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Research Article

The response of benthic foraminifer, ostracod and mollusc assemblages to environmental conditions: a case study from the Camalti Saltpan (Izmir-Western Turkey)

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Abstract

The subject of this report is benthic foraminifer populations preserved in the saltpan of Camalti in the Province of Izmir. High salinity in certain habitats of *Ammonia tepida* Cushman may be the primary cause of the high rate of twins and triplets as well as other morphological abnormalities recorded within this species (50 % as compared to an anomaly rate of 1 % in normal marine waters). Thicker cyst membrane developing in extremely saline environments may encourage twins and other morphological deformities by denying free movement of the offspring. Ecological factors such as heavy metal contamination of ambient waters as well as contamination by other wastes are also not ruled out as leading to such developmental anomalies. Of the 27 collected samples, Number 5 (that is closest to the sea) includes the typical marine foraminifers. *Nonion depressulum* (Walker and Jacob), *Ammonia tepida* Cushman and *Porosononion subgronosum* (Egger) are the dominant species in other samples. A total of 63 abnormal individuals (8 triplets, 24 twins, and 31 morphological anomalies) was found within seven of the 27 samples collected. Ten samples contained freshwater ostracods: *Darwinula stevensoni* (Brady and Robertson), *Leptocythere lacertosa* Hirschmann, *Cyprideis torosa* (Jones), *Cyprideis* (C.) *anatolica* Bassiouni, and *Loxochoncha elliptica* Brady. Among these samples (some of which contained only a few species of ostracods - and those limited in number of offspring), one had an unusually high ratio of healthy foraminifers those with anomalies. Worthy of note in another sample was a high abundance of molluscs. Among pelecypods, were found *Ostrea edulis* Linné, *Lucinella divaricata* (Linné), *Pseudocama gryphina* Lamarck, *Cerastoderma edule* (Linné), and *Scrobicularia plana* da Costa; and among gastropods were identified *Hydrobia (Hydrobia) acuta* (Draparnaud), *Rissoa labiosa* (Montagu), *R. parva* (da Costa), *R. violacea* Desmarest, *Pirenella conica* (Blainville), *Bittium desayesi* (Cerulli and Irelli), *B. lacteum* Philippi and *B. reticulatum* Philippi.

Keywords: Benthic foraminiferal deformities; Gastropods; Molluscs; Geochemistry; Camalti Saltpan; Izmir-Turkey.

Introduction

Because of their short life cycles and special habitat requirements, benthic foraminifers are affected by environmental changes and can be used as bio-indicators of pollution in coastal environments (FERRARO *et al.,* 2006). Morphological abnormalities in foraminifer tests are observed in polluted environments and may represent a useful bio-marker for evaluating long-term environmental impacts (VILELA *et al.,* 2004). However, strong natural stress caused by hypersalinity or salinity variations is found to be more effective on abnormal test development, disturbing the test construction (GESLIN *et al.,* 1998 and 2002). Twins, triplets and other morphological aberrations have been reported worldwide from different locations with hypersaline environments, such as the Araruma Lagoon in Rio de Janeiro (STOUFF *et al.,* 1999a), several small inland pools in Israel (ALMOGI-LABIN *et al.,* 1992) and coastal environments of middle Aegean Sea affected by anthropogenic activities (TRIANTAPHYLLOU *et al.,* 2005). Morphologically abnormal foraminifer specimens were observed in some of the locations in the Camalti Saltpan (İzmir, Turkey) where the salinity ranges between 40 and 273 ‰ in August (Table 1). The purpose of this study is to verify the twins, triplets and other morphological aberrations in foraminifers from the Camalti Saltpan and the possible causes of their origin.

Despite the observed relation between shell deformities in bivalves and tributyltin (TBT) pollution (MINCHIN *et al.,* 1996; ALZIEU, 2000; COELHO *et al.,* 2006), little if any studies have focused on the effect of TBT on gastropod shell morphology. TBT is one of the pollutants of concern in the North Sea (VAN DEN BROECK, *et al.,* 2009). This organometal has been used as a biocide in antifouling paints on ships, boats and off-shore installations and as fungicide in agriculture and wood preservation (BAUER *et al.,* 1997; OEHLMANN *et al.,* 1998a). High levels of TBT may affect the ecosystems and cause hazards to

Table 1
Annual averages salinity in sampling stations.

Sample No.	Salinity ‰ S		
	February	April	August
1	--	35,0	52,5
2	--	35,0	52,5
3	--	35,0	88,7
4	--	45,0	88,7
5	--	--	44,8
6	--	35,0	267,7
7	--	--	267,7
8	202,7	192,0	273,0
9	202,7	202,7	257,2
10	202,7	202,7	257,2
11	130,0	130,0	250,0
12	130,0	120,0	144,0
13	120,2	120,0	177,7
14	--	110,0	215,0
15	82,0	70,0	70,0
16	82,0	60,0	70,0
17	--	33,0	40,0
18	--	33,0	40,0
19	--	33,0	40,0
20	--	33,0	44,8
21	--	35,0	44,8
22	--	35,0	44,8
23	--	35,0	44,8
24	--	35,0	52,5
25	--	--	88,5
26	--	--	45,0
27	--	--	45,0

organisms, such as imposex, reproduction, deformities, etc. (ISMAIL, 2006). In bivalves TBT has the potential to induce shell deformities and may reduce reproductive success (BEAUMONT *et al.,* 1992; MINCHIN *et al.,* 1996; ALZIEU, 2000; COELHO *et al.,* 2006), while in female gastropods TBT can cause masculinization (SMITH, 1981; BAUER *et al.,* 1997; OEHLMANN *et al.,* 1998b; RILOV *et al.,* 2000; STRAND and JACOBSEN, 2002; TEWARI *et al.,* 2002). Thus, some molluscs can help in the monitoring and management of heavy metals in the coastal ecosystems.

In Turkey salt is produced from four different sources in seas, lakes, outcroppings and springs. The only saltpan utilizing seawater is located in the Camalti region in the Province of İzmir. The Camalti Saltpan, north of the city on the eastern reaches of the Gulf of İzmir, was established by the Italians in 1906. After the founding of the Republic of Turkey, it continued to operate under the name of 'Tuz Inhisari' (the 'Salt Monopoly') until it was incorporated into the Turkish State Monopolies (Tekel Genel Müdürlüğü) in 1932.

At the Camalti Saltpan, production is based on the very old and slow locomotive system: seawater is pumped into salt pools and the evaporation procedure is very slow. The crystallization pools have a soft substrate and need special modernization techniques. There are two by-products of salt production. The first one concerns the waste water discharge into the sea, which contains salt derivatives such as $MgCl_2$, Br, KCl and also the economically important $Mg(OH)_2$. Modernization of the system will make it economically feasible to enlarge the capacity of the saltpan. Turkey does not have solid potassium sources and the KCl used in the fertilization industry is imported.

The other by-product at Camalti Saltpan is *Artemia salina* living within high salinity pools and channels. It is used at aquarium and cultural fisheries as fish food and is produced and marketed at the Camalti Saltpan. Because this species is vital for salt formation, it is forbidden to collect and dispose of *Artemia salina* eggs (UCAL AND ERGEN, 1994).

The Camalti Saltpan (Fig. 1) covers an area of approximately 10 km^2, a long narrow coastal strip cordoned off from the Gulf southward of the mouth of the Gediz River (sections İzmir L 17 b2 and Kütahya K 1 on the official maps at 1/25000). There are 36 evaporation pools with a total surface area of 20000 m^2, 15 collection pools with a total surface of 600 m^2, 21 cold freshwater reservoirs with a total surface of 3000000 m^2, and 74 crystallization pools with a total surface of 1195000 m^2. In March and April the saltpan is rinsed with water from the sea to clear the flats of seaweed and other unwanted components; the rinse-water is subsequently diverted back into the sea. Then in May the seawater that has reached the Baumé temperature of 2.5-5.0 (25.5-52.25 ‰) is let into the collection pools and left to reach Baumé 12 (12 ‰), after which it is conducted into the freshwater reservoirs where $Ca SO_4$ is deposited when it reaches Baumé 23 (25 ‰) at the cold water pools Fe_3O is precipitated with CO_3. Brine (18 Baumé) is transferred to other pools for evaporation until it reaches 23 Baumé. From here the precipitate is taken into the hot-water crystallization pools, where it reaches Baumé 27.5 (28.5 ‰) within 3-4 days. A 25-30 cm layer of salt is precipitated here. At this stage the sodium chloride content of the precipitate is 94-95 % and its color is pinkish due to its plankton content. It is then stored in heaps over the winter. With drainage and winter

