Spatio-temporal distributions of zoobenthos in Mersin Bay (Levantine Sea, eastern Mediterranean) and the importance of alien species in benthic communities

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Abstract
Spatio-temporal variations of soft-bottom zoobenthic communities in Mersin Bay were examined at seven stations between February and October 2009. A total of 337 species were encountered, of which Polychaeta had the highest number of species (136 species), and Mollusca possessed the highest number of individuals (65% of total specimens) and biomass (59% of total biomass). The highest benthos density (max. 9760 ind. m$^{-2}$) and biomass (max. 133 g m$^{-2}$) were found at shallow-water stations, whereas the highest diversity index values were calculated at the deepest station. The molluscs Cerithidium diplax, Corbula gibba and Bittium reticulatum dominated the area. Changes of zoobenthic communities were spatial rather than temporal and were strongly correlated with depth and the sediment structures. A total of 40 alien species were found in the area, of which 15 species were possibly transported to the area by ships and the others were Lessepsian migrants. The most dominant alien species in the area were C. diplax, Finella pupoides, Notomastus mossambicus and Amphiodia obtecta. Alien species formed dense populations at shallow water stations, and accounted for 12% of total number of species and 31% of total number of individuals in the area. The community parameters estimated for alien species significantly differed among stations but not among sampling periods. The main factors negatively affecting the number of alien species and individuals were depth, the clay percentage and total organic carbon concentration in sediment. The number of native species and individuals in the area show moderate positive correlations with those of aliens.

Key words: Zoobenthos, alien species, environmental factors, impact, Mersin Bay, eastern Mediterranean Sea

Introduction
The Mediterranean Sea is under invasion by alien species mainly introduced from the Red Sea via the Suez Canal (60% of the number of alien species) or from different oceans via shipping (Zenetos et al. 2010). Until now, a total of 955 alien species have been reported from the area, comprising almost 6% of total number of species in the Mediterranean Sea. The majority (718 species) were known from the eastern part that includes the Suez Canal. Some alien invertebrates such as Hydroidea spp., Spirobranchus kraussi (Baird, 1865), Peronion gibbesi (H. Milne-Edwards, 1853), and Conomurex persicus (Swainson, 1821) have become dominant components of the region and greatly altered benthic community structures (Çinar et al. 2011). These species, known as invasive species, can drastically alter the food web in the area, compete with native species for food and space, and import new diseases for native species (Por 1978; Galil & Lützen 1998; Çinar et al. 2005). As a result of today's increasing maritime traffic among regions, the ship-transferred alien species dominate harbour environments in the Mediterranean and replace some native species that were previously considered as pollution indicator species (Çinar et al. 2005; Dagli & Çinar 2008). The introduction of alien species (biological invasions) is considered to be a major factor threatening marine biodiversity together with overfishing, pollution, habitat destruction and global climate change (Ruiz et al. 1997; Carlton 2000; Bax et al. 2003).
Benthic habitats along the coasts of Turkey (especially the southern coast) have been densely colonized by Lessepsian species (i.e. species entering the Mediterranean via the Suez Canal) mainly due to the proximity to the Suez Canal. The southeastern part of the country (especially Iskenderun and Mersin Bays) also has large international harbours and jetties for crude oil and coal transfers. Therefore, the region is also a recipient area for ship-transferred species into the Mediterranean Sea. In Mersin Bay where the present study was performed, almost 105 alien invertebrates have been reported from the area to date, of which 25 are Polychaeta, 23 are Crustacea and 53 are Mollusca (authors’ database), accounting for 40% of the total alien invertebrates reported along the coasts of Turkey (Cınar et al. 2011). However, we have few biological data from the area and zoobenthos have rarely been a subject of study. Some papers reported faunistic (i.e. Holthuis & Gottlieb 1956; Lindner 1987; Engl 1995; Cınar 2009; Dagli & Cınar 2009) and ecological properties (Ergev et al. 2003; Stöhr et al. 2010) of native and alien species. Zoobenthic communities and their distributional patterns in Mersin Bay have been studied by Mutlu & Ergev (2008) and Mutlu et al. (2010). However, Mutlu & Ergev (2008) only considered epifauna sampled by a dredge and Mutlu et al. (2010) only studied the distribution of polychaetes in the area. This study is a first attempt to elucidate the structures of soft-bottom zoobenthic communities in the area.

The aims of this study are to determine the species composition, abundance and distribution of the zoobenthic fauna in Mersin Bay, to address the main environmental factors affecting the distribution of the species and to find out the importance of alien species in the zoobenthic communities.

**Material and methods**

**Sampling**

The field sampling for the present study was conducted at 7 stations in Mersin Bay. Shallow-water stations (9–21 m depth) 3 and 2 are situated near Mersin Marina and Mersin Harbour, respectively. Another shallow-water station, station 1, is more or less under the influence of the Seyhan River (high silicate concentration). Three deep-water stations (38–72 m depth) were chosen in the area (Table I). Soft-bottom samples were collected with a van Veen grab (sampling an area of 0.1 m²) over 4 months (February, April, August, October) in 2009 by R/V ‘Bilim’ (Figure 1). At each station, three replicates were taken for benthic community analysis and an additional sample for granulometric and chemical analysis of the sediment. On board the R/V ‘Bilim’, benthic samples were sieved with a 0.5-mm mesh and the fauna retained were put in jars containing 10% seawater–formalin solution. Deep seawater samples were taken by using a Nansen bottle at each grab station during the sampling period. Temperature, salinity and dissolved oxygen concentration were determined in the field. The physico-chemical properties of stations will be presented by Tugrul et al. (in preparation).

