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Broad-Scale Ecological Distribution of Dominant Macrozoobenthic Taxa of The Northern Cilician Shelf, Eastern Mediterranean Sea: Molluscs

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Abstract

Potential benthic molluscan community were studied seasonally in associated with the environmental parameters in 2005-2007, by covering broad scale region of the Cilician shelf with three transects containing seven different bottom sampling depth (10, 25, 50, 75, 100 150 and 200 m),. Totally, 61 molluscan species composing of 3 placophoran, 45 bivalve and 13 gastropod classes were recorded in the different habitats of vegetated and non-vegetated soft bottoms that have ecologically disturbed and undisturbed conditions along the Turkish coasts of the Cilician Basin in the Levantine Sea. Most effects of habitat, eco-hydrographical conditions on the molluscan community occurred on the bottom shallower than 50 m. The community of deeper zone of the shelf was not affected significantly by the conditions. Accordingly, spatio-temporal shifts in the feeding types of species dominating the community in terms of numbers and biomass were concluded to sustain the ecosystem of an oligotropihic sea.

Keywords: Zoobenthos, Mollusca, Cilician shelf, Turkey

INTRODUCTION

In the world fauna, the widest biological species richness and diversity belongs to the Mollusca inhabiting a variety of different habitats and hydropgraphy. Therefore, the molluscs are good indicator for defining the ecosystem [1]. The molluscs are not so much sensitive to environmental disturbance in a certain level compared to crustaceans and polychaetes. The feeding regimes of benthic molluscs are highly variable from suspended filter feeding, deposit feeding to scavengers and predator. Such different feeding regimes sustain the ecosystem functions with their major changes and shifts of the species diversity in space and time of the marine ecosystem, particularly an oligothrophic sea such as the Levantine Sea [2-4]. The molluscs are very dominant in mediolitoral and sublittoral zone of the continental shelf of the Mediterranean Sea, and good indicators for regional differences in ecosystem under changes of water quality and sedimentation derived by riverine discharge rates and transported materials [1, 5]. They have some other ecological niches in natural environments and are subjectively used for artificial marine environments aiming to determine the contaminant level and filter feeders that clean the water in mariculture. The Levantine Sea, particularly the Cilician shelf, has been recently targeted for fish farms. Therefore, the information about spatio-temporal distribution of potential molluscan community and species could be paramount of their future use in the fish farms. Furthermore, determined the ecological features of molluscan communities would be beneficial for the coastal management.

The molluscan community is however, a taxon which has been less studied among the macrozoobenthos along the Turkish coasts with no attempt to the deep sea research yet. Some studies performed on the community level were only representative for a small area of the coasts in the exclusive region of the Seas [6-16]. Many of the studies recorded the new occurrence of the molluscan species [17-33]. Some studies concerned with creating a list of molluscan species found in the Turkish seas [34-35] and identifying the new species [36].

In the eastern Mediterranean Sea, the last decadal zoobenthic studies were generally carried in Greek, Turkish and Israeli waters [22, 37-45]. Molluscan species richness has increased by contributions of the new researches that emphasizes the records of especially alien species in the Levantine Sea [46-49]. Mutlu & Ergev [10] and Mutlu & Ergev [12] outlined the distribution of Mersin Bay's epi/infaunal molluscs in space and time with changing the environmental parameters. Nevertheless, some studies concerned with spatio-temporal distribution of macrozoobenthos and the relationships with abiotic parameters, and in these studies, it was found that the bottom depth was a significant explanatory variable for the benthic assemblages taxonomically combined or separated in only sandy and muddy bottoms of the Cilician Basin [10-14, 16]. In Turkish coasts of the Levantine Sea, there were no significant studies on the benthic molluscs so far that related their distribution to depth-related ecological factors from the seagrass beds, regions enriched with the dissolved nutrients and soft-bottoms all together on a broad scale including the shelf and Cilician Basin. Ecology of each taxon such as molluscs, crustaceans and polychaetes could be separately undertaken since each taxon has different ecological niches to be described by previous studies for another area of the Cilician Basin [11-12, 16]. The broad-scale spatio-temporal distribution of benthic molluscs along the coast has not been a subject of any study until now.

This study aimed to determine the spatio-temporal changes in the molluscan diversity and equilibrium of the feeding types among the different habitats that were disturbed/undisturbed of vegetated and non-vegetated soft bottoms of the Cilician shelf.

MATERIAL AND METHODS

Material and methods were already published in Mutlu [50] as follows: The area of the basin is fed by Seyhan, Ceyhan and Göksu Rivers in nutrition. The Mersin and Iskenderun Bays are considered to having non-vegetated bottoms while bottoms of shallow stations (A1 and A2) off Cape Anamur are covered by *Posidonia* beds. Inner part (I1 and I2) of Gulf Iskenderun is generally disturbed by its own nutritional dynamic derived from the enclosed eddies and anthropogenic activities. Distribution of macrobenthic molluscs was studied in 3 transects (including depths of 10, 25, 50, 75, 100 and 200 m) located in Iskenderun, Mersin and Anamur Bays soft bottoms of the Cilician shelf to show its relations with depth-dependent environmental parameters in representative months for each season (winter, spring, summer and autumn) between 2005-2007 (Fig. 1). Onboard R/V Bilim-2, a Van-Veen grab (0.10 m^2 surface area) was used to take one sample from each station. However, some stations (I5 in November, I5-I7 in March, and last few deep stations off Anamur) could not be attempted to sample due to the bad weathers and close depth contours of the Bay in the March-January sampling only (Fig. 1). About 0.25 l of sediment taken by the grab were reserved into a nylon bag and preserved in a deep-freezer for the geochemical (grain size, TOC and carbonate contents) analyses.