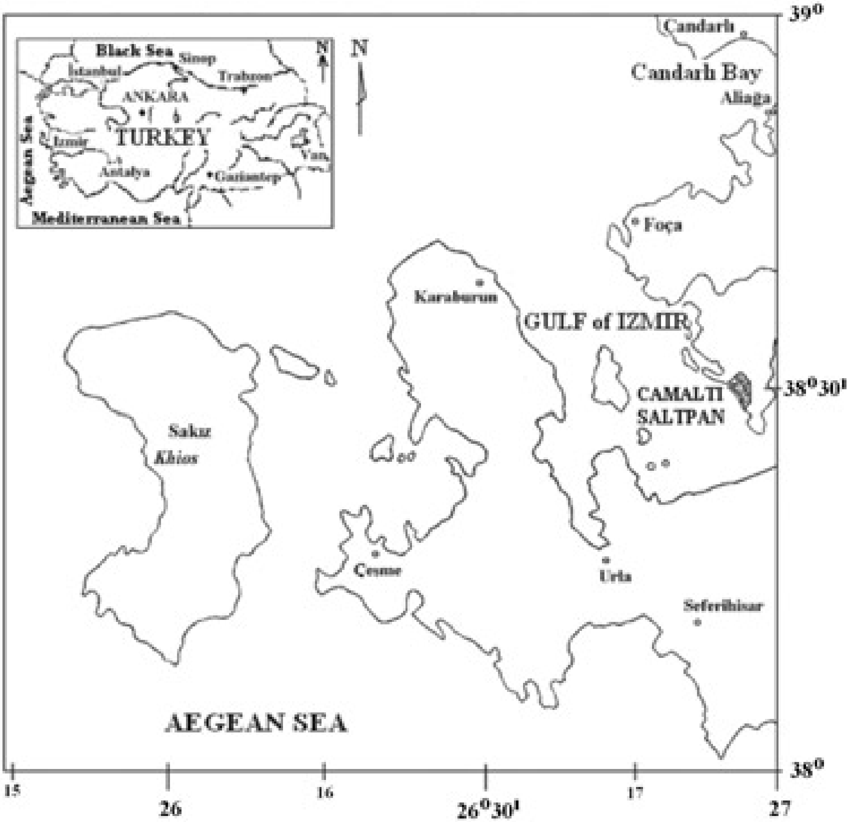


Fig. 1: Location map of study area.

precipitation, the sodium chloride content rises to 98%.

Materials and Methods

Investigation of foraminifer, ostracod and mollusc populations was performed on dead individuals. The research was carried out on sediment samples from 27 different points in the saltpan (Fig. 2). The samples were hand collected using a spoon, a total of 20 gr of each wet sample was soaked in 7% hydrogen peroxide (H_2O_2) solution for 24 hours. Then, the samples were dried after flushing under pressurized water in a sieve with a 0.063 mm mesh size. Carbon tetrachloride was added to the dried samples to bring foraminifer and ostracod populations in the material to the surface. Both the foraminifer and ostracod specimens were collected on filter paper and separated by size using different sieves with 2.00, 1.00, 0.500, 0.250 and 0.125 mm mesh size. The mollusc populations were directly collected from the 0.063 mm mesh size sieve. The samples were analysed under a binocular microscope.

The heavy metals (Fe, Mn, Pb, Cu, Zn, Ni, Co and Cr) analyses on sediment samples were performed in the laboratory of the Institute of Marine Sciences and Management at Istanbul University. The samples

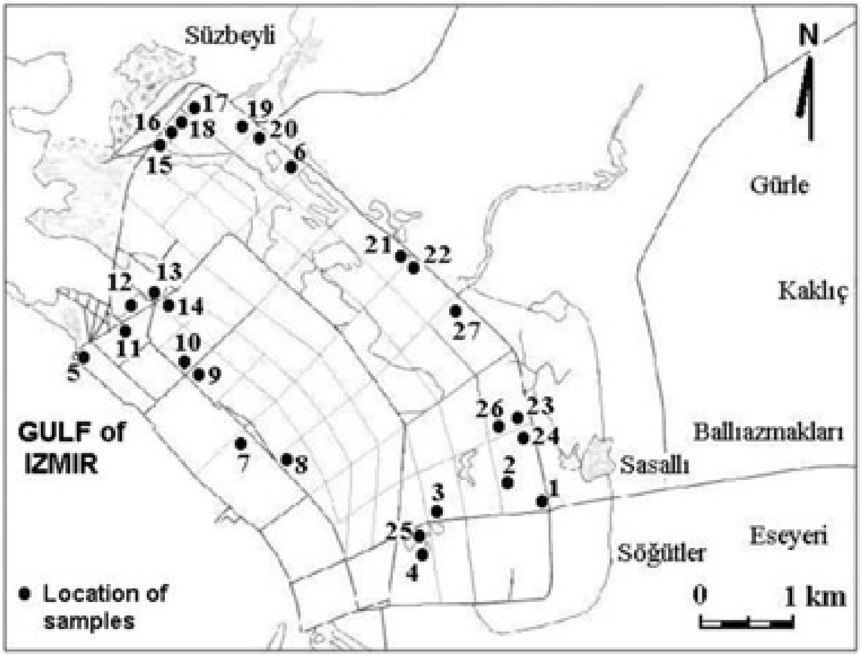


Fig. 2: Sampling stations of Camalti Saltpan.

that were taken during each extraction phase (both total and selective extraction) were analyzed on Shimadzu AA-6701-F Atomic Absorbtion Spectrophotometry and on the air-acetylene fire (LANDING AND LEWIS 1991; BOUGHRIET *et al.,* 1994). Aluminium was analyzed on nitrus oxide (N2O) acetylene fire. In five replicate analyses precisions were: Al ±8%, Fe ±8%, Mn ±4%, Pb ±2%, Cu ±8%, Zn ±4%, Ni ±14%, Co ±18% and Cr ±4% with 95% confidence interval. Hg analysis was performed on AAS with the cold vapor method on the Hydride Unit. The precision of five replicate analyses on Hg is 2% with a 95% confidence interval.

At the Gebze Institute of Technology laboratories, the sediment samples were dried at room temperature for 24 hours without any prewashing step and mollusc tests were separated. Nitric and hydrochloric acids were added to 0.35 grams of test samples in a teflon container (BELZUNCE *et al.,* 2001). The material was dissolved using a Milestone Ethos 1600 microwave digestion apparatus. Chemical analyses were performed on Perkin Elmer SIMAA 6000 Simultaneous Atomic Absorbion Spectrofotometry with the graphite oven technique.

We encountered diverse and abundant foraminifer fauna at stations 21, 22 and 23 which required different chemical analyses. Thus, geochemical analyses of major and minor elements were done in two different laboratories with different capabilities: Istanbul University, Institute of Marine Sciences and Management (Pb, Cu, Ni, Cd, Hg, Zn, Al, Cr, Fe, Na, Mg and Si), and Gebze Institute of Tecnology, Department of Environmental Engineering (As, Cd, Cu, Fe, Hg, Mn, Pb, Se, Si, Sn and V).

Results

Faunal assemblage composition

Benthic foraminifer assemblage

Eight genera and 13 species of benthic foraminifers were recognized in the 27 sediment samples. Sample 5, which was nearest to the sea, contained marine foraminifer populations of *Textularia bocki* Höglund, *Adelosina cliarensis* (Heron-Allen and Earland), *A. mediterranensis* (Le Calvez and Le Calvez), *Quinqueloculina disparilis* d'Orbigny, *Q. seminulum* (Linné), *Nonion depressulum* (Walker and Jacob), *Ammonia compacta* Hofker, *A. tepida* (Cushman), *Elphidium complanatum* (d'Orbigny), and *E. crispum* (Linné). In the other 26 samples, however, *Nonion depressulum* (Walker and Jacob), *Ammonia tepida* Cushman, and *Porosononion subgronosum* (Egger) were dominant (CIMERMAN & LANGER, 1991; HOTTINGER *et al.,* 1993; SGARRELLA & MONCHARMONT-ZEI 1993; MERIC *et al.* 2004). In most of the samples, the foraminiferal assemblages were found to be composed of only two or three different genera and species, which are represented by few individuals; whereas in Samples 1 and 21, large populations were represented. In Sample 24, young individuals of *Quinqueloculina seminulum* (Linné) were abundant, but *Ammonia tepida* Cushman and *Nonion depressulum* (Walker and Jacob) were very rare.

Adelosina carinata striata Wiesner was previously found only in one of the samples collected from nearby Dikili Bay, during another study of benthic foraminifers in the Eastern Aegean coasts (MERIC *et al.* 2004). Its presence in samples 12, 19, 21 and 22, suggests that this species displays a high tolerance of salinity. Also, *A. cliarensis* (Heron-Allen and Earland) in Samples 18 and 19; *Spiroloculina ornata* (d'Orbigny) in Sample 21, *Ammonia compacta* Hofker in Samples 9, 21 and 25, *Elphidium complanatum* (d'Orbigny) in Samples 2, 12 and 25, and *E. crispum* (Linné) in Sample 25 were found in the present study (Table 2; Plate 1-5).