**Laboratory procedures**

Water samples for analysing nitrite, nitrate, ammonium, phosphate phosphorus and silicate were frozen after pre-filtration and then immediately transferred to the laboratory. Nutrients and Chlorophyll a were analysed by using spectrophotometer (Parsons et al. 1984). The total organic carbon concentration (TOC) in each sediment sample was estimated according to the modified Walkley Black titration.
Table I. Depth, coordinates and dominant species of each station, and the percentages of total abundance of alien and native species at stations.

| Stations | Original station codes | Coordinates       | Depth (m) | Dominant species (%) | Dominance of alien species (%) |
|----------|------------------------|-------------------|-----------|----------------------|-------------------------------|
| 1        | 34                     | 36°43'33"N        | 9         | Corbula gibba (12)   | 29                            |
|          |                        | 34°52'11"E        |           | Cerithium diplax (9) |                               |
| 2        | 17                     | 36°46'24"N        | 13        | C. diplax (25)       | 44                            |
|          |                        | 34°40'13"E        |           | C. gibba (12)        |                               |
| 3        | 2                      | 36°44'30"N        | 20        | C. diplax (34)       | 54                            |
|          |                        | 34°34'59"E        |           | C. gibba (23)        |                               |
| 4        | 43                     | 36°33'59.8"N      | 21        | Bittium reticulatum (28) | 9                             |
|          |                        | 35°7'59.7"E       |           | Pseudofabriciola longipinna (6) |                               |
| 5        | 27                     | 36°41'17"N        | 38        | Tierrellia communis (14) | 17                            |
|          |                        | 34°49'12"E        |           | C. gibba (13)        |                               |
| 6        | 14                     | 36°41'38"N        | 47        | T. communis (37)     | 25                            |
|          |                        | 34°42'00"E        |           | Finella pupoides (13) |                               |
| 7        | 10                     | 36°37'16"N        | 72        | T. communis (22)     | 6                             |
|          |                        | 34°34'34"E        |           | Nephtys incisa (6)   |                               |

method (Gaudette et al. 1974). The granulometric analyses were made according to Erguvanli (1995). Three particle size fractions were determined in the area: sand (particle size: 2–0.063 mm), silt (0.063–0.002 mm) and clay (<0.002 mm).

The material was sorted according to major taxonomic groups under a stereomicroscope and preserved in 70% ethanol. The specimens were then identified and counted, and the total wet weight of each systematic group was estimated by using a balance of 0.0001 g sensitivity.

Data analysis

The number of species (S), the number of individuals (N), Shannon’s diversity index (log2 base) (H’), Pielou’s evenness index (J’) and the total biomass value (wet weight) (B) were calculated for each station in each sampling period.

The temporal variations at each station were analysed using one-way ANOVA. In order to check the null hypothesis that the community parameters (S, N, B, H’, J’) did not differ significantly between sites and sampling periods, a two-way ANOVA test was also carried out. Prior to the analyses, data were tested for normality by the Kolmogorov–Smirnov test (K–S test), while the homogeneity of variances was tested by the Cochran’s C test. The Fisher’s LSD test was used for post-hoc comparisons. The raw data were ln(x+1) transformed if they did not meet the assumptions of normality and homogeneity of variances.

The Spearman’s rank correlation analysis was used to determine the correlation between the community (diversity index, evenness index, species richness, number of species and number of individuals) and environmental parameters.

Canonical correlation analysis (CCA), a canonical extension of principal component analysis (Teer Braak & Smilauer 2002), was performed to analyse the relationship between the zoobenthic assemblages and environmental factors. Prior to the analysis, the raw data (number of individuals) were transformed using the transformation of yj = log(xj + 1). Monte Carlo permutations were used to test the significance of the ordination axes.

Distance-based permutational multivariate analysis of variance (PERMANOVA; Anderson et al. 2008) was used to test two null hypotheses of no differences among the zoobenthic assemblages: (i) between the stations and (ii) among the four sampling months. The experimental design has two factors: stations (with seven levels) and months (with four levels and crossed with stations). All factors were random. For each pseudo-F test, post-hoc tests for significant effects (pairwise) were also estimated. Prior to analysis, the data were subjected to the ln(x+1) transformation.

All statistical analyses were performed by using PRIMER 6 & PERMANOVA+, STATISTICA 7.0 and CANOCO 4.5.

The specimens identified were deposited at the Museum of Faculty of Fisheries, Ege University (ESFM).

Results

Species composition

A total of 337 zoobenthic species and 16705 individuals belonging to 8 systematic groups were identified from benthic samples taken at 7 stations and 4 different sampling periods in Mersin Bay (see Supplementary Table online). The majority of species (93%) belong to 3 groups, namely Polychaeta (136 species, 40% of total number of species), Mollusca (122 species, 36%) and Crustacea (59 species, 17%). Mollusca were represented by the highest number of individuals (65% of total specimens) and biomass (59% of total biomass) in the area. Polychaeta (21%
of total number of specimens) and Echinodermata (24% of total biomass) are the other important groups in terms of total abundances and biomass. This order did not change in relation to depths. However, the abundance of Mollusca in shallow waters (0–21 m) (67% of total specimens) was higher than that in deep waters (22–72 m) (55%).

A total of 40 alien species (5277 specimens) belonging to 5 systematic groups were found in Mersin Bay (Supplementary Table). Mollusca (20 species) and Polychaeta (16 species) were the most diverse groups, accounting for 50% and 40% of the total number of species, respectively. These groups accounted for almost 92% of total number of individuals. Fifteen species (38% of total number of species) could have been transferred to the area by ships and accounted for 52.8% of total number of individuals of alien species in the area. The other species are Lessepsian migrants.