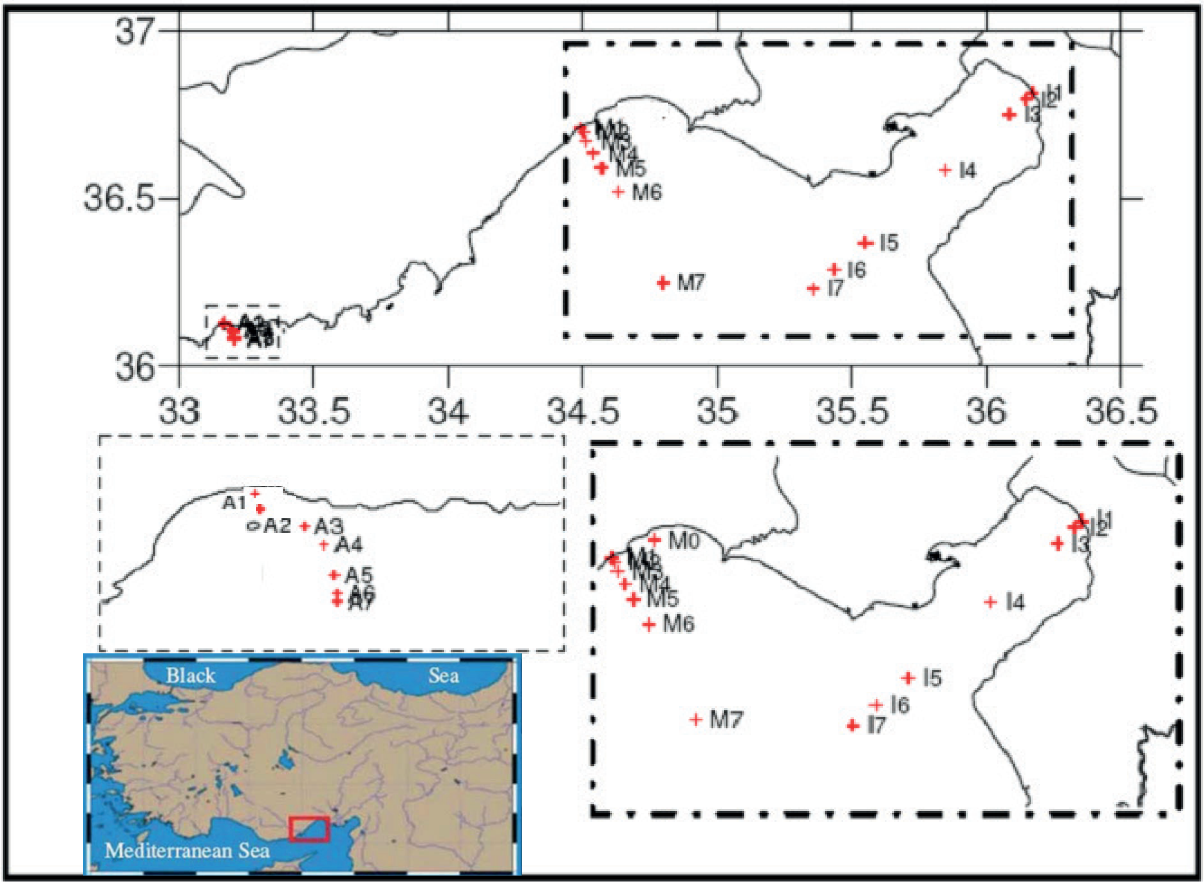


Fig. 1: Study area and Turkish part of the Cilician basin (Transects; M, m: Mersin, I, i: Iskenderun, A, a: Anamur) and location of the sampling stations (Depth code: 1: 10 m, 2: 25 m, 3: 50 m, 4: 75 m, 5: 100 m, 6: 150 m and 7: 200 m) visited in November 2005 (n), March (m), July 2006 (j), and January 2007 (ja).

During the onboard, the sediment was sifted with a set of sieves (0.5, 1 and 2 mm mesh sizes in square), then benthic materials were left into a 5% $MgCl_2$ solution for anesthetizing the organisms, and then transferred into a 10% formalin solution.

Hydrographical parameters of water column were profiled by casting a SeaBird CTD probe (SBE 19*plus* profiler) from sea surface to the bottom. In the laboratory, nutrient salts (PO_4, NO_2+NO_3 and Si) and dissolved oxygen of the sea surface (SSx) and near bottom (NBx and/or Nx) water taken in the Niskin bottles by a rosette-water sampler were read by using an auto-analyzer and following the Winkler method, respectively. Grain size analyses of the sediment were carried out with a standard technique as described [50]. Titrimetrical method as described [50] was applied to read the Total Organic Carbon (TOC) of the sediment, and the $CaCO_3$ content was measured applying a method determined by Müller [51].

Species names were updated according to the checklist of species-group taxa of the Taxonomic Database on European Marine Mollusca [52]. Feeding types of the mollusc species were sorted out according to the information on a website of Worldwide Mollusc Species Data Base [53] to underline a possible shifting balance in the feeding types to maintain the oligotrophy of the Cilician shelf environments in time and space.

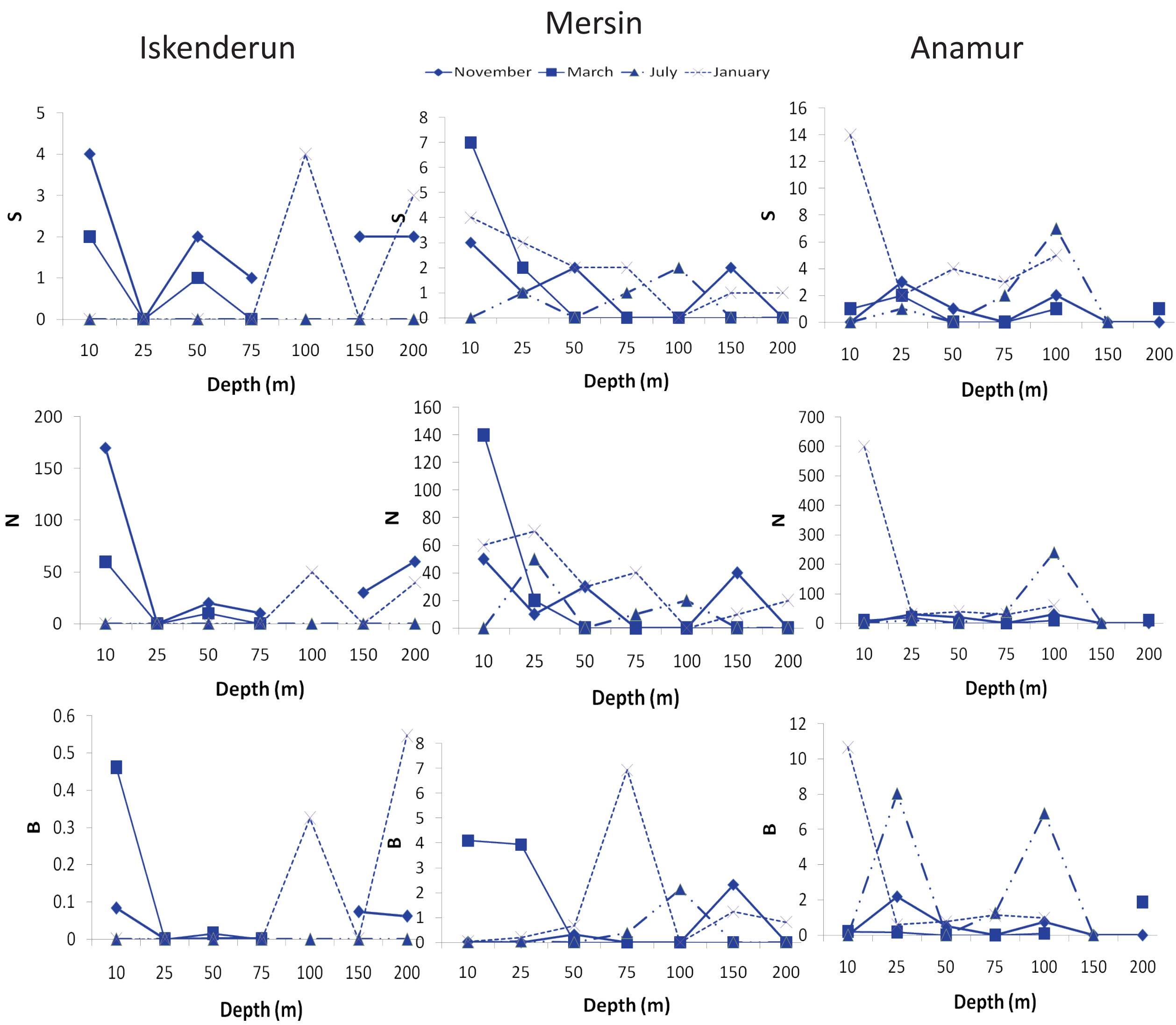
As an indication of molluscan faunistic characters, a set of variables was formed composing of Shannon-Wiener diversity (H', log_2base), Margalef's species richness (d), and Pielou's evenness (J') indices, and percent dominance (D%) and numerical occurrence (NO%). Difference of the molluscan community among the seasons, transesct and months were tested statistically by a method, PERMANOVA [54]. The Bray-Curtis dissimilarity matrix of the log10-transformed abundance data was applied to the nonparametric PERMANOVA in three-way modeled with fixed transect, random season and depth [55]. Canonical correspondence analysis (CCA) was applied to determine the molluscan assemblages and then to show their relationships with the spatio-temporal bathymetrical, physical and sedimentary variables (CANOCO 4.5) [56]. Choice of CCA for the usage was determined by applying the Log_{10}(N+1)-transformed abundance data to