Twins and triplets among foraminifers

In Samples 1, 2, 4, 6, 19, 21, 22, 23 and 27 (on the north-northeast and south-southeast of the saltpan; Fig. 2) an abundance of aberrant specimens, including twins, triplets and other morphological abnormalities were observed. In nine of the samples, a total of 55 individuals showing aberrant test morphology were determined; seven triplets (Pl. 1, Figs. 1-8), 20 twins (Pl. 1, Figs. 9-16; Pl. 2, Figs. 1-16), and 28 other examples of abnormal morphology (Pl. 3, Figs. 1-15; Pl. 4, Figs. 1-13). Sample 1 revealed a remarkably large population, as it was also observed in Sample 21. The salinities of Stations 1 and 21 in August of 2002 were 52.5‰ and 44.8‰, respectively (Table 1). Four triplets and four twins were counted in Sample 1, whereas two triplets and 10 twins were found in Sample 21. Another 12 specimens with abnormal chamber development were detected in these two samples. In addition, a total of 28 twins or triplets were observed in Sample 2 (eight individuals), Sample 4 (three individuals), Sample 6 (four individuals), Sample 19 (one individual), Sample 22 (three individuals), Sample 23 (one individual) and Sample 27 (three individuals). The percentage of abnormal individuals was found to be 1.50 %, however it was found that only 0.075 % of the population showed morphological abnormalities in marine sediment samples (MERIC, 1996). *Ammonia tepida* was found to be the dominant species with aberrant individuals in all the analysed samples, thus most of the twins, triplets and other morphologically

Table 2

Distribution of ostracoda, pelecypoda, gastropoda and benthic foraminiferal species among stations. (Individual showing of O 1-2, ● 3-5, ▲ 6-15, ■ 16-25, ★ more than 25 number.

Sample No.	**FAUNA**																														
	Foraminifer													**Ostracod**					**Mollusc**												
																			Pelecypod					**Gastropod**							
	Textularia bocki	*Adelosina carinata striata*	*Adelosina clarensis*	*Adelosina mediterranensis*	*Spiroloculina ornata*	*Quinqueloculina disparilis*	*Quinqueloculina seminulum*	*Nonion depressulum*	*Ammonia compacta*	*Ammonia tepida*	*Porosononion subgronosum*	*Elphidium complanatum*	*Elphidium crispum*	*Darwinula stevensoni*	*Leptocythere lacertosa*	*Cyprideis torosa*	*Cyprideis (C.) anatolica*	*Loxoconcha elliptica*	*Ostrea edulis*	*Lucinella divaricata*	*Pseudochama gryphina*	*Cerastoderma edule*	*Scrobicularia plana*	*Hydrobia (Hydrobia) acuta*	*Rissoa labiosa*	*Rissoa parva*	*Rissoa violacea*	*Pirenella conica*	*Bittium desayesi*	*Bittium lacteum*	*Bittium reticulatum*
1								★		★	▲					●	O														
2							O			★	▲	O					O														
3								■		★	●																				
4								●		■	O																				
5	O		O	O	O	O	●	O	●	■		O	O																		
6							★			★	O					O		O						■				★			
7										●																					
8								O		●							●														
9							O	O	O	▲										O										■	
10							O	●		●																					
11								●		■																					
12		O					●	▲		★		O																			

(continued)

Table 2 (continued)

Sample No.	FAUNA																														
	Foraminifer													Ostracod					Mollusc												
																			Pelecypod					Gastropod							
	Textularia bocki	*Adelosina carinata striata*	*Adelosina cliarensis*	*Adelosina mediterranensis*	*Spiroloculina ornata*	*Quinqueloculina disparilis*	*Quinqueloculina seminulum*	*Nonion depressulum*	*Ammonia compacta*	*Ammonia tepida*	*Porosononion subgronosum*	*Elphidium complanatum*	*Elphidium crispum*	*Darwinula stevensoni*	*Leptocythere lacertosa*	*Cyprideis torosa*	*Cyprideis (C.) anatolica*	*Loxoconcha elliptica*	*Ostrea edulis*	*Lucinella divaricata*	*Pseudochama gryphina*	*Cerastoderma edule*	*Scrobicularia plana*	*Hydrobia (Hydrobia) acuta*	*Rissoa labiosa*	*Rissoa parva*	*Rissoa violacea*	*Pirenella conica*	*Bittium desayesi*	*Bittium lacteum*	*Bittium reticulatum*
13							O	●		▲																					
14							●	▲		★	▲					●		O													
15										▲	O																				
16								O		O																					
17																						●						O			
18			O							●																					
19		O	O				★			■				O				O													
20										●												●						O			
21		O			O		O	★	●	★	O					●	★	■	●		●	★	▲	▲				■		O	
22		O					O	●		★	O											●		O			O	●			O
23							★	▲		●						●	●	■				■	O	★		O	O	★			O
24							■	●		■					O																
25							O	●	O	▲		O	O			O						O			O			O	●		▲
26							O	O		●														O							
27							●	▲		★	●													●							

abnormal individuals were *A. tepida* (Table 3).

The ostracod assemblages

In 10 of the 12 samples analyzed were found the following ostracod species: *Darwinula stevensoni* (Brady and Robertson), *Leptocythere lacertosa* Hirschmann, *Cyprideis torosa* (Jones), *Cyprideis* (C.) *anatolica* Bassiouni, and *Loxoconcha elliptica* Brady. While some samples contained only one or two species with few specimens, Sample 21 displayed a relatively high individual abundance of ostracods as well as foraminifers (Table 2; Plate 5, figs. 10-13).

Table 3
Distribution of normal and abnormal benthic foraminiferal individuals.

Sample no.	Abnormal individuals	Twins	Triplets	Other abnormalities	Number of individuals	Abnormality %
1	15	4	4	7	457	3.28
2	8	1	1	6	186	4.3
3					153	
4	3			3	247	1.22
5					65	
6	4	2		2	147	2.72
8					15	
9					31	
10					11	
11					52	
12					158	
13					15	
14					148	
15					10	
16					1	
18					7	
19	1	1			86	1.16
20					2	
21	17	10	2	5	1534	1.11
22	3	1		2	127	2.36
23	1	1			109	0.92
25					23	
26					10	
27	3			3	62	4.84
Total	55	20	7	28	3656	1.50

Of the above, *Darwinula stevensoni* is characterized as thriving in sandy beds under fresh or slightly saline waters (oligohaline) with a salt content of 0.5-12 ‰, and generally in muddy sediments rich in organic matter (WAGNER 1957; KEYSER 1976; GUILLAUME *et al.,* 1985; BESONEN 1997; MISCHKE 2001). *Leptocythere lacertosa* is typical of rather brackish (mesohaline) littoral regions in tidal zones (VON MORKHOVEN 1963; BONADUCE *et al.,* 1975; GUILLAUME *et al.,* 1985). *Cyprideis torosa* is a frequent and ubiquitous species found in brackish coastal waters (mesohaline) with a salt content of 8-40 ‰. Preferring a rather high salt content (25-40 ‰), it is thus often found in lagoons, gulfs, and estuaries as well as at river mouths and along tidal plains (WAGNER 1957; BARBEITO-GONZALES 1971; BREMAN 1975; CARBONEL *et al.,* 1975; GUILLAUME *et al.,* 1985; WITTE 1993, BESONEN 1997; MISCHKE 2001). *Cyprideis (C.) anatolica* was described typically from river mouths (BASSIOUNI 1979). *Loxoconcha elliptica* is another frequent and ubiquitous species found in brackish coastal waters (mesohaline) with a salt content of 18-30 ‰; it thrives at relatively shallow depths (20 m or less) in lagoons, gulfs, estuaries, river mouths and tidal plains (BONADUCE *et al.,* 1975; CARBONEL *et al.,* 1975; PASCUAL & CARBONEL 1992; BESONEN 1997).

These genera and species have been recovered from waters with different salt content from 45 to 273 ‰. Most probably they were transported from the sea and trapped in the evaporation pools. The oligohaline species *Darwinula stevensoni* might have been transported from a nearby river branch or cold water reservoir. Samples 21 and 23, in which the greatest number of ostracods were found, come from areas with a salt content of 45 ‰ in August (when collected), which is one of the lowest salinity values measured, indicating that low salinity might have enhanced the survival rate of ostracods.

<u>The mollusc assemblages</u>

A total of 10 of the 27 collected samples from the saltpan are rich in mollusc fauna. The pelecypods are represented by *Ostrea edulis* Linné, *Lucinella divaricata* (Linné), *Pseudochama gryphina* Lamarck, *Cerastoderma edule* (Linné), and *Scrobicularia plana* da Costa. The gastropods are represented by *Hydrobia (Hydrobia) acuta* (Draparnaud), *Rissoa labiosa* (Montagu), *R. parva* (da Costa), *R. violacea* Desmarest, *Pirenella conica* (Blainville), *Bittium desayesi* Cerulli and Irelli, *B. lacteum* Philippi, and *B. reticulatum* Philippi (Table 2; Plate 6). Although *Ostrea edulis* Linné and *Lucinella divaricata* (Linné) are found in the Black Sea as well, all of the species are Aegean Sea populations.