The dominant species in the area were Cerithidium diplax (Watson, 1886) (14.2% of total number of specimens), Corbula gibba (Olivi, 1792) (11.6%), Bittium reticulatum (Da Costa, 1778) (7.8%), Nassarius pygmaeus (Lamarck, 1822) (4.8%) and Turrriella communis Risso, 1826 (%3.7). The dominant species changed according to sampling periods. Bittium reticulatum (23.8%), C. diplax (19.5%) and Finella pupoides Adams, 1860 (6.6%) became the most dominant species in February; C. gibba (24%), C. diplax (6.3%) and Ampelisca typica (Bate, 1856) (5.7%) in April; C. diplax (12.7%), N. pygmaeus (8.6%) and C. gibba (8.3%) in August; C. diplax (28.3%), Notomastus mossambicus (Thomassin, 1970) (8.9%) and N. pygmaeus (6.9%) in October. Stations had different dominant species, but C. diplax, T. communis and C. gibba were the most important species at all stations, except for station 4 where B. reticulatum and Pseudofabriciola longipygta Fitzhugh, Giangrande & Simboura, 1994 were represented by the highest number of individuals. Shallow-water stations near Mersin harbour (stations 2 and 3) and Seyhan River (station 1) were numerically dominated by two species, C. diplax and C. gibba. Among the most dominant species, C. diplax formed dense populations at stations 3 (2030 ind. m⁻², February), 2 (3250 ind. m⁻², October) and 1 (1050 ind. m⁻², August); C. gibba at stations 3 (1680 ind. m⁻², April), 2 (1490 ind. m⁻², April) and 1 (1770 ind. m⁻², April); B. reticulatum at station 4 (3470 ind. m⁻², February); N. pygmaeus at stations 2 (1270 ind. m⁻², February) and 1 (1230 ind. m⁻², August); and T. communis at station 6 (1060 ind. m⁻², February).

The most frequent species (present in 71% of samples) were C. gibba, N. pygmaeus, C. diplax and Nepthys incisa Malmgren, 1865 in February; N. incisa (90%), C. gibba (86%), Abra alba (Wood W., 1802) (76%) and Amphiodia obtecta Mortensen, 1940 (71%) in April; C. gibba (81%), E. pupoides (76%) and N. incisa (76%) in August; and N. mossambicus (81%), C. diplax (71%) and A. obtecta (62%) in October.

The most dominant alien species in the area were C. diplax (45.5% of total individuals of alien species), E. pupoides (11.8%), N. mossambicus (9.3%), A. obtecta (7.7%), Pyrunculus fourierii (Audouin, 1826) (4.6%) and Glynceinde bonhourei Gravier, 1904 (4.5%). A total of 29 species had a dominance value less than 1%. The species presenting more than 50% of total samples were C. diplax (64%), E. pupoides (58%), N. mossambicus (58%), A. obtecta (54%) and G. bonhourei (51%). The maximum population density of C. diplax (3250 ind. m⁻², October) was found at station 2; that of E. pupoides (800 ind. m⁻², February) at station 3; that of N. mossambicus (430 ind. m⁻², October) at station 2; that of A. obtecta (420 ind. m⁻², August) at station 1; and that of G. bonhourei (170 ind. m⁻², April) at station 1.

**Temporal variations of community parameters**

Temporal variations in the number of individuals, number of species, biomass, and diversity and evenness values at all stations are presented in Figure 2. The mean number of species was generally high in April at all stations, except for station 47. The lowest number of species in shallow (9–21 m) and deep (22–72 m) waters were found in October and February, respectively. Temporal changes in the number of species at stations 1, 2, 4 and 5 were statistically significant (p < 0.05). The highest zoobenthos densities were encountered at stations 2 (9760 ind. m⁻² in February) and 1 (9480 ind. m⁻² in April). The highest mean density (8860 ind. m⁻²) was determined at station 1 in April, the lowest density (347 ind. m⁻²) at station 6 in October. Only at stations 1 and 4, the monthly changes in the zoobenthos density were significant (p < 0.05). It was also observed that the mean number of individuals fluctuated greatly at shallow-water stations, whereas it was fairly constant at deep-water stations (especially at stations 5 and 7). The highest biomass (wt weight) of zoobenthos was estimated at stations 2 (max. 55 g m⁻², February), 5 (133 g m⁻², April), 1 (91 g m⁻², August) and 7 (41 g m⁻², October). The highest mean score was determined as 93 g m⁻² at station 5 (April) and the lowest score as 3 g m⁻² at station 4 (October). The main reason for changes in biomass scores at stations is the densities of some mollusc and echinoderm species that have high individual biomass. The mean biomass values were generally high in April and August. The biomass of zoobenthos at four stations represented significant changes with respect to sampling periods (p < 0.05) (Figure 2).
The mean diversity index values were always higher than 3 at stations 1 and 7, and always lower than 3 at station 3 in three sampling periods (February, April and August) (Figure 2). The highest diversity index value ($H' = 4.9$) was encountered at station 7 (October) and the lowest value ($H' = 1.07$) at station 5 (February). Except for stations 3, 5 and 7, the diversity index value at stations varied significantly between sampling periods ($p < 0.05$). As for the evenness index values at stations, the highest score ($J' = 0.92$) was found at the deepest station (station 7, February and April), the lowest score ($J' = 0.43$) at...
station 4 (February). The mean evenness values at stations 7 and 1 were always higher than 0.70 in all sampling periods. Seasonality significantly changed the evenness values at all stations \((p < 0.05)\), except for stations 5 and 1.