Detrended Correspondence Analysis and it concluded that the maximum gradient exceeded 3 standard deviations, SD among the calculated SD (0.000, 0.000, 10.309 and 8.025 for the first four axes, respectively). Furthermore, Euclidean distance matrix based on biomass and log10-transformed abundance of the mollusc specimens assorted for feeding types was tested by PERMANOVA to determine the differences of stations associated with the feeding types in three-way of fixed transect and random depth and season.

RESULTS

Faunistic characters

A total of 61 molluscan species was identified belonging to 3 classes found at depths between 10 m and 200 m along the Levantine coast of Turkey (Appendix 1). 32 bivalve, 4 gastropod and 2 placophoran species were found to be distributed in the Atlanto-Mediterranean Seas. In addition to the species, 4 bivalve and 5 gastropod species were recorded to be distributed in the Mediterranean and Indian waters as well. Few some of them inhabited the Pacific or the Atlantic Oceans. The classes of Bivalvia (45 species) and Gastropoda (13 species) were represented by the highest number of species. The species with the highest dominance values were *Abra prismatica* with D=11%, *Nucula nitida* with D=15%, and *Corbula gibba* with D=16%. All of the total species had dominance values that were less than 50%. As the most frequent species at stations, *Abra prismatica* (FO=8%) was found with a maximum density of 50 ind m^{-2} at the depth of 26 m on Mersin in July, *Nucula nitida* (FO%=12%) with 30 ind m^{-2} at 75-100 m on Anamur and Mersin in July and January, and *Corbula gibba* with 30 ind.m^{-2} at 14 m on Iskenderun in March (Appendix 1). The number of species was found to be the highest in January (35 spp), and it was followed by a number 20 spp in November and remained about 10-13 spp in March and July (Appendix 1; Fig. 2).