The habitats for these pelecypoda are inferred from the work of POPPE & GOTO (1991, 1993). *Ostrea edulis* generally lives in shallow waters at depths of up to 90 m, thriving in waters of 25 and 33 ‰ salinity. *Lucinella divaricata* is found from the tidal line to depths of 60 m in waters with 25 ‰ salinity and *Pseudochama gryphina* at depths from 10 to 60 m in salt content of about 30 ‰. *Cerastoderma edule* is found at depths of only a few meters along tidal plains, in sandy bays and also in fresh water. *Scrobicularia plana* thrives along tidal plains, at up to 30 m water depth between 25 and 30 ‰ salinity.

Gastropod habitats are also based on the work of POPPE & GOTO (1991, 1993). *Hydrobia (Hydrobia) acuta* lives in freshwater, saline mineral waters and seawater at depths varying from 3 to 40 meters. It can tolerate up to 33 ‰ salinity. *Rissoa labiosa* lives in very shallow waters at depths up to 25 m, favoring a salt content between 20 and 30 ‰. *Rissoa parva* is found off the coastline at depths of 30 m in waters with a salt content of around 30 ‰. *Rissoa violacea* thrives at depths of 0-25 m in salty waters (25-33 ‰), while *Pirenella conica* inhabits shallow waters with low salinity. *Bittium desayesi, B. lacteum* and *B. reticulatum* are all found in seawater with a salt content as 25-30‰ from tidal plains down to 250 m.

The geochemistry of sediment and mollusc tests

Among the analyzed heavy metals, Hg is found to have the lowest value in ppb (Table 4).

Figure 3 illustrates the distribution of heavy metals. Fe is measured at highest ppm value compared to other heavy metals (Si, Al, Zn, Hg, Pb, Cd, Cr, Cu, Ni, Mg and Na). Si, Al, Mg and Na values are considered as important. Zn values are close to each other in Samples 5, 9, 25. Cr has almost the same values in Samples 12 and 24, while Pb, Cu, Ni and Cd values are close to each other in all samples. Cd is < 0,01 in all samples. The Al, Mg, Na values show parallel curves in Samples 3, 4, 5, 6, 7, 8, 9, 10, 11, 14, 15, 16, 21, 22 and 23. When the locations of the stations are taken into consideration, we observe no significant difference between the saltpan and the pools. The Si value is highest in Samples 5, 13, 20, 22 and it is found to be lowest in Sample 19. Although the locations of Stations 19 and 20 are juxtaposed, their Si values are very different. This discrepancy can be explained by the fact that Station 19 is located on the point of discharge of a river branch into the saltpan.

Geochemical analysis of both sediment samples and mollusc tests from Samples 21 and 23 are given in Figure 4. The tests collected from Samples 21 and 23, where the

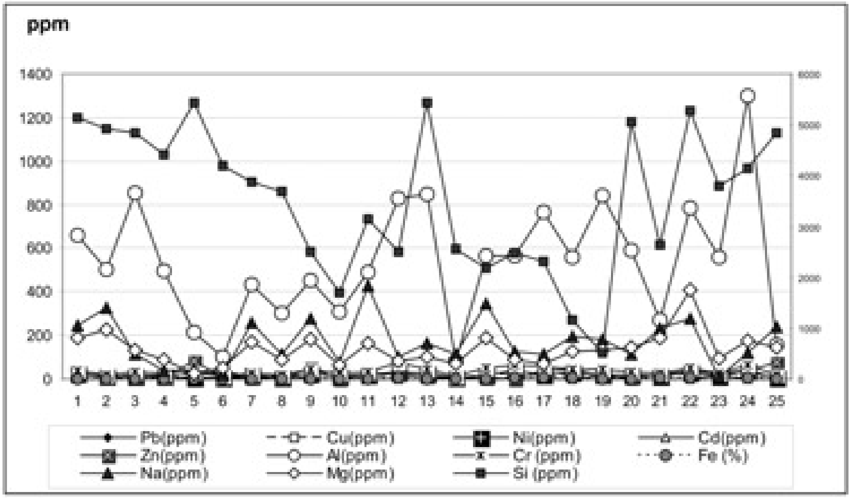


Fig. 3: The distribution of heavy metal and major cation concentrations in the sediment samples from Camalti Saltpan (%Fe, the others ppm) (by Istanbul University, Institute of Marine Sciences and Management).

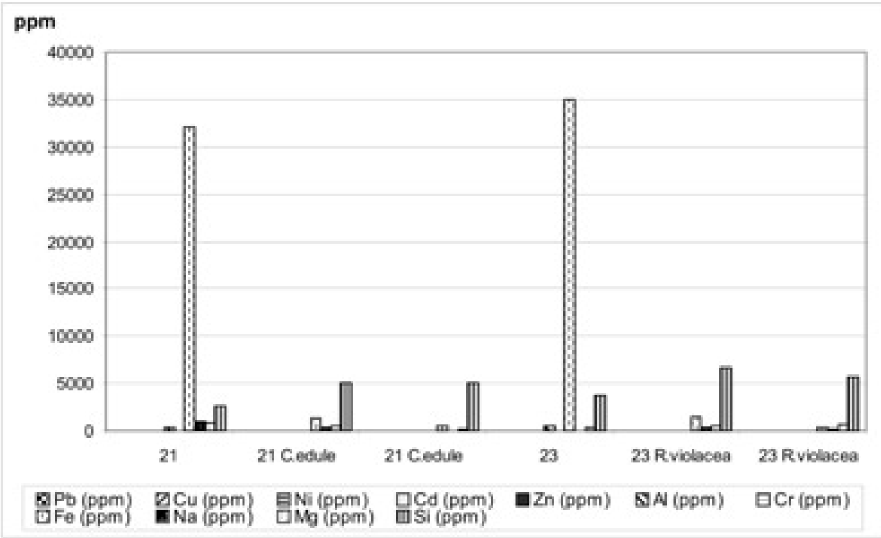
Table 4
The values of heavy metal and major cation concentrations in *Cerastoderma edule* (Linné) and *Rissoa violacea* shells (Fe%, the others ppm) and in the sediment samples in Camalti Saltpan (Fe %, the others ppm)
(by Istanbul University, Institute of Marine Sciences and Management)

Station No.	Pb (ppm)	Cu (ppm)	Ni(ppm)	Cd (ppm)	Hg (ppb)	Zn(ppm)	Al(ppm)	Cr (ppm)	Fe (ppm)	Fe (%)	Na(ppm)	Mg(ppm)	Si (ppm)
1	18	17	23	<0.01	42	22	661.82	36.95	26838.5	2.68385	1053	813	5141.43
2	15	10	10	<0.01	26	4	501.95	18.605	21687	2.1687	1393.5	979.5	4911.57
3	13	11	14	<0.01	25	10	856.715	28.69	22313	2.2313	492	564	4839
4	16	9	10	<0.01	68	8	493.32	22.68	19287.8	1.92878	162	364.5	4415.58
5	45*	24	7	<0.01	66	79	211.135	30.11	26820.5	2.68205	156.93	102	5431.77
6	29*	31	5	<0.01	243	5	100.49	12.975	13803.8	1.38038	78	217.5	4209.93
7	26*	7	16	<0.01	141	4	433.43	26.055	21306	2.1306	1108.5	729	3871.2
8	17	1	7	<0.01	67	<0.01	298.43	16.435	9656.25	0.96563	477	387	3689.73
9	32*	22	26	<0.01	34	51	453.225	41.455	28069.5	2.80695	1192.5	786	2504.16
10	23*	6	12	<0.01	27	0.02	307.055	24.41	17506.3	1.75063	319.5	264	1693.65
11	22*	13	18	<0.01	40	17	490.275	29.315	23420.5	2.34205	1822.5	691.5	3145.35
12	23*	16	31	<0.01	77	27	829.815	75.235	36178.3	3.61783	418.5	352.5	2504.16
13	23*	9	23	<0.01	51	10	844.535	45.71	28195	2.8195	699	442.5	5443.86
14	12	<0.01	4	<0.01	26	<0.01	81.205	10.88	5348.25	0.53483	483	286.5	2552.55
15	22*	12	17	<0.01	49	8	567.93	47.165	26520	2.652	1474.5	817.5	2189.64
16	34*	30	37	<0.01	24	92*	567.93	60.185	32208.3	3.22083	541.5	381	2479.98