The maximum number of alien species, number of individuals, and the diversity index value were encountered at station 1, with peaks in August (Figure 2). The temporal trend of the diversity index values estimated for alien species was somewhat similar to that estimated for all zoobenthic species. This is more apparent at stations 1, 2 and 4. The mean diversity index values estimated for alien species ranged from 0.31 (station 7) to 2.97 (station 1). The highest evenness index values were found at stations 5 and 7. Alien species formed dense populations at shallow-water stations (max. 3790 ind. m\(^{-2}\) at station 2, October) and were represented by a small number of individuals at deep-water stations. The community parameters did not show any temporal differences at the deepest station (station 7, \(p > 0.05)\), but at least one parameter showed a significant fluctuation \((p < 0.05)\) at other stations. The highest diversity index values (max. \(H' = 3.21\) at station 1, August) were also estimated at shallow-water stations (2 and 1).

Community parameters varied significantly between stations, sampling periods and the combined effect of time and stations \((p < 0.01)\) (Table II). The stations 1, 3, 4 and 7, and the April period are mainly responsible for these significant differences. However, it should be kept in mind that small-scale heterogeneity of substrates at stations might exist and affect the results given in Table II.

Table II. Result of two-way ANOVA of the community parameters estimated for total species and alien species. MS, mean square; \(p\), level of probability; * \(p < 0.05\); ** \(p < 0.01\); *** \(p < 0.001\); df, degrees of freedom; C, Cochran’s test; ns, non-significant. Post-hoc test (Tukey HSD) shows the stations and sampling periods which determine statistical differences.

| Transformation | Sources of variation | df | MS | \(p\) | MS | \(p\) | MS | \(p\) | MS | \(p\) |
|----------------|----------------------|----|----|------|----|------|----|------|----|------|
| Number of species | \(C = 0.16^{*ns}\) |    |    |      |    |      |    |      |    |      |
| Number of individuals | \(C = 0.46^{***}\) |    |    |      |    |      |    |      |    |      |
| Evenness index (J) | \(C = 0.47^{***}\) |    |    |      |    |      |    |      |    |      |
| Diversity index (H) | \(C = 0.15^{*ns}\) |    |    |      |    |      |    |      |    |      |
| Biomass | \(C = 0.35^{***}\) |    |    |      |    |      |    |      |    |      |

| Transformation | Sources of variation | df | MS | \(p\) | MS | \(p\) | MS | \(p\) | MS | \(p\) |
|----------------|----------------------|----|----|------|----|------|----|------|----|------|
| Number of species | \(C = 0.28^{*ns}\) |    |    |      |    |      |    |      |    |      |
| Number of individuals | \(C = 0.33^{***}\) |    |    |      |    |      |    |      |    |      |
| Evenness index (J) | \(C = 0.20^{***}\) |    |    |      |    |      |    |      |    |      |
| Diversity index (H) | \(C = 0.24^{***}\) |    |    |      |    |      |    |      |    |      |

Correlation between community parameters and environmental variables

The Spearman’s rank correlation analysis between the mean scores of community parameters and the environmental variables indicated that the number of species and individuals were negatively correlated with the depth, salinity, the
concentration of organic carbon and the percentage of clay in sediment ($p < 0.05$) (Table III). The other significant correlations were estimated between the evenness index and depth ($r = -0.38$); between biomass, and salinity ($r = -0.44$) and dissolved oxygen ($r = -0.44$); between the diversity index and the concentration of carbon in sediment ($r = -0.54$) (Table III).

The main factors negatively affecting the number of species and individuals of alien species in the area were depth ($\rho_t = -0.85$, $\rho_t = -0.78$, respectively), the clay percentage ($\rho_t = -0.37$, $\rho_t = -0.26$, respectively) and TOC ($\rho_t = -0.41$, $\rho_t = -0.20$, respectively) in sediment (Table III). The concentrations of nutrients and Chl $a$ in water samples were positively correlated with the community parameters, except for evenness index values. Depth (negatively), temperature (positively), and the concentrations of silicate (positively) and TOC (negatively) were significantly correlated with the diversity of alien species (Table III).

**Table III.** Spearman’s rank correlation coefficients between environmental and community variables estimated for all and alien species. Bold numbers are statistically significant ($p < 0.05$)

|                  | Number of species | Number of individuals | Biomass | Diversity index | Evenness index |
|------------------|-------------------|-----------------------|---------|-----------------|---------------|
| **ALL SPECIES**  |                   |                       |         |                 |               |
| Depth            | -0.60             | -0.74                 | -0.35   | -0.16           | 0.38          |
| Temperature      | -0.02             | -0.07                 | -0.18   | 0.35            | 0.33          |
| Salinity         | -0.49             | -0.48                 | -0.44   | -0.04           | 0.35          |
| Phosphorus       | 0.08              | 0.08                  | -0.25   | 0.21            | 0.10          |
| Total            | 0.09              | 0.19                  | 0.16    | 0.09            | -0.03         |
| Nitrogen Silicate| 0.04              | 0.13                  | -0.13   | 0.22            | 0.14          |
| Oxygen           | 0.45              | 0.41                  | 0.49    | -0.02           | -0.32         |
| TOC              | -0.61             | -0.47                 | -0.26   | -0.54           | -0.19         |
| Chl $a$          | 0.18              | 0.37                  | 0.28    | -0.04           | -0.34         |
| Sand             | 0.45              | 0.32                  | 0.03    | 0.15            | -0.05         |
| Silt             | -0.23             | -0.06                 | 0.13    | -0.11           | -0.07         |
| Clay             | -0.44             | -0.44                 | -0.17   | -0.09           | 0.20          |
| **ALIEN SPECIES**|                   |                       |         |                 |               |
| Depth            | -0.85             | -0.78                 | -0.74   | 0.61            |               |
| Temperature      | -0.14             | -0.05                 | -0.38   | 0.06            |               |
| Salinity         | -0.25             | -0.28                 | -0.06   | 0.32            |               |
| Phosphorus       | 0.25              | 0.21                  | -0.32   | -0.16           |               |
| Total            | 0.41              | 0.43                  | -0.32   | -0.27           |               |
| Nitrogen Silicate| 0.32              | 0.34                  | -0.39   | -0.26           |               |
| Oxygen           | 0.20              | 0.17                  | -0.02   | -0.16           |               |
| TOC              | -0.41             | -0.20                 | -0.57   | 0.01            |               |
| Chl $a$          | 0.30              | 0.41                  | -0.11   | -0.42           |               |
| Sand             | 0.11              | 0.01                  | 0.03    | 0.03            |               |
| Silt             | 0.21              | 0.28                  | 0.17    | -0.29           |               |
| Clay             | -0.37             | -0.26                 | -0.34   | 0.18            |               |