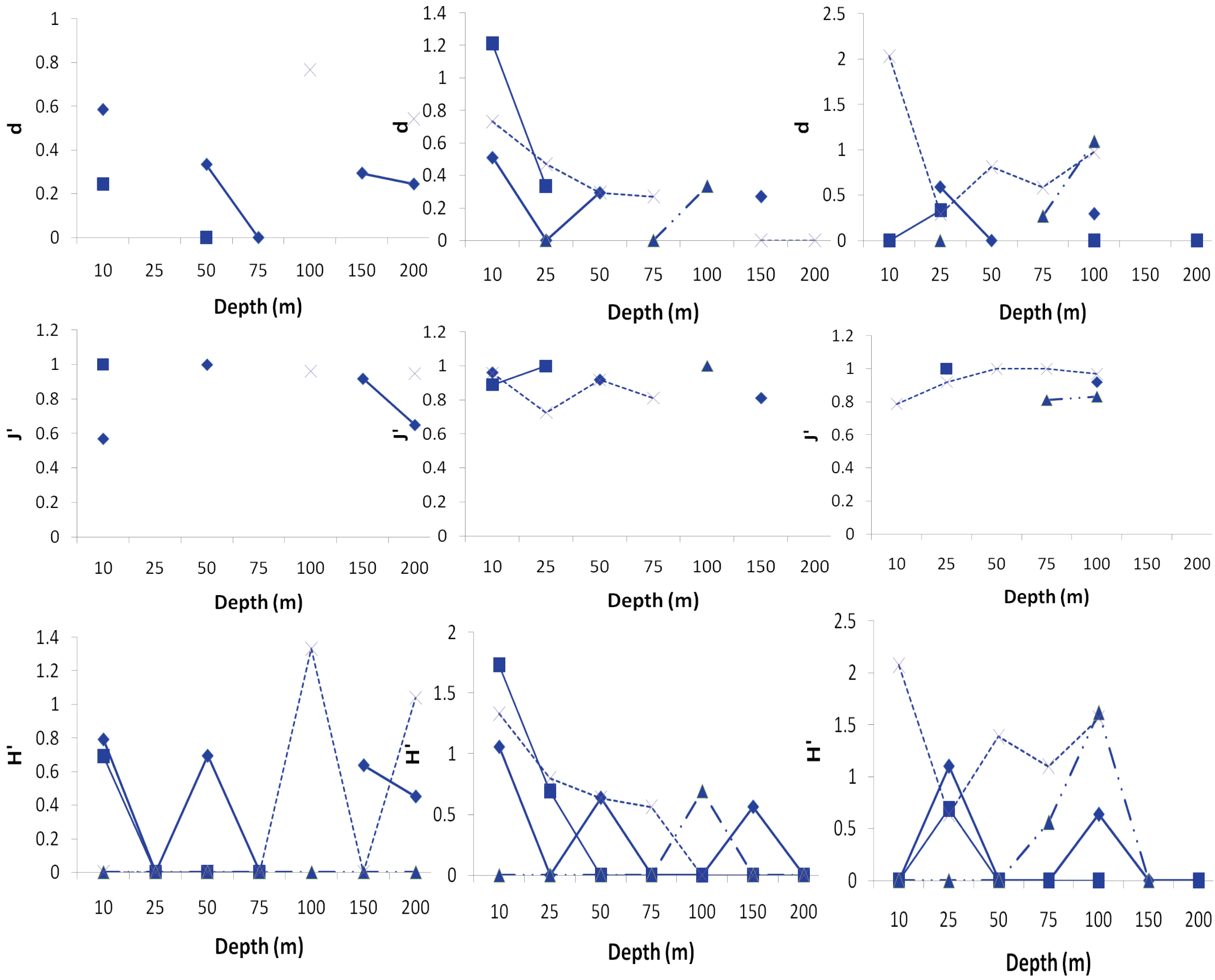


Fig. 2. Spatio-temporal (depths and months) and annual (average) changes of crustacean faunistic parameters at each season and transect of the Cilician shelf: Number of mollusc species (S), density (N ind m^{-2}), biomass (B g m^{-2}), species richness (d), evenness (J'), and Shannon-Wiener's diversity (H') indexes.

In November, *Corbula gibba* (D=15% and FO=12%) was the most common and frequent species, followed by *Abra alba* (D=10% and FO=8%), *Abra prismatica* (D=10% and FO=8%), and *Kellia suborbicularis* (D=10% and FO=8%). The most common species were *Corbula gibba* (D=18% and FO=12%), *Abra prismatica* (D=18% and FO=12%), and *Paphia textile* (D=18% and FO=12%) in March, *Nucula nitida* (D=20% and FO=29%) and *Abra prismatica* (D=10% and FO=14%) in July, and *Nucula nitida* (D=37% and FO=7%), *Corbula gibba* (D=21% and FO=4%), *Abra prismatica* (D=11% and FO=2%), *Barbatia barbata* (D=11% and FO=2%), *Thyasira flexuosa* (D=11% and FO=2%) and *Goodallia triangularis* (D=11% and FO=2%) in January. However, *Kellia suborbicularis* had the maximum density with 130 ind m^{-2} in January in Iskenderun Bay, *Abra nitida* with 50 ind m^{-2} in March in Mersin Bay, *Saccella commutata* with 100 ind m^{-2} in July and *Arca tetragona* with 130 ind m^{-2}, *Glans trapezia* with 150 ind m^{-2} and *Septifer cumingii* with 130 ind m^{-2} in January in Anamur Bay. The number of species was found to be the highest in January (14 spp at 10 m on the transect Anamur, Fig. 2). However, the number of species was not significantly different among seasons, depths and transects (Table 1).

Abundance was found to be significant among transects, depths and seasons (Table 1). The total abundance was calculated as 2230 ind., and the average abundance value was 37.17 ind m^{-2} in the study area. *Nucula nitida* (NO=9.4% of the total abundance), *Corbula gibba* (NO=7.1%), *Glans trapezia* (NO=6.7%) and *Kellia suborbicularis* (NO=6.7%) were abundantly found species at the study area. The average individual number of molluscs at the Anamur stations (49 ind m^{-2}) was higher than those at the Iskenderun (19 ind m^{-2}) and Mersin stations (21 ind m^{-2}, Fig. 2). The highest density that was found in January (57 ind m^{-2}) was two-fold higher than those (17-25 ind m^{-2}) in March-July (Fig. 2). However, the average abundance decreased from the shallow depth (90 ind m^{-2}) abruptly through 25 m (20 ind m^{-2}), gradually to a depth of 75 m (10 ind m^{-2}), and showed variations among the greater depths (Fig. 2). The abundance was higher at 10 m and 100 m (41 ind m^{-2}) in depths than those at 25-75 m, and 150-200 m (Fig. 2).

Table 1. Calculated p values from three-way Analysis of Variance for the faunistic characters. Bold number shows that p values are significantly different at p<0.05. Two values given for **d** and **J’** indices belong to values calculated with insufficient data because of one species occurrence and excluded insufficient data of the indices, respectively. NaN: insufficient indices for the analysis (see Fig. 2).

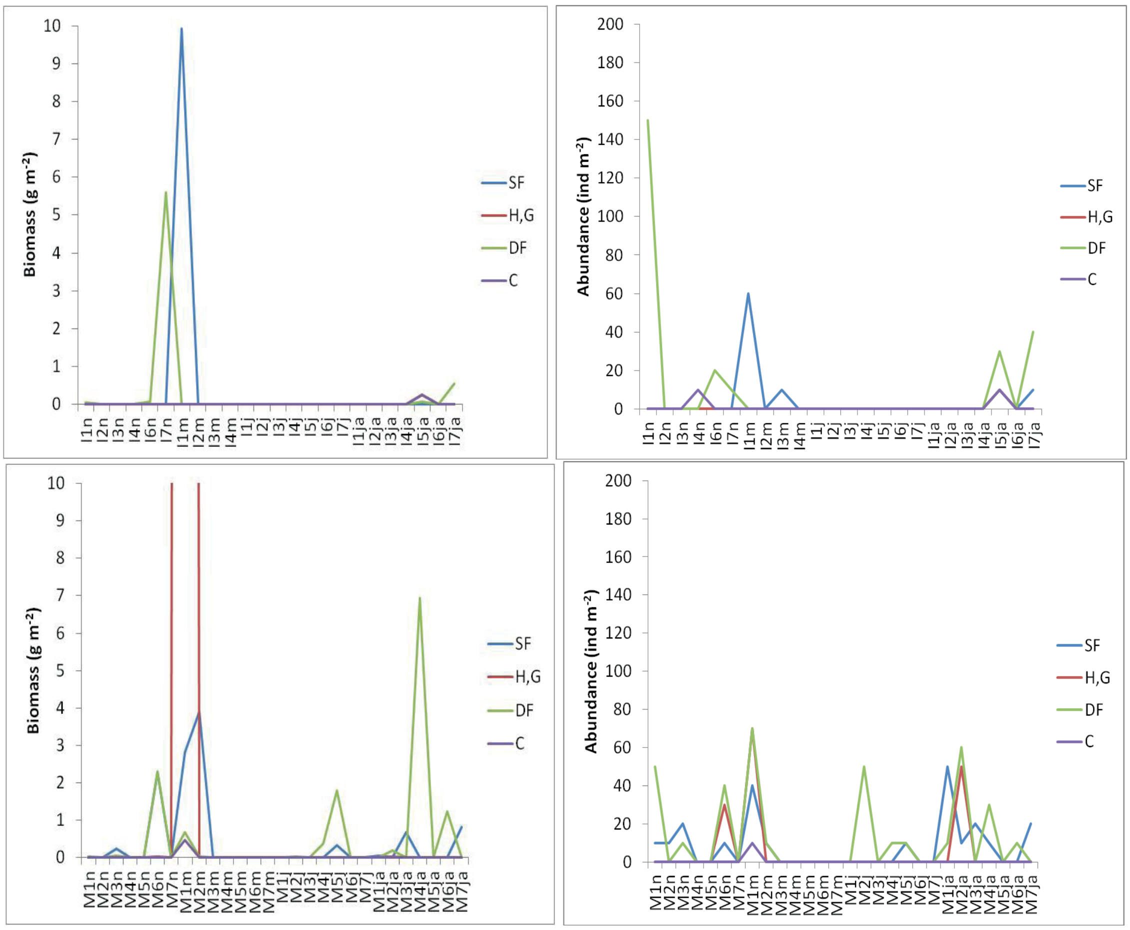
Source	d.f.	S	N	B	d		J’		H’
Transect	2	0.119	0.391	0.431	0.722	0.135	NaN	0.439	0.147
Season	3	0.054	0.448	0.382	0.525	**0.025**	NaN	**0.022**	**0.009**
Depth	6	0.142	0.280	0.482	0.627	0.115	NaN	0.561	0.111
Transect*Season	6	0.094	0.367	0.367	0.678	0.068	NaN	0.329	0.084
Transect*Depth	12	0.816	0.985	0.687	0.994	0.806	NaN	0.144	0.307
Season*Depth	18	0.760	0.908	0.485	0.956	0.808	NaN	0.332	0.617