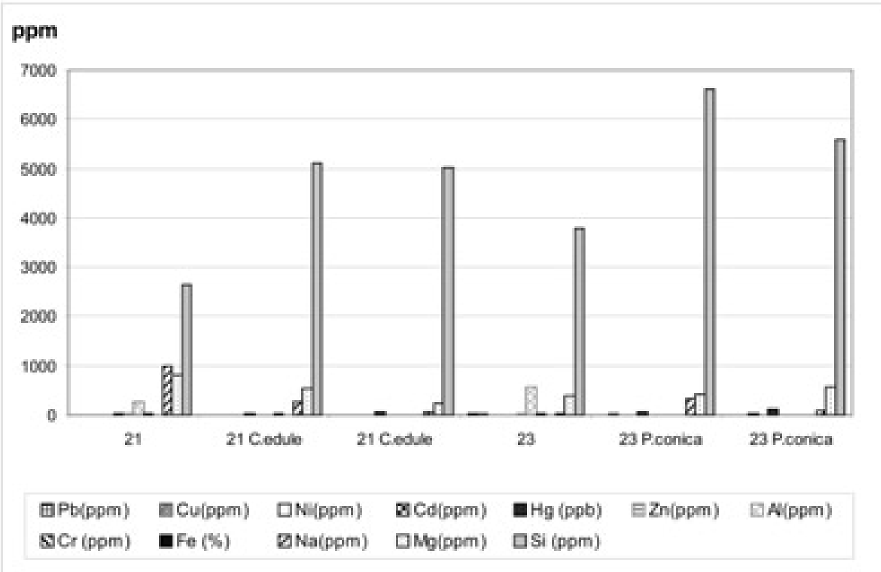
(continued)

Table 4 (continued)

Station No.	Pb (ppm)	Cu (ppm)	Ni(ppm)	Cd (ppm)	Hg (ppb)	Zn(ppm)	Al(ppm)	Cr (ppm)	Fe (ppm)	Fe (%)	Na(ppm)	Mg(ppm)	Si (ppm)
17	30*	14	21	<0.01	29	38	766.375	54.94	36043.8	3.60438	481.5	306	2310.63
18	31*	20	33	<0.01	10	41	556.255	46.445	33266.8	3.32668	832.5	531	1149.27
19	20	8	16	<0.01	29	10	838.44	45.255	26618.5	2.66185	774	565.5	508.08
20	23*	6	16	<0.01	52	7	592.795	28.48	19090.5	1.90905	493.5	615	5056.74
21	33*	14	10	<0.01	38	18	267.47	25.535	32068.5	3.20685	982.5	819	2637.24
22	29*	22	33	<0.01	1	36	787.69	51.345	38477.8	3.84778	1192.5	1737	5286.6
23	19	17	10	<0.01	14	24	558.79	28.205	34949.5	3.49495	21.45	403.5	3786.51
24	28*	23	36	<0.01	15	39	1300.295	63.9	41679.3	4.16793	516	754.5	4137.33
25	225*	7	9	<0.01	17	77	159.365	15.83	13901.8	1.39018	1024.5	625.5	4851.09
21 *C.edule*	160*	8	8	1.66*	30	<0.01	3.0249	15.64	1319.7	0.13197	276	538.5	5093.04
21 *C.edule*	73*	5	8	0.56*	71	<0.01	2.4565	13.72	1378.25	0.13783	73.5	229.5	5008.35
23 *R.violacea*	41*	35	14	2*	65	<0.01	2.1012	12.45	516.22	0.05162	328.5	412.5	6605.22
23 *R.violacea*	147*	14	21	1.2*	119	<0.01	4.0501	6.65	304.84	0.03048	86.19	580.5	5601.12



a.



b.

Fig. 4: **a.** The distribution of heavy metal and major cation concentrations (ppm); **b.** The distribution of heavy metal and major cation concentrations (% Fe, the others ppm) in in *Cerastoderma edule* (Linné) and *Rissoa violacea* Desmarest for samples 21 and 23 in Camalti Saltpan (by Istanbul University, Institute of Marine Sciences and Management).

fauna was found to be diverse, were analyzed and the values were compared with the sediment analyses. Si, Mg, Na and Al (in ppm) values are significant. Cr and Zn values show a slight tendency to increase. In Figures 4a and b, Fe values are given in %, and the relation of values of other metals in sediment and mollusc tests to each other can be shown as .

The heavy metal analyses of the sediment samples and tests from Samples 21 and 23 were performed in Gebze at the Institute of High Technology and they are comparatively shown in Table 5 and Figure 5 . Fe, Hg, Mn, Pb, Si, V and As values tend to increase the sediments and test values are found to be parallel. Sediment samples from Samples 21 and 22 Si> Pb>Fe>Mn, from Samples 23 Pb>Si>Fe>Mn.

The As, Cd, and V values are close to each other and Se and Sn values are very small.

In sediment from Sample 21; Al< Mg< Na< Si and on the test Na<Mg<Si , from Sample 23; Na<Al<Mg<Si and on the test Na<Mg<Si (Table 6).

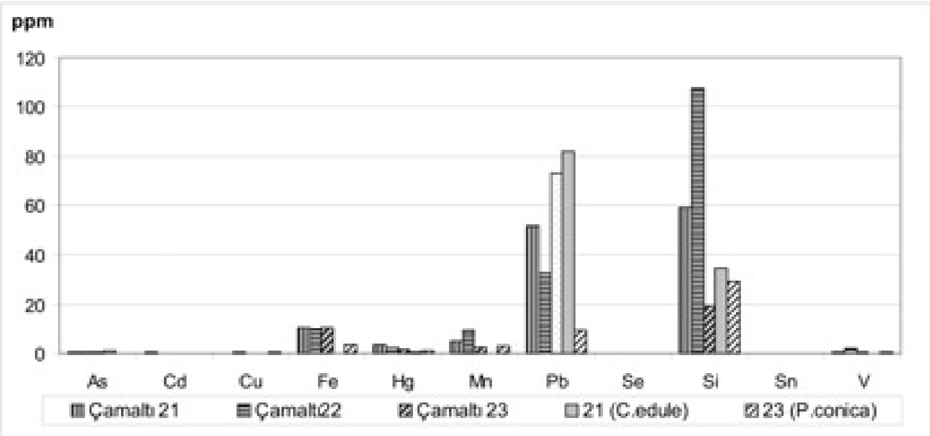


Fig. 5: The distribution of of heavy metals and major cation concentrations (ppm) in shells of *Cerastoderma edule* (Linné) and *Rissoa violacea* Desmarest for samples 21 and 23 in Camalti Saltpan (by Gebze Institute of Technology, Dept.of Environmental Eng.)

Table 5
The values of heavy metal and trace elements concentrations (ppm) in *Cerastoderma edule* (Linné) and *Rissoa violacea* Desmarest shells in samples 21, 22 and 23 in Camalti Saltpan (by Gebze Institute of Technology, Dept. of Environmental Eng.)

Sample location	As	Cd	Cu	Fe	Hg	Mn	Pb	Se	Si	Sn	V
Çamaltı 21	0,29	0,32	0,14	10,34	3,42	5,09	51,40	0,06	58,98	0,01	0,66
Çamaltı 22	0,27	0,09	0,26	10,15	2,30	9,57	32,80	0,03	107,59	0,01	1,85
Çamaltı 23	0,52	0,10	0,21	10,48	1,70	2,60	72,69	0,04	19,55	0,01	0,32
21 *(C.edule)*	1,12	0,07	0,06	<0.01	0,68	0,24	81,85	0,05	34,80	0,02	0,15
23 *(R.violacea)*	0,08	0,10	0,25	3,53	1,10	3,16	9,24	0,04	29,45	<0.01	0,47

Table 6
Correlation of Fe, Si, Al, Mg, Na (ppm) between their values in the shells of *Cerastoderma edule* (Linné) and *Rissoa violacea* Desmarest and their values in sediment samples.