**Relationship between the zoobenthic assemblages and environmental factors**

The CCA showed that zoobenthic assemblages differed greatly according to depths in the area (Figure 3). The samples taken at four sampling periods at the deepest stations (station 3, 6 and 7) grouped separately in the ordination. The shallow-water stations also grouped separately, showing some dissimilarity in sampling periods. All four canonical axes together explained 53.6% of the variability, but the first two axes contributed 32.1%. The Monte Carlo test proved that all canonical axes were statistically significant ($F = 1.566$, $p = 0.002$). Depth, the percentage of clay in the sediment and salinity had the strongest correlations with the first axis; the percentages of silt and sand in the sediment with the second axis; and the total organic carbon content of sediment with the third axis (Figure 3).

The CCA showed that depth is the major factor influencing the alien species assemblages in the area (Figure 3). The temporal samples at deepest stations (stations 5, 6 and 7) grouped separately in the ordination. The shallow-water stations also grouped separately. All four canonical axes together explained 71.4% of the variability, but the first two axes contributed 49.2%. The Monte Carlo test proved that all canonical axes were statistically significant ($F = 1.511$, $p = 0.002$). Depth and salinity had the strongest correlations with the first axis; the percentages of sand and clay in sediment with the second axis; and bottom layer temperature with the third axis (Figure 3). The species responsible for station’s groupings are indicated in Figure 3. The species that were only present at station 7 (the deepest station) were *Aspidosiphon mexicanus* (Murina, 1967), *Pista unibranchiata* Day, 1963 and *Chaetozone corona* Berkeley & Berkeley 1941. The species that preferred a sandy bottom (station 4) were *Rhinoclavis kocki* (Philippi, 1848), *Cerithium scabridum* Philippi, 1848, *Zafra savignyi* (Moazzo, 1939) and *Prionospio depauperata* Imajima, 1990. The species such as *Finella pupoides*, *Notomastus mosambicus* and *Cerithium diplax* dominated shallow-water stations (stations 1, 2 and 3) that are characterized by relatively high Chla and total nitrogen concentrations. *Polydora cornuta* Bosc, 1802 and *Anadara natalensis* (Krauss, 1848) showed a significant positive correlation with the total nitrogen concentration.

**Changes of zoobenthic communities at stations and sampling periods**

The analysis of two-way PERMANOVA indicated that there were significant differences in the distributions of zoobenthos with stations and sampling
periods ($p < 0.001$) (Table IV). Pairwise analysis showed that all comparisons among stations and sampling periods were significant ($p < 0.001$).

Importance of alien species in the area

The importance of alien species at stations was presented in Table I. In total, alien species accounted for 12% of total number of species and 31% of total number of individuals in the area. Except for deep-water stations (stations 4 and 7), alien species accounted for almost 20–25% of the total number of species at stations in the sampling periods. At stations 2 and 3, alien species comprised more than 50% of total number of individuals in February and October. At station 3, the total number of individuals of alien species was higher than that of native species (Table I).

Correlation between abundances of dominant alien species and environmental factors

Abundances of dominant alien species in the area were negatively correlated with depth ($r = -0.74$ for Cerithidium diplax, $r = -0.58$ for Amphiodia obtecta, $r = -0.87$ for Glycinde bonhourei, $r = -0.77$ for Notomastus mossambicus and $r = -0.58$ for Pyrunculus fourierii). Abundances of C. diplax ($r = 0.40$) and P. fourierii ($r = 0.61$) significantly increased with the increase in total nitrogen concentrations. Sediment textures played important roles in distribution and abundances of Cerithium scabridum ($r = 0.45$, with sand), A. obtecta ($r = 0.51$, with silt) and N. mossambicus ($r = -0.59$, with clay).

Natives vs. aliens

Although the values of correlation coefficients are moderate, the number of species and individuals of natives in the area show positive correlations with those of aliens (Figure 4). This general pattern does not change according to seasons and stations. However, the highest correlations between the number of species of aliens and natives were encountered in winter ($r = 0.70$) and summer ($r = 0.62$), and the lowest in autumn ($r = 0.28$). The correlation coefficients between the number of individuals of aliens

Figure 3. Upper: Biplot of CCA performed on total abundance of all species and environmental variables (arrows) at samples (Chl: chlorophyll a; O: oxygen, P: phosphorus, Si: silicate, T: temperature, TIN: total inorganic nitrogen, TOC: total organic carbon). Lower: Biplot of CCA performed on total abundance of alien species and environmental variables (arrows) at temporal samples. Species having the lower number of specimens (1–2 specimens) were omitted in the analysis. (Am: Aspidosiphon mexicanus; An: Anadara natans; Ao: Amphiodia obtecta; Cc: Chaetozone corona; Cd: Cerithidium diplax; Cp: Cerithidium perparvulum; Cs: Cerithium scabridum; Ff: Fulvia fragilis; Fp: Finella pupoides; Gb: Glycinde bonhourei; Ln: Leucotina natans; Lp: Lomnates persicus; Mg: Macrophthalmus graeffei; Ml: Monotigma lauta; Na: Notomastus aberans;Nm: Notomastus mossambicus; Np: Nereis persica; Ol: Odostomia loriolii; Pc: Polydora cornuta; Pd: Prionospio depauperata; Pf: Pyrunculus fourierii; Pp: Prionospio pulchra; Pp: Pseudopolydora pascibranchiata; Ps: Prionospio saccifera; Pt: Paphia textile; Pu: Pista unibranchiata; Rk: Rhinoclavis hochst; Sf: Syrinoa fasciata; Sl: Syrinoa lendix; Sp: Conomurex persicus; Zs: Zafra savignyi).
and natives were estimated as 0.37 in winter, 0.72 in spring, 0.92 in summer and 0.20 in autumn. The values of correlation coefficients between the number of species of aliens and natives ranged from 0.14 (station 5) to 0.69 (station 3), and those between the number of individuals of aliens and natives ranged from 0.06 (station 3) to 0.80 (stations 4 and 6).

