGEM, MARA, Ankara.

Yerli, S.V. (1999). *General View of Lagoons in Turkey In: Demirsoy, A., (ed.) General Turkish Zoogeography*. Meteksan Publication. (in Turkish).

Zaninetti, L. (1982). Les foraminifères des marais salants de Salins de Giraud (Sud de la France): milieu de vie et transport dans le salin, comparaison avec les microfaunes marines. *Géol. Méditer.,* 9: 447–470.

Zaninetti, L. (1984). Les foraminifères du salin de Bras del Port (Santa Pola, Espagne), avec remarques sur la distribution des Ostracodes. *Rev. Inv. Geol.,* 38/39: 123-138.

Zar, J.H. (1984). *Bio-statistical Analysis*. 2nd edn. Prentice Hall Inc. New Jersey.

Zarikian, C.A., Blackwelder, P.L., Hood, T., Nelsen, T.A. & Featherstone, C. (2000). Ostracods as indicators of natural and anthropogenically-induced changes in coastal marine environments. Coasts at the millennium, Proceedings of the 17th International Conference of the Coastal Society. p. 896–905.

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