	Sediment	Shell
Fe	High	Low
Mn	Low High	*Rissoa violacea* high in the shell *Cerastoderma edule* low in the shell
Pb	High Low	*Rissoa violacea* low in the shell *Cerastoderma edule* high in the shell
Si	High Low	*Cerastoderma edule* low in the shell *Rissoa violacea* high in the shell
Hg	High	Low

The chemical and physical parameters have been routinely measured by the saltpan management. Pump water data from the new area of the second saltpan which is near to Sample 27 and pool water data from crystalization pool are given in Table 7 and Table 8, respectively. Ca and Mg values vary between the pool water and the water from the pumping system:

Pool water Ca^{2+} : 0.4008- 0.4810 g/l
Mg^{+2} : 30.6432-34.4979 g/l
Pump water Ca^{2+} : 0.5010 g/l
Mg^{+2} : 14.0448 g/l

Discussion and Conclusions

Foraminifer twins and triplets are rarely observed in natural environments (about 1% of the population) However, we found that in laboratory conditions, exposing *Ammonia tepida* to a hypersaline (50‰) environment greatly facilitates abnormal development, mainly of twins (STOUFF *et al.,* 1999b).(In this report the researchers also estimated that the maximum salinity tolerated by *Elphidium crispum* individuals was 42‰). Furthermore, twins have been observed in a dominant *Ammonia* population in salt pools near the Dead Sea in Israel (ALMOGI-LABIN *et al.,* 1992). COLE (1960) determined that a delay in the disintegration of the cyst enclosing the microspherical individuals produced by schizogonic reproduction can lead to a fusing of the individual offspring. Thicker cyst walls grown in hypersaline environments disintegrate more slowly and bring about twins and triplets as well as many other abnormal developments. This delay may keep the young offspring locked within close contact for a considerably longer time. If two or more offspring develop at the same rate, their tests will have the same size and shape. Likewise, the first chambers of the tests may develop on the same or different planes. One can sometimes exhibit more development than the other (STOUFF *et al.,* 1999a). Thus the offspring trapped longer within the same limited space may become fused to each other, hence, will be destined to continue living in this state after the disintegration of the cyst wall.

An interesting characteristic among twins and triplets is that there is striking dif-

Table 7
The result of salt waters analysis from the new area of second saltpan (near of the sample 27) (by Management Camalti Saltpan).

Sample Name	The date of sample collection	(Ca^{+2}) (g/l)	(Mg^{+2}) (g/l)	BOME (Be°) Values	(°C)	Baumé (Be°) Calculation with the factor of correction
New area A-1 1(West) Poolwater	05.08.2003	0,4008	30,6432	27,9	**27,0**	28,30
New area A-1 1(East) Poolwater	05.08.2003	0,4609	34,4979	28,4	**28,0**	28,85
New area A-2 2(West) Poolwater	05.08.2003	0,4810	31,8106	28,0	**28,5**	28,50
Saltwater of pump which feed the new area	07.08.2003	0,5010	14,0448	25,8	**25,0**	26,10
Saltwater from reserv feeding New area	07.08.2003	0,4609	14,3123	25,9	**25,5**	26,2
Feeding water from New area (2-A)	08.08.2003	0,5411	14,0205	24,5	**34,0**	25,3
2 Poolwater new area feeding water	11.08.2003	0,6012	14,3488	24,8	**28,0**	25,25
Feeding water from reserv number 36	09.06.2003	1,0020	11,5520	24,2	**26,0**	24,5
Feeding water to the new area	13.06.2003	0,6012	12,7680	24,25	**32,5**	25,0
Feeding water for the pools 1A-2A	06.06.2003	0,8016	11,4304	24,5	**27,0**	24,9
First salt water for A-1; A-2 New area	30.05.2003	0,9018	9,5456	22,1	**23,0**	22,5

ference in the formation of the twins or triplets. Sometimes they are attached from the very first chambers (Pl. 1, Fig. 9), but mostly they show great differences in the community, which then contradicts the mechanism of development proposed by STOUFF *et al.* (1999a). Therefore, the twin or triplet formation is caused by entrapment within cysts which have not disintegrated in time in hypersaline environments; it appears to be a matter of chance, as the specimens illustrated on Plates 1 and 2 would seem to confirm.

Still another subject is the morphological changes that occur in the tests of foraminifers living in hypersaline environments. Test formation depends on the chemical composition of the water, its turbidity,

Table 8
The analysis of the salt precipitated in the crystallisation pools in the new area of Camalti Saltpan Management.

Sample Name	The date of sample collection	Quantity of insoluble matter (%gr)	Ca^{2+} (%gr)	Mg^{2+} (%gr)	SO_4^{2-} (%gr)	$CaSO_4$ (%gr)	$MgSO_4$ (%gr)	$MgCl_2$ (%gr)	NaCl (Dry) (%gr)
Salt of channel in New area	29.07.2003	0,0100	0,1603	0,4134	0,8374	0,5446	0,5679	1,1698	97,5078
10.Vinc A-1 Salt of pool	06.08.2003	0,0170	0,0601	0,3101	0,6378	0,2042	0,6187	0,7248	98,2353

pH, salt content and temperature, as well as the presence of heavy metals and environmental pollution (ALVE, 1991; SHARIFI *et al.,* 1991; ALMOGI-LABIN *et al.,* 1992; YANKO *et al.,* 1998). This may explain the morphological abnormality that occurs in foraminifer tests in hypersaline environments. Increasing concentrations of heavy metals in the evaporation pools might have been the cause of morphological abnormalities observed in the foraminifer specimens.

Adelosina carinata striata was previously found only in one of the samples collected from nearby Dikili Bay during another study of benthic foraminifers in the Eastern Aegean coasts. (MERIC *et al.* 2004). Its presence in four of our samples (No. 12, 19, 21, 22) suggests that this species displays a high tolerance of enhanced salinites. Also, *Adelosina cliarensis* in Samples 18 and 19; *Spiroloculina ornata* in Sample 21, *Ammonia compacta* in Samples 9, 21 and 25, *Elphidium complanatum* in Samples 2, 12 and 25, and *E. crispum* in Sample 25 were found in the present study.

Although the salinity generally tolerated by *Ammonia tepida* was accepted as 52.5‰, we show that in the Camalti Saltpan it can survive to a limited number in hypersaline environments with 89‰ salinity. The study confirms that the twins and triplets, rarely seen in environments with normal salinity (the western Black Sea, the Gulf of İzmit, and the Aegean Sea) (MERIC 1996; MERIC *et al.,* 2001, 2003; TRIANTAPHYLLOU *et al.,* 2005), are considerably more abundant in hypersaline environments.

The ostracods were represented in the saltpan by 4 genera and 5 species. These genera and species have been recovered from waters with different salt content from 45 to 273 ‰. Most probably they were transported from the sea and trapped in the evaporation pools. The oligohaline species *Darwinula stevensoni* might have been transported from a nearby river branch or cold water reservoir. Samples 21 and 23, in which the greatest number of ostracods were found, come from areas with a salt content of 45 ‰ in August (when collected), which is one of the least salinity values measured, indicating that low salinity might have enhanced the survival rate of ostracods.

The mollusc fauna was also found not to be vey rich; pelecypods were represented by 6 genera and 6 species and gastropods were represented by 4 genera and 8 species. The habitats for these pelecypoda are inferred from the work of POPPE & GOTO (1991, 1993). *Ostrea edulis* generally lives in shallow waters at depths of up to 90 m, thriving in waters of 25 and 33 ‰ salinity. *Lucinella divaricata* is found from the tidal line to depths of 60 m in waters with 25 ‰ salinity and *Pseudochama gryphina* at depths from 10 to 60 m in salt content of about 30 ‰. *Cerastoderma edule* is found at depths of only a few meters along tidal plains, in sandy bays and also in fresh water. *Scrobicularia plana* thrives along tidal plains, but at up to 30 m water depth between 25 and 30 ‰ salinity.

Gastropod habitats are also based on the work of POPPE AND GOTO (1991, 1993). *Hydrobia (Hydrobia) acuta,* lives in freshwater, saline mineral waters and seawater at depths varying from 3 to 40 meters. It can tolerate up to 33 ‰ salinity. *Rissoa labiosa* lives in very shallow waters at depths up to 25 m, favoring a salt content between 20 and 30 ‰. *Rissoa parva* is found off the coastline at depths of 30 m in waters with a salt content of around 30 ‰. *Rissoa violacea* thrives at depths of 0-25 m in salty waters (25-33 ‰), while *Pirenella conica* inhabits shallow waters with low salinity. *Bittium desayesi, B. lacteum* and *B. reticulatum* are all found in seawater with a salt content of 25-30‰ from tidal plains down to 250 m.

The heavy metal analyses on mollusc tests showed that the Fe concentration is very much less compared to sediment values, indicating that accumulation in tests is not the same for every metal. So mollusc tests cannot be used for monitoring every kind of heavy metal pollution.