Discussion

A spatio-temporal analysis of zoobenthic communities in Mersin Bay yielded a total of 337 species, a maximum density of 9760 ind. m$^{-2}$ (station 2, in February) and a maximum biomass of 133 g m$^{-2}$ (station 5, in April).

Density of zoobenthos

As no detailed previous study on zoobenthos is available in Mersin Bay, or on the southern coast as a whole, the results of the present study could not be compared with any other studies. However, on the Levantine coast of Israel, Galil & Lewinsohn (1981) encountered 245 zoobenthic species between 18 and 80 m depths. Tom & Galil (1991) reported 401 species between 12 and 80 m depths in Haifa Bay. Similar to the present study, Zenetos et al (1997) reported 351 zoobenthic species between 10 and 100 m depths in the central Mediterranean. Parallel

Figure 4. Correlations between number of native and alien species (upper figure), and abundances of native and alien species (lower figure).
with our findings, Galil & Lewinsohn (1981) also found that Mollusca were the most important group. Unlike this finding, Polychaeta are known to be the most dominant group in soft substrata, comprising more than 60% of total populations (Pinedo et al. 1996; Karakassis & Eleftheriou 1997; Hoey et al. 2004). This can be explained by a shift created by the alien species. The alien gastropods such as Cerithidium diplax (this study), Finella pupoides (this study), and Rhinoclavis kocki (cited as Cerithidium kocki by Galil & Lewinsohn 1981 and Tom & Galil 1991) seem to have replaced some detritivorous polychaetes. At this stage, we cannot point out which polychaete species had been partly or totally eliminated from shallow-water soft substrata in Mersin Bay, but comparisons among the present data and those obtained from the neighbouring Aegean Sea indicate that the species belonging to Spionidae, Paraonidae, Cirratulidae and Sternaspis scutata were represented by relatively lower numbers of individuals in the present study.

The eastern Mediterranean, especially the Levantine Sea, was considered as one of the most oligo-trophic waters of the world’s oceans (Chla < 0.5 μg l⁻¹ and primary production 45 mgC m⁻² day⁻¹) (Ediger & Yılmaz 1996). In the summer of 1996, the primary production was estimated as 350–450 mgC m⁻² day⁻¹ in the western Mediterranean and 150 mgC m⁻² day⁻¹ in the eastern Mediterranean (Moutin & Raimbault 2002). Therefore, the amount of organic material production in the bottom sediment could be expected to be relatively low (Karakassis & Eleftheriou 1997). The mean density of soft-bottom zoobenthos in Mersin Bay was calculated as 1989 ind. m⁻² [range: 110 (at station 5, February)–9760 ind. m⁻² (station 2, February)]. In the South Aegean Sea, the mean zoobenthic density was determined as 4250 ind. m⁻² at 40 m (Karakassis & Eleftheriou 1997; Tselepides et al. 2000), which is more than 7 times higher than the density [mean: 550 ind. m⁻² at 38 m (station 5)] found at the same depth in Mersin Bay. In the Atlantic coast of Spain, the maximum density of zoobenthos was estimated as 6456 ind. m⁻² in muddy substratum (Polychaeta comprising 69% of total populations) (Junoy & Viéitez, 1992). In the shallow water of the western Mediterranean, the zoobenthos density can reach up to 51,600 ind. m⁻² in Blanes Bay (Pinedo et al. 1996), 600,000 ind. m⁻² off Barcelona (polluted) and 40,000 ind. m⁻² off Santa Margarida (Sardà et al. 1995). In the Theraikos Gulf, the density of zoobenthos ranged from 540 to 2992 ind. m⁻² (Zarkanellas & Kattoulas 1982). Zenetos et al. (1997) reported that the zoobenthos density between 10 and 104 m depths on the Ionian coast of Greece varied between 500 and 7830 ind. m⁻², with the mean density of 1903 ind. m⁻². In polluted areas of Izmir Bay (Aegean Sea), the zoobenthos density reached up to 81,720 ind. m⁻² (Çınar et al. 2006).