The total biomass was measured as 310.75 g and the average biomass value as 5.18 g m^{-2} in the study area. The larger species, *Strombus persicus* was the dominant species in biomass, amounting up to 76% of the total biomass. *Nucula nitida* (4.3%), *Dosinia exoleta* (3.1%), *Anomia ephippium* (2.6%) and *Glans trapezia* (2.0%) were the other most contributor species to the total biomass in the study area. The molluscan biomass value (wet weight) was not significantly different among transects, depths and seasons (Table 1), being in a range of 1.1 (10.2 g m^{-2} with included biomass of *S. persicus*) and 0.46 g m^{-2} (Fig. 2). The average biomass showed fluctuations seasonally: the minimum value (0.24 g m^{-2}) occurred in July and the highest values were found in January (1.47 g m^{-2}) and May (1.31 g m^{-2} with excluded *S. persicus*) (Fig. 2). The average biomass value decreased from 1.16-1.53 g m^{-2} at the depths of 10-55 m to 0.78-0.04 g m^{-2} at the deeper zone (Fig. 2).

Feeding types

The feeding regimes of molluscan species (Appendix 1) were significantly different with an interaction transect and season over their abundance, but not significant over their lowest biomass as compared with the other bays of the Cilician Shelves (Fig. 3; Tables 2 and 3). Biomass of the molluscan species was differentiated by only season according to their feeding types (Table 3).

In terms of biomass, eutrified region (Iskenderun Bay) of the Cilician Basin was dominated by the molluscan species typified with suspension and deposit feeding (Fig. 3). The feeding types were not well diversified for Iskenderun Bay. The deposit feeders with low biomass in specimens occurred in deeper zone of shelf in November and January and suspension feeders with high biomass were replaced in spring month at shallow waters.



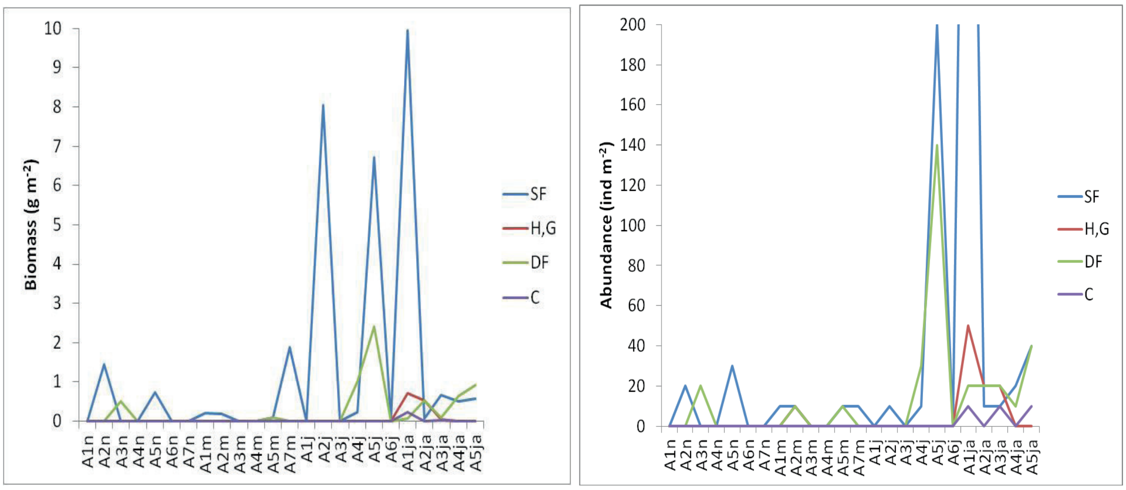


Fig. 3. Spatio-temporal distribution of the feeding regimes (Filter feeders; SF: suspension feeder, DF: deposit feeder, H, G; Herbivore and C; Carnivore) of molluscan species at each season (n: November, m: March, j; July and ja; January) and transect (I: İskenderun, M: Mersin, and A: Anamur) along the depth gradients (1: 10, 2: 25, 3: 50, 4: 75, 5: 100, 6: 150 and 7: 200 m) of the Cilician shelf along the depth.

Table 2. Non-parametric (Permutation-based) MANOVA for the Euclidean distance matrix of the abundance (X) data transformed on $\log_{10}(X+1)$ of feeding types of the molluscan species. Transect is fixed, and depth and season are random. Bold number shows that p values are < 0.05.

Source	df	SS	MS	F	p
Transect	2	5.8675	2.9338	1.1378	0.2878
Depth	6	8.4607	1.4101	0.7773	0.5292
Season	3	8.6475	2.8825	1.2214	0.2524
Transect x Depth	12	16.0408	1.3367	2.0851	0.0754
Transect x Season	6	11.2966	1.8828	2.9369	**0.018**
Depth x Season	18	20.1305	1.1184	1.7445	0.1518
Residual	36	23.079	0.6411		
Total	75	93.5226			

Table 3. Non-parametric (Permutation-based) MANOVA for the Euclidean distance matrix of biomass (X) data of feeding types of the molluscan species. Transect is fixed, and depth and season are random. Bold number shows that p values are < 0.05.