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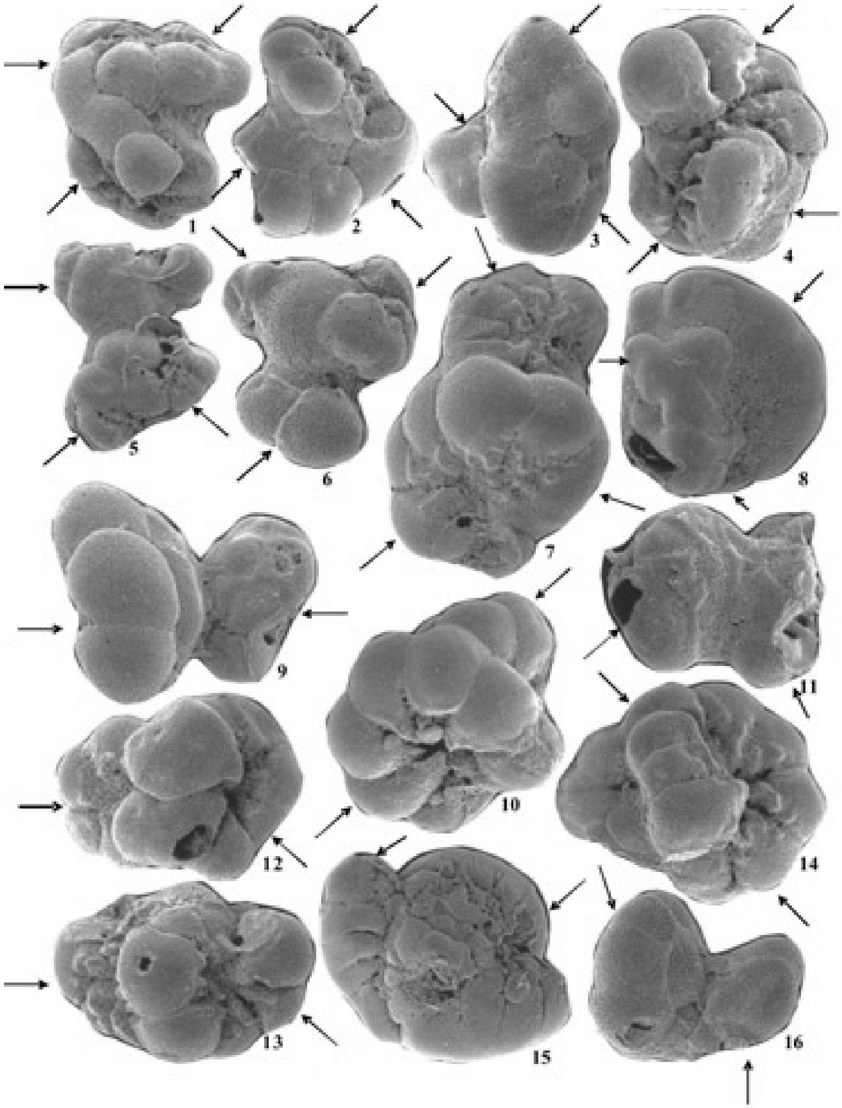

PLATE 1

1-16. *Ammonia tepida* Cushman. Camalti Saltpan, İzmir, Turkey.

1. Triplet forms , x 66, Sample 1.
2. Triplet forms , x 73, Sample 1.
3. Triplet forms , x 98, Sample 1.
4. Triplet forms , x 98, Sample 1.
5. Triplet forms , x 56, Sample 2.
6. Triplet forms , x 84, Sample 21.
7. Triplet forms , x 112, Sample 21.
8. Triplet forms , x 73, Sample 27.
9. Twin forms , x 112, Sample 1.
10. Twin forms , x 73, Sample 1.
11. Twin forms , x 98, Sample 1.
12. Twin forms , x 98, Sample 1.
13. Twin forms , x 90, Sample 2
14. Twin forms , x 84, Sample 6.
15. Twin forms , x 73, Sample 6.
16. Twin forms , x 140, Sample 21.

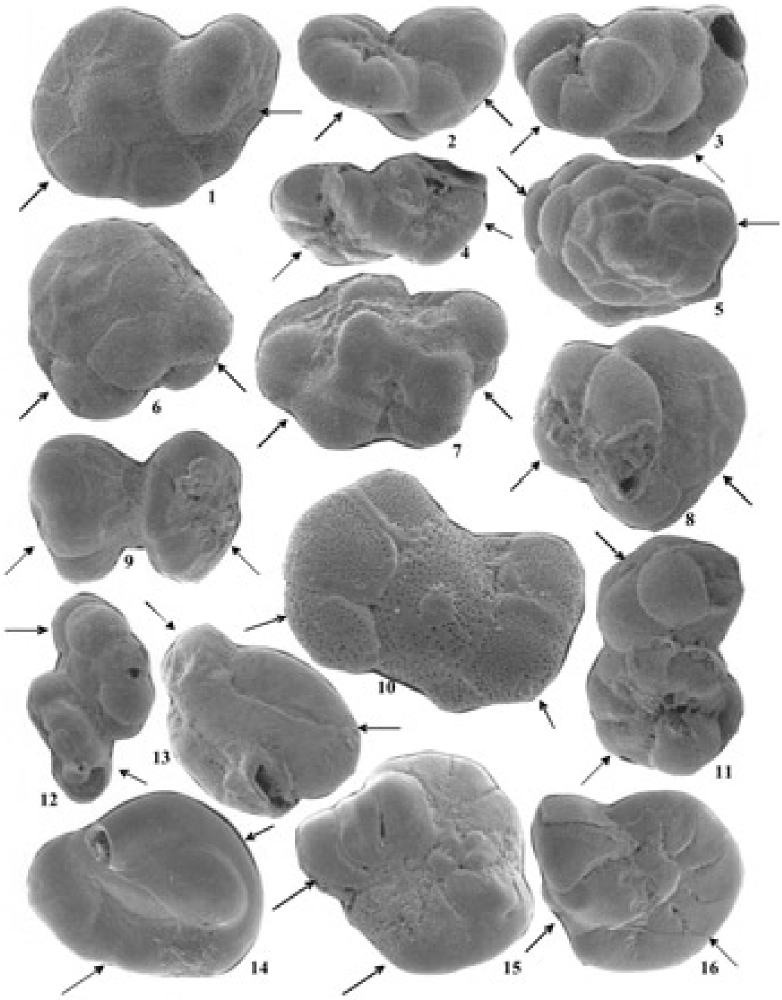

PLATE 2

1-12. *Ammonia tepida* Cushman. Camalti Saltpan, İzmir, Turkey.

1. Twin forms , x 140, Sample 21.
2. Twin forms , x 140, Sample 21.
3. Twin forms , x 165, Sample 21.
4. Twin forms , x 90, Sample 21.
5. Twin forms , x 98, Sample 21.
6. Twin forms , x 112, Sample 21.
7. Twin forms , x 112, Sample 21.
8. Twin forms , x 140, Sample 21.
9. Twin forms , x 90, Sample 21.
10. Twin forms , x 84, Sample 22.
11. Twin forms , x 98, Sample 23.
12. Twin forms , x 73, Sample 27.

13-14. *Quinqueloculina seminula* (Linné), Camalti Saltpan, İzmir, Turkey.

13. Twin forms , x 73, Sample 19. 14. Twin forms , x 90, Sample 23.

15. *Nonion depressulum* (Walker and Jacob), Camalti Saltpan, İzmir, Turkey.

Twin forms , x 98, Sample 1.

16. *Porosononion subgronosum* (Egger), Camalti Saltpan, İzmir, Turkey.

Twin forms , x 98, Sample 21.

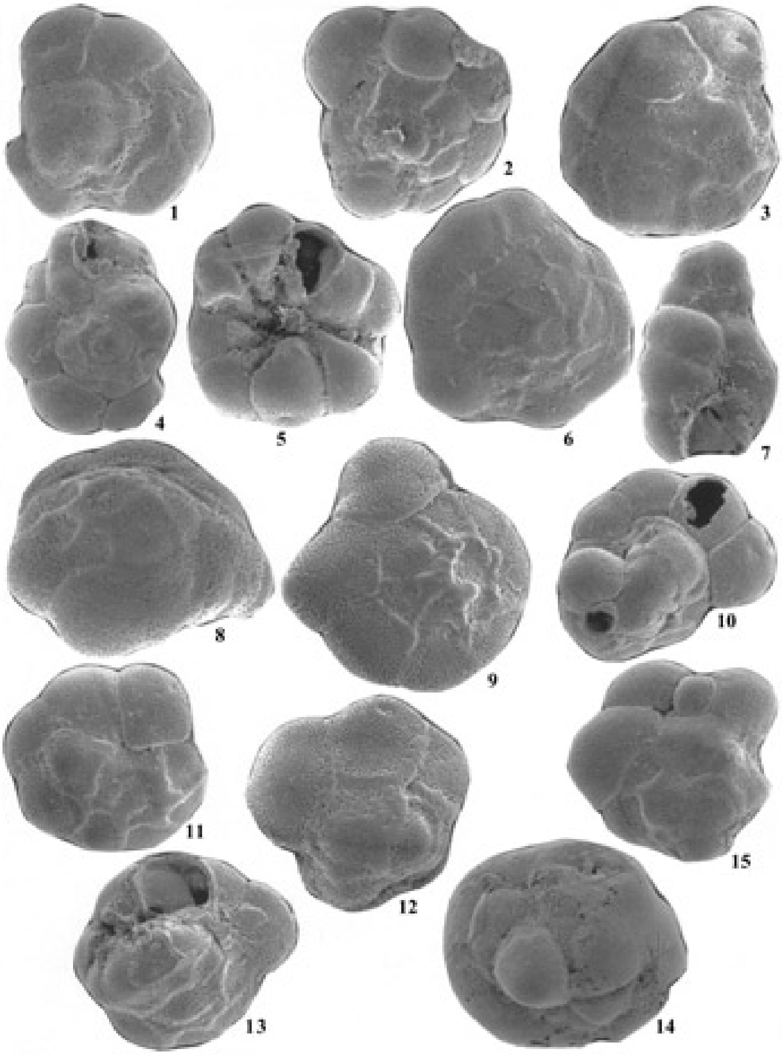

PLATE 3

1-15. *Ammonia tepida* Cushman. Speciments have abnormal chamber development, Camalti Saltpan, İzmir, Turkey.