**Dominant species**

The most abundant species found in this study were Bittium reticulatum, Cerithidium diplax, Corbula gibba, Nassarius pygmaeus and Tirritella communis. All these species are detritivorous or suspensivores (C. gibba), indicating the high amounts of detrital materials in the area, especially stations 1 and 2 that are located near Mersin City and Seyhan River. Interestingly, the abundance of these species, including the thermophilic species C. diplax, a small-sized alien species (shell 2–3 mm in height) introduced to the area from the Persian Gulf or Pacific Ocean via ships (Aartsen 2006), had a peak in February. Their abundances greatly diminished in August and October. Corbula gibba was known to form dense populations in stressed environments, i.e. 1217 ind. m⁻² in the Po River Delta (Hrs-Brenko 2006), 633 ind. m⁻² in Thermiko Bay (Aegean Sea) (Zarkanellas & Kattoulas 1982), 3000 ind. m⁻² in the north Adriatic Sea (Occhipinti-Ambrogi et al. 2005) and 15,860 ind. m⁻² in the polluted inner part of Izmir Bay (Çınar et al. 2006). It was also considered as an indicator of organic enrichment and anoxic conditions (Diaz & Rosenberg 1995). The maximum density (1770 ind. m⁻²) of this species was found at station 1, which is more or less influenced by the Seyhan River. The alien species C. dispar formed dense populations at stations 2 and 3 that are close to the Mersin Harbour and Marina. At deep stations (6 and 7), the most abundant species was T. communis, which was also reported in semi-polluted waters (Moreira et al. 2010). This species is known to be a characteristic species of the VTC community (Vase Terrigenous Silt) in the Mediterranean Sea (Pérès & Picard 1964; Zarkanellas & Kattoulas 1982). Nassarius pygmaeus, which sustain high populations in heavily polluted waters (Çınar et al. 2006), preferred shallow-water stations in Mersin Bay. Galil & Lewinsohn (1981) reported the dominance of the Lessepsian migrant Rhinoclavis kochi (1306 specimens) in soft substrates on the coast of Israel, but this species rarely occurred in Mersin Bay (at station 4, 3 specimens in total). However, they used different sampling gear such as grab, dredge and beam-trawl and collected motile macro fauna such as Erugosquilla massavensis (Kossmann, 1880) and Charybdis longicollis Leene, 1938 that were absent in the present study (where only the grab was used). The examination of the material collected by a sledge in Mersin Bay revealed that the alien species Conomurex persicus was the most dominant at 10 m depth, comprising 94% of total populations (Mutlu & Ergev
2008). As we used a grab for sampling, this large species was represented by a smaller number of specimens in samples.

**Polychaetes**

Polychaetes with different feeding modes (Fauvel & Jumars 1979) and life-history traits (Giangrande et al. 1994) dominate soft-bottom environments. They were represented by 136 species in the present study, with *Notomastus mossambicus* (14% of total polychaeta abundance and 3% of total abundance), *Mediomastus sp.* (8.3% and 1.7%), *Sigambra tentaculata* (Treadwell, 1941) (7% and 1.5%), *Nephtys incisa* (6.8% and 1.4%) and *Glycine bonhourei* (6.5% and 1.3%) being the most abundant species. The first three species are deposit feeders and dominated shallow-water stations near Mersin harbour (station 2) and Seyhan River (station 1), which sustain relatively high loads of organic matter. Among the species, *N. mossambicus* and *G. bonhourei* are Lessesian migrants (see Çınar et al. 2011) that seem to have been well acclimatized in the Levantine Sea. We do not know at this stage with which species they have competed in the area for food and space, but the native species such as *Heteromastus filiformis* (Clapare`de, 1864) and *Glycine nordmanni* (Malmgren, 1866) that occupy the same niche and form relatively dense populations in the Aegean Sea (i.e. Ergen et al. 2006) seem to have been partly or totally eliminated from the area. When compared to other studies on soft-bottom polychaetes in the Mediterranean, it can be seen that the polychaete diversity in Mersin Bay is as high as in the other parts of the Mediterranean [i.e. 146 species in Amvrakikos Bay (Nicolaidou & Papadopoulos 1989), 97 species in Tyrrhenian Sea (Gambì & Giangrande 1986), 101 species in Alfacs Bay (Martin et al. 2000) and 153 species in Izmir Bay (Dogan et al. 2005)]. A recent study dealing with polychaetes in Mersin Bay (Mutlu et al. 2010) reported 184 polychaeta species between 5 and 200 m depth, with *H. filiformis*, *Prionospio saccifera* Mackie & Hartley, 1990 and *Monticellina heterochaeta* Laubier, 1961 being the most dominant species. The first two species were less important in the present study, accounting for 0.11% (15% in the previous study) and 1.5% (8.5% in the previous study) of total number of polychaeta individuals, respectively. These differences between two studies can be attributed to differences in the sampling strategies. Mutlu et al. (2010) examined more samples (252 samples between 10 and 200 m depths) than we did in the present study (84 samples between 9 and 72 m).

**Temporal variations**

The abundance and biomass of zoobenthos in Mersin Bay had a peak during April, coinciding with the recruitment of several benthic species. Seasonality did not play important roles in density and biomass of zoobenthos in deep waters (stations 7 and 6) but was apparent at shallow-water stations as indicated by Tom & Galil (1991). The zoobenthos density and biomass fluctuated most at stations 1 and 5 that are more or less influenced by the Seyhan River flow. Interestingly, the diversity index and evenness values attained their maxima in August or October, indicating sharp decreases in abundances of dominant species due to predation or possibly other reasons. The temporal pattern of zoobenthos in Mersin Bay is somewhat similar to the findings in the western (Sardà et al. 1995) and eastern (Çınar et al. 2006) parts of the Mediterranean, with a peak during spring, a sharp decrease during summer and lower abundances through autumn. Sardà et al. (1995) attributed this pattern to the phytoplankton productions observed in the area. We also estimated a positive correlation ($\rho = 0.37$) between the Chla concentrations and abundances of zoobenthos. The abundance of alien species at stations did not follow this pattern and were generally high in February or October when the diversity values increased. ANOVA did not detect significant temporal changes in community parameters of alien species, whereas PERMANOVA confirmed drastic changes in community structures of alien species among sampling periods. For example, *Cerithidium diplax* was the dominant species in all sampling periods but the dominance level increased in February and October (ca. 55% of total populations), and diminished in April and August (ca. 35%), unlike *Pyrunculus fourierii*, which became an important component in April and August. In relation to sampling periods, the composition of alien species did not change but their importance in the communities did change.