Source	df	SS	MS	F	p
Transect	2	1.26E+03	628.678	1.1122	0.2604
Depth	6	3.95E+03	658.6091	1.0613	0.1134
Season	3	2.54E+03	845.0444	1.5913	**0.048**
Transect x Depth	12	8.02E+03	668.0184	0.9806	0.7296
Transect x Season	6	3.47E+03	578.5156	0.8492	0.9056
Depth x Season	18	1.14E+04	633.7909	0.9303	0.898
Residual	36	2.45E+04	681.2643		
Total	75	5.52E+04			

Carnivorous molluscan species having low biomass appeared in the intermediate zone of the Iskenderun Bay in November and January. However, none of the molluscan specimens was found in July. The Mersin Bay with slightly eutrified shallow waters was composed of a variety of feeding types of the molluscan species along the depth in season (Fig. 3). The shallow waters were dominated with suspension and deposit feeders in low biomass and the deeper parts with the deposit grazers in high biomass in November. The filter feeders on deposited with specimens in low biomass and suspended matter with specimens in high biomass were more pronounced on the shallow waters in spring when the herbivorous and carnivorous appeared. The deeper zones were however deserved by the specimens. In summer (July), only deposit feeders with low biomass prevailed the shallow waters whereas suspension feeders with low biomass and few deposit feeders with high biomass predominated in deeper zone as compared with less pronounced than that in March. The suspension and deposit feeders tended to decrease from shallow to deeper waters by increasing biomass in January when deposit grazers with low biomass was observed at 25 m depth.

Of the undisturbed and unpolluted area of the Cilician Basin, Anamur Bay, filter feeders associated with bottom and pelagic environment was less pronounced in biomass and abundance through the depth in November-March as compared with those of the other bays. By summer and winter, such feeders, especially suspension feeders, increased in the biomasses and abundances. In summer, suspension feeders with high biomass and low abundance of the molluscan specimens were dominated in shallow waters whereas abundant and weight specimens of both suspension and deposit feeders were found at deeper zone. Sea meadows of Anamur Bay in winter were diversified with occurrence of herbivorous and carnivorous with molluscan specimens having moderate abundance and biomass in additions to dominant suspension and less dominant deposit feeders. Suspension deposit and herbivorous feeders were appeared in respect of order of abundance along depth of 10 m to 100 m whereas the carnivorous undergo homogeneously with low biomass and abundance (Fig. 3).

The assemblages

Only the season has a significant effect on the values of diversity index, evenness index and species richness ($p<0.05$, three-way ANOVA showed Table 4). However, these parameters were not significantly different among the depths and transects (Table 4). The species richness and diversity index values decreased along the depth gradient in the shelf. The evenness increased slightly with the bottom depth and showed a seasonal fluctuation on the bottom between 10 m and 50 m (Fig. 4).

Table 4. Non-parametric (Permutation-based) MANOVA for the Bray-Curtis similarity matrix of the abundance (X) data transformed on $\log_{10}(X+1)$ of the molluscan species. Transect is fixed, and depth and season are random. Bold number shows that p values are < 0.05.

Source	df	SS	MS	F	p
Transect	2	0.9773	0.4887	0.6253	0.675
Depth	6	2.2582	0.3764	0.6449	0.7512
Season	3	1.7357	0.5786	0.8226	0.4696
Transect x Depth	12	5.2182	0.4349	2.0903	**0.0122**
Transect x Season	6	3.3277	0.5546	2.666	**0.0042**
Depth x Season	18	6.4219	0.3568	1.715	0.0634
Residual	36	7.4892	0.208		
Total	75	27.4283			

In general, molluscan assemblages were not oriented in association with a certain environmental parameters, but some common parameters played a crucial role on division of the CCA quadrates (Fig. 4): The quadrate located on the left-top (Q1) of the CCA, typifying very nearshore stations influenced by the terrestrial inputs, was specified for the molluscan assemblages associated with increasing nutrients of Si, SNO_2+NO_3 and NBT, and sand content; the left lower-quadrant (Q2) with depth, and fine sediment grains and carbonate fractions, to the right-lower upper quadrant (Q3) mainly with the dissolved oxygen, and the right-upper quadrate (Q4) with increasing salinity and density (Fig. 4).

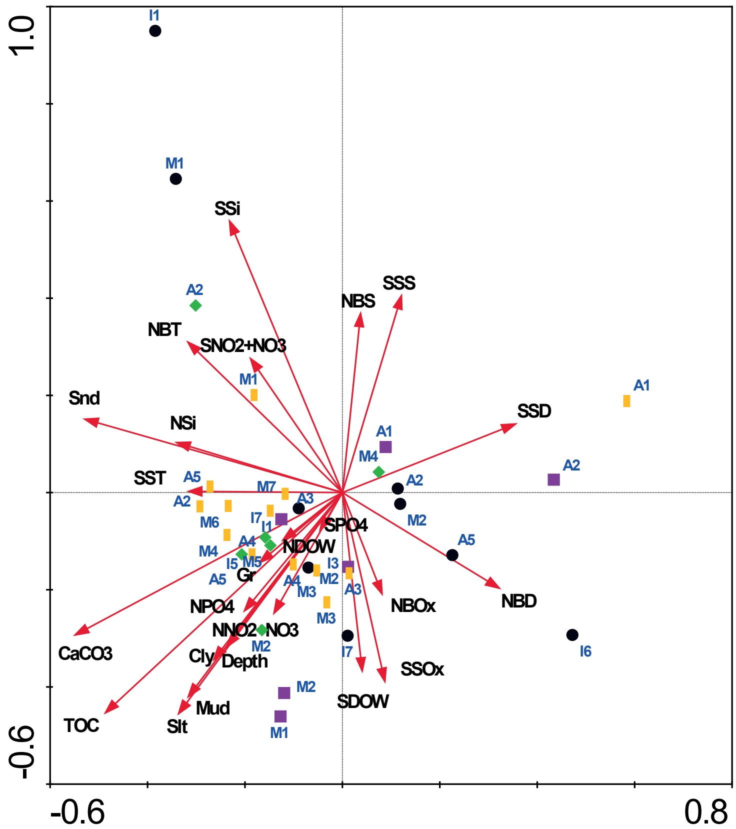


Fig. 4. Biplot of CCA (Plane 1-2) performed on log-transformed ($\log_{10}(N+1)$) density values (N) of the molluscs and environmental variables (arrows) at seven depth samples (1: 10, 2: 25, 3: 50, 4: 75, 5: 100, 6: 150 and 7: 200 m) on three transects (I: Iskenderun Bay, M: Mersin Bay, and A: Anamur Bay) in four sampling months. Arrows refer to the direction and relative importance of environmental variables (see Appendix II for abbreviations of the parameters) in the ordination.

There were no explicit accumulations or clusters depending on either transect, season or bottom depth. The explained variance in percentage for the first two component axes was only 18% for the relationship between the environmental parameters and species data (Table 5). Monte-Carlo test showed the explained variance of all four axes to be statistically significant (F: 1.289, P: 0.02).

Table 5. Summary of statistical measures of molluscan species characteristics and environmental variables for CCA (see Appendix II for abbreviations of the parameters).

Environmental variables	Species Axis 1	Species Axis 2
Depth	-0.2337	-0.3155
Physical parameters		
SST	-0.3121	0.0022
SSS	0.1197	**0.4023**
SSD	0.3501	0.1402
SSOx	0.0857	-0.3866
NBT	-0.3134	0.3076
NBS	0.0364	0.3662
NBD	0.3173	-0.1959
NBOx	0.0802	-0.2073
Sedimentary parameters		
Gr	-0.1673	-0.143
Snd	**-0.5225**	0.1502
Mud	-0.3123	**-0.4179**
Slt	-0.3323	**-0.4523**
Cly	-0.2608	-0.3421
$CaCO_3$	**-0.542**	-0.2916
TOC	**-0.4809**	**-0.4505**
Chemical parameters		
SDOW	0.04	**-0.3653**
SPO4	-0.0456	-0.0766
SNO2+NO3	-0.186	0.274
SSi	-0.2286	**0.5547**
NDOW	-0.1204	-0.0974
NPO4	-0.1989	-0.2417
NNO2+NO3	-0.1391	-0.247
NSi	-0.336	0.1022
Eigenvalues	0.939	0.878
Species-environment correlations	0.987	0.994
Cumulative percentage variance		
of species data	7.0	13.5
of species-environment relation	9.3	18.0

Spatially-quarterly divided molluscan assemblages were weighed with certain species groups (Fig. 4). A community composed of species *Acanthocardia* sp., *Kellia suborbicularis*, *Tellina* spp., *Abra alba*, *Myrtea spinifera, Barbatia barbata*, and *Thyasira flexuosa* were formed inside the Q1 nutritionally enriched. Dominant species composition of the Q4 characterized with low SST and high water density was made up of *Tricolia pullus pullus*, *Sphenia binghami*, *Arca noae*, *Hanleya hanleyi*, *Glans aculeata*, *Glans trapezia* and *Modiolarca subpicta*. *Pseudominolia nedyma* and *Parvicardium pinnulatum* were the species characterizing stations (Q3) with high NBD and *Goodallia triangularis*, *Leptochiton cimicoides* and *Tellina nitida* with dissolved oxygen, particularly in November. The rest of the species were the deep waters species (>50 m) of the shelf (Fig. 4 and Appendix 1).

DISCUSSION

In the result of sampling three different areas on the depth-wise transects (Iskenderun, Mersin and Anamur Bays) covering the most eastern and western edges of the Turkish Cilician Basin Shelf, a total of 61 molluscan species belonging to three classes were found. This broad-scale was a good example of mollusc assemblages changing on the way of faunal succession path ways associated with eutrophication levels that was decreased from the east to the west of the Cilician Basin which is one of important basins of the Levantine Sea with regard to the invasion status of macrozoobenthos with alien species. Of a total of 263 alien species invented for the Levantine Sea, 202 species [21] were recorded from the Turkish coasts with a total alien species of 400 [49]. The information about mollusc biodiversity has been increased in time by contributing the results of the new researches on potential mollusc species check-list [31]. Some mollusc species as alien and some species as new species records contributing to a total of 98 mollusc alien species for the Turkish coasts of the Cilician Basin were reported by Öztürk [31]. 105 molluscs (216 alien species with 84 molluscs) were compiled for the Levantine Sea by Çinar *et al*. [57]. Of a total of 745 mollusc species [58], 277 alien species with 90 molluscs were listed for the Turkish molluscan fauna [57]. A changing number of species (139-213) of the total (a total of 955 alien species in a total mollusc species of 2113 [59] was found for the Mediterranean Sea [19, 31, 60-61] and this situation could be resulted from a variety of introduction the species via Suez Canal, connected with the Atlantic Ocean and intensive maritime [57, 62]. Therefore, succession of the incoming molluscan species was recently achieved so intensively that the Levantine Sea was paid attention with status of the alien faunal species by the scientists and researchers especially of species population registrants, marine biologists and ecologists. The studies showed that locality type of the molluscan species that have been introduced particularly to the Levantine Sea were of the Atlantic and the Indo-Pacific Oceans and the Red Sea [63]. The succession path of species could be considered through the North Africa from the Atlantic Ocean and through region of Sukhumi gyre, corner of the most eastern-south of the Levantine Sea, from the Indian Ocean or the Red Sea to the Levantine Sea with all undertaken throughout the rim current of the Mediterranean Sea [35, 64]. Most of the species were established at the Israeli coasts (127 alien molluscs with 284 the Red Sea-Indo-Pacific originated in a total of 296 alien species, [65]), then distributed increasingly in one of the eutrified area, Iskenderun Bay (77 alien mollusc as 18 new records of 286 mollusc species with 197 gastropod, 81 bivalve and 5 polyplacophoran species included in a total 424 mollusc species compiled by Bakır *et al*., [35] and coastal waters of Mersin Bay (122 mollusc species of 337 macrozoobenthic species, [14]). Recently, many new records have been come from the Greek waters (Crete) in the Levantine Sea after many observed in the Turkish coasts [30, 64]. As a consequence of the species succession pathway and the differences in the habitat types, spatio-temporal sampling area coverage as well and the number of soft-bottom molluscan species found in this study was found to be less than those given in the previous studies performed in the Turkish Levantine Sea, the Levantine Sea, the Eastern Mediterranean Sea and adjacent regions of the study area [1, 15, 38, 40-41, 43, 46, 66-68]. The reasons of this difference could be attributed to different habitats particularly for Iskenderun Bay which has hydrodynamic and eutrophication levels (more oligotrophic) among the areas. 256 mollusc species inhabited the sedimentary non-vegetated soft-bottom of Iskenderun Bay [35]. The study area was nutritionally fed by very small brooks and the content of TOC was well below the lower critical limit (<10 mg g^{-1}) corresponding to the coastal areas without organic loading [69]. Being lowed number of molluscan species for the present work was not in good concordance with the findings on the recent number (122 molluscan species) given for the shelf of Mersin Bay [14]. In addition, high salinity and temperature values in Mersin Bay create an unsuitable condition for many Mediterranean mollusc species. Çinar *et al*. [14] reported 20 alien molluscan species as new occurrence from the samples collected in 2009. A decadal temporal increase in the species number for the biodiversity of the Mediterranean Sea was increased up to 8500 species [70].

The most dominant mollusc species in the area were *Abra prismatica*, *Corbula gibba* which were common on sandy and muddy bottom in a depth range of 10-200 m and *Nucula nitida* that was found on pure muddy bottom deeper than 50 m where a carbonate zone extend along depth contour of 50-75 m in the Turkish Cilician Basin [71]. *Abra prismatica* most commonly found in Mersin Bay was a common species over a wide range [13-14] of bottom depth in the Mediterranean Sea and the Atlantic Ocean [72]. *Nucula nitidosa* was found at depth greater than 50 m of the gravelly muddy bottom with relatively high TOC in all three bays. This species was found to be characteristic species for fine or mixed sediments [73-74] and forms scarce populations in undisturbed environmental conditions [75]. *Corbula gibba* was found with the highest abundance in an eutrified region, Iskenderun Bay, followed by Mersin and Anamur bays with decreased abundance in shallow waters of the study area. The mid- to outer shelf sector, characterized by the *Corbula gibba* biofacies, comprises zones of bottom instability in the Nile Delta shelf [76]. This species was distributed at the depths greater than 20 m in the Strait of Messina [77] and on the coast of Crete [46]. Hrs-Brenko [78] outlined that *C. gibba* forms dense populations in organically polluted bottoms. This occurrence was related to the feeding plasticity as an adaptation to switch between suspension and deposit feeding [79]. This species usually lives on muddy bottoms that are rich in organic matter [80]. Therefore, *C. gibba* was reported to be abundant in eutrophic seas and polluted area: the Sea of Marmara and the Black Sea [81], Izmir Bay [43, 68]). *Corbula gibba* reached a maximum density of 70-83 ind m^{-2} in Edremit Bay, the Aegean Sea [9], 16 ind m^{-2} in Augusta Harbour, Sicily [82], 15860 ind.m^{-2} [43], and the 70-150 ind m^{-2} in a period by start of the water treatment when few species from the molluscs, such as *Abra alba* and *Kurtiella bidentata* measured the highest abundance (580 and 340 ind m^{-2}, respectively) in the polluted part of Izmir Bay [14]. *Nucula nitidosa* had lower abundance in muddy bottom than in sandy mud in a macrotidal bay of Marennes–Oléron, France [83]. In Edremit Bay, *N. nitidosa* was reported with a maximum abundance of 13-40 ind m^{-2} [9]. The highest abundance (130-150 ind.m^{-2}) was found in Anamur Bay recognized as an area undisturbed by the pollutants [84] with a certain species list of *Saccella commutata, Arca tetragona, Glans trapezia* and *Septifer cumingii*. *Bathyarca pectunculoides* and *B. philippiana* were found on muddy bottom of the deeper waters (95 m) in Anamur Bay. *S. cumingii* (synonym, *Septifer forskali*), confirmed with the correction in a web page (http://www.ciesm.org/atlas/Septiferforskali.html) for misidentification of *S. biocularis* by Albayrak *&* Çeviker [74], and reconfirmed that was not the misidentification [20], was reported the first time in Iskenderun Bay, and began to appeared in Kaş, Antalya by 2006 and became abundant in an increasing abundance of 4 ind m^{-2} to 133 ind m^{-2} by date of 2009 [85]. *Bathyarca pectunculoides* reported already in the Turkish seas and *B. philippiana* known as deep sea molluscs [58, 86] in the Atlantic Oceans and the Mediterranean Sea. *B. philippiana* was found to occur in the first time for the Turkish coast of the Levantine Sea, at 200 m depth in Anamur Bay [29]. *Bathyarca pectunculoides* biofacies was found to be associated with muddy sediment of the Nile shelf [76]. Moderately polluted area of Iskenderun Bay [84] measured the highest abundance on the shallowest station by a species *Kellia suborbicularis* (130 ind.m^{-2}) followed by *Tellina albicans* (50 ind.m^{-2}) at the deepest station, and slightly polluted area of the Mersin Bay by the species of *Abra nitida* and *Bittium reticulatum* (50 ind.m^{-2} for each species). Çinar *et al*. [13] found the mollusc species of *Cerithidium diplax* (about 1500-1800 ind m^{-2}), *Corbula gibba* (about 1000-3000 ind m^{-2}) and *Bittium reticulatum* (about 20-3500 ind m^{-2}) to be dominant in the shallowest waters of Mersin Bay. *Anadara transversa* was the only mollusc species found on the shallower water of Mersin Bay. This species was known to be lived in waters influenced by the anthropogenic effects [87]. Bakır *et al*. [35] reported that *Tellina albicans* and *Kellia suborbicularis* were found between depths of 3 m and 25 m of the different stations in Iskenderun Bay. Mutlu & Ergev [12] observed *K. suborbicularis* in a trend of decreasing abundance from 8 m to 59 m depths in Mersin Bay with the highest abundance in spring.

The oligotrophy could be defined indeed as short food web continuously restructured in a food chain to sustain the life with shortage of the nutrients, and concludes short life, slow metabolism, low population density, and replacement of feeding types in the ecological niches of the organisms in space and time for a marine environment (www.wikipedia.org; [57, 88-89]. The Mediterranean Sea was divided in consequence of geological evolution, existing rim current system and availability of riverine inputs into two parts, the eastern and western parts. The western part was enhanced with the nutrients fed by the Atlantic Ocean and rivers. The eastern Mediterranean Sea remained in the oligotrophy due to non-existence of the forces occurred in the western part during ancient geological times [90]. The temporal replacement of the various feeding types could occur in a year due to the existing low biological diversity with introduced species [91-92]. Such environment could be good favor for establishment of alien organisms to complete gap in the ecological niches and to suffer to compete food for native species in the ecosystem of oligotrpohic eastern Mediterranean continuously [57, 90]. The molluscs are one of taxa having a various feeding regimes such as suspension, deposit filter feeder, scavenger, predator and grazer as herbivore, carnivore and omnivore organisms. The following observations in the present study could be in good concordance with the definition of the oligotrophy and establishment of the alien species in the eastern Mediterranean Sea. Feeding types of molluscan species varied significantly between transects in a trend from moderately through slightly eutrified bays to undisturbed bay of an oligotrophic region of the Cilician Basin by the season. Abundance and biomass of the feeders seemed to be associated with the replacement along the depth gradients in season. Filters feeders, a unique type as filter feeding suspended and deposited matters, were dominated all the year, but suspension filterers more pronounced in Iskenderun Bay by the spring bloom. The feeding types shifted to be well diversified from eutrified bay to the undisturbed bays. There looked like equilibrium of a variety of feeding types along the depth gradient and