1. Spiral side, x 98, Sample 1.
2. Spiral side, x 73, Sample 1.
3. Spiral side, x 98, Sample 1.
4. Spiral side, x 112, Sample 1.
5. Umblical side, x 98, Sample 1.
6. Spiral side, x 84, Sample 1.
7. Umblical side, x 112, Sample 2.
8. Spiral side, x 98, Sample 2.
9. Spiral side, x 140, Sample 2.
10. Spiral side, x 90, Sample 2.
11. Spiral side, x 112, Sample 4.
12. Spiral side, x 125, Sample 4.
13. Spiral side, x 125, Sample 4.
14. Spiral side, x 84, Sample 6.
15. Spiral side, x 90, Sample 21.

PLATE 4

1-8. *Ammonia tepida* Cushman. Speciments have abnormal chamber development, Camalti Saltpan, İzmir, Turkey.

1. Spiral side, x 150, Sample 21.
2. Umblical side, x 195, Sample 21.
3. Umblical side, x 125, Sample 21.
4. Spiral side, x 98, Sample 21.
5. Umblical side, x 125, Sample 22.
6. Spiral side, x 70, Sample 22.
7. Spiral side, x 98, Sample 27.
8. Umblical side, x 73, Sample 27.

9. *Quinqueloculina* cf. *seminula* (Linné).

External view, x 73, Sample 6.

10-11. *Nonion depressulum* (Walker and Jacob).

10. External view, x 98, Sample 2. 11. External view, x 112, Sample 2.

12-13. *Porosononion subgronosum* (Egger).

12. External view, x 112, Sample 1. 13. External view, x 98, Sample 27.

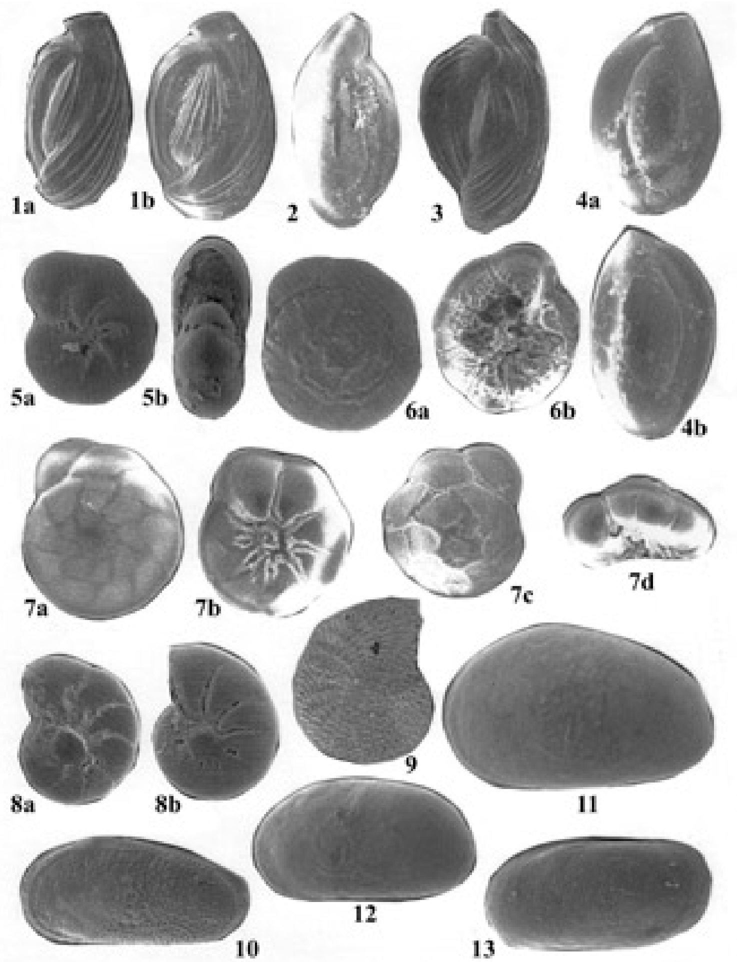

PLATE 5

1. *Adelosina carinata striata* Wiesner. a and b, external views, x 85, Camalti Saltpan, Sample 19.
2. *Adelosina cliarensis* (Heron-Allen and Earland). External view, x 45, Camalti Saltpan, Sample 5.
3. *Adelosina* cf. *mediterranensis* (Le Calvez J. and Y.). External view, x 40, Camalti Saltpan, Sample 5.
4. *Quinqueloculina seminula* (Linné). External views; a, x 40 and b, x 60, Camalti Saltpan, Sample 5.
5. *Nonion depressulum* (Walker and Jacob). External views, x 73, Camalti Saltpan, Sample1.
6. Ammonia compacta Hofker. External views; a, spiral side and b, umblical side, x 40, Camalti Saltpan, Sample 5.
7. *Ammonia tepida* Cushman. External views; a, spiral side and b, umblical side, x 70, Camalti Saltpan, Sample 5; c, spiral vand d, edge view, x 65; Camalti Saltpan, Sample 1.
8. *Porosononion subgranosum* (Egger). a and b, external views; a, x 73, Camalti Saltpan, Sample 1; b, x 85, Camalti Saltpan, Sample 21.
9. *Elphidium complanatum* (d'Orbigny). External view, x 30, Camalti Saltpan, Sample 2.
10. *Leptocythere lacertosa* (Hirschmann).External view, left valve, x 98, Camalti Saltpan, Sample 24.
11. *Cyprideis* (C.) *anatolica* Bassiouni. External view, x 63, left valve, Camalti Saltpan, Sample 21.
12. *Cyprideis torosa* (Jones). External view, x 38, left valve, Camalti Saltpan, Sample 21.
13. *Loxoconcha elliptica* Brady. External view, x 63, left valve, Camalti Saltpan, Sample 23.

PLATE 6

1a-b. *Hydrobia (Hydrobia) acuta* (Draparnaud), x 4.5, 1a apertural view, 1b dorsal view, Sample 21.
2a-b. *Hydrobia (Hydrobia) acuta* (Draparnaud), x 3.5, 2a apertural view, 2b dorsal view, Sample 23.
3a-b. *Rissoa labiosa* (Montagu), x 3, 3a apertural view, 3b dorsal view, Sample 25.
4a-b. *Rissoa parva* (da Costa), x 6, 4a apertural view, 4b dorsal view, Sample 23.
5a-b. *Rissoa violacea* Desmarest, x 3, 5a apertural view, 5b dorsal view, Sample 22.
6a-b. *Pirenella conica* (Blainville), x 3.5, 6a apertural view, 6b dorsal view, Sample 21.
7a-b. *Bittium desayesi* Cerulli and Irelli, x 4, 7a apertural view, 7b dorsal view, Sample 25.
8a-b. *Bittium lacteum* (Philippi), x 4, 8a apertural view, 8b dorsal view, Sample 9.
9a-b. *Bittium lacteum* (Philippi), x 4, 9a apertural view, 9b dorsal view, Sample 9.
10a-b. *Bittium lacteum* (Philippi), x 2.5, 10a apertural view, 10b dorsal view, Sample 21.
11a-b. *Bittium reticulatum* Philippi, x 2.5, 11a apertural view, 11b dorsal view, Sample 25.
12a-b. *Columbella* sp., x 3, 12a apertural view, 12b dorsal view, Sample 26.
13a-b. *Ostrea edulis* Linné, x 5.5, 13a left valve, external view, 13b left valve, internal view, Sample 21.
14a-b. *Ostrea edulis* Linné, x 5, 14a left valve, external view, 14b left valve, internal view, Sample 21,
15a-b. *Lucinella divaricata* (Linné), x 3.5, 15a left valve, external view, 15b left valve, internal view, Sample 9.
16a-b. *Pseudochama gryphina* Lamarck, x 3, 16a right valve, external view, 16b right valve, internal view), Sample 21.
17a-b. *Pseudochama gryphina* Lamarck, x 5.5,17a left valve, external view, 17b left valve, internal view, Sample 21.
18a-b. *Cerastoderma edule* (Linné), x 1.5, 18a left valve, external view, 18b left valve, internal view, Sample 17.
19a-b. *Scrobicularia plana* da Costa, x 2, 19a left valve, external view, 19b left valve, internal view, Sample no 21.