**Environmental factors influencing zoobenthic communities**

The main environmental factors affecting benthic communities in the area were depth, sediment structures and TOC in sediment. These factors were known to have strong impacts on distributional patterns of zoobenthos (Hyland et al. 2005; Labrune et al. 2007; Arrighetti & Penchasazdeh 2010). Although the concentrations of TOC did not change significantly relative to stations (ANOVA, $p > 0.05$), relatively low TOC concentrations resulted in the formation of a different benthic community at stations
5 and 6, where detritus feeders such as those belonging to the families Spionidae and Capitellidae had low densities. Negative correlations were estimated between the TOC concentrations and all community parameters of total and alien fauna. Gray (2002) and Guzmán-Alvis et al. (2006) showed that most of the observed biological variability was spatial rather than temporal, and was determined by the sediment heterogeneity and depth. Ellingsen (2002) regarded depth, median grain size and silt–clay content as the major environmental variables influencing the faunal patterns. In the present study, increasing sand percentage in sediment significantly increased the number of species whereas the clay percentage in sediment was negatively correlated with all community parameters (except for evenness index). Covazzi Harriague & Albertelli (2007) reported that the increase in particle diameter of sediment negatively affected the number of species but abundance of species were more or less constant for all particle sizes, which was only related to the food quality (protein : carbohydrate ratio). Some patterns in the structures of benthic communities cannot be solely expained by the effects of abiotic factors, biotic factors such as the availability of food, larval recruitments and predation can also significantly alter benthic community structures (Ambrose 1991; Woodin 1976; Wilson 1991; Giangrande et al. 1994).

Importance of alien species in communities

The present study indicated the importance of alien species in benthic communities on the northern Levantine coast, which is very close to the Suez Canal. Alien species comprised 12% of total number of species and 31% of total number of individuals in the area. Such high percentage was also noted in the polluted soft-bottom of Izmir Bay (Aegean Sea) where alien species accounted for more than 90% of total zoobenthos abundance (Çinar et al. 2006). In the polluted soft-bottom of the Golden Horn Estuary (Sea of Marmara), alien species comprised 46% of total polychaete populations (Çinar et al. 2009). Lee et al. (2003) also found that 90% of total populations in the San Francisco Estuary belonged to alien species. Although alien species (especially large invasive species) could affect native species negatively by overlapping their niches in the ecosystem (Ruiz et al. 1997; Carlton 2000), Olenin & Leppäkoski (1999) postulated that alien species somewhat increased the functional diversity in the Baltic Sea. In the present study, a positive correlation ($r = 0.49$) was found between the abundances of alien and native species. The same result was also noted in the polluted inner part of Izmir Bay where positive correlations were estimated between densities ($r = 0.33$) and biomass ($r = 0.29$) of alien and native species (Çinar et al. 2006).

Disturbed environments are known to be easily colonized by alien species (Occipinti-Ambrogi & Savini 2003; Çinar et al. 2006). During the recovery of polluted bottoms after the pollution-abatement programme, opportunistic and alien species are the pioneering ones, as indicated in Izmir Bay (Aegean Sea) and the Golden-Horn Estuary (Sea of Marmara) (Çinar et al. 2006; 2008; 2009). In organically polluted waters where more empty niches are available, alien species can considerably contribute to recycling of organic matter, without eliminating the prevailing biodiversity. However, the opportunistic polychaete species such as Capitella capitata (Fabricius, 1780) and Malacoceros fuliginosus (Claparède, 1870) disappeared or were represented by a few individuals in habitats where alien spionid polychaetes such as Polydora cornuta and Sreblospio gynobranchiata Rice & Levin, 1998 were highly dominant (Çinar et al. 2006). Stations near a large international harbour (station 2) and yacht marina (station 3) were exposed to the dense invasion by the ship-mediated alien species, Cerithium diplax. The other dominant alien species such as Finella pupoides and Notomastus mossambicus that are Lessepsian migrants also preferred station 2. This area that is shallow and close to harbour and city center can be classified as a ‘hot spot’ for alien species. The deep-water station (station 7) and the station (station 4) far from this ‘hot spot’ area were weakly affected by the alien species. Station 1, which is shallow and very close to the mouth of Seyhan River, also had relatively dense settlements of the Lessepsian migrants such as Glycine bonhouri, Amphiodia obtecta and Leucotina natalensis Smith, 1910. The first two species are carnivorous and appeared to benefit from high populations of animals in low trophic levels such as detritivores that are fed by Seyhan River. As the Suez Canal is shallow (21 m at present), the majority of the Lessepsian migrants are shallow-water species. Çinar et al (2011) estimated that 80% of alien species reported from the Turkish coasts inhabit habitats between 0 and 10 m depths. Ship-mediated species also prefer shallow waters, building up dense populations in harbor environments or on artificial substrates such as quay, piers and platforms (Çinar 2006; Çinar et al. 2006; 2008). They comprised the majority of alien specimens (53%) in the area and preferably dominated stations near the harbour and marina. It is known that harbours act as a suitable recipient area for alien species and 60% of all alien species worldwide have been
introduced from one area to another via ships (Gollasch 2007).

Conclusion

The present study is the first comprehensive work on the distribution of zoobenthos on the southern coast of Turkey. It showed that the shallow water soft-substrates in Mersin Bay have been intensively invaded by alien species and the structures of benthic communities have largely changed. In contrast to other studies performed in other basins of the Mediterranean, Mollusca intensively occupied soft bottom benthic habitats in the area due to the dense settlements of alien gastropod species. The detritivore alien gastropods ( Cerithidium diplax and Finella pupoidea) and polychaete ( Notomastus mossambicus) became dominant components of benthic communities near pollution sources. The distributions of alien and all species in the area were related to depth, sediment structures and organic carbon in sediment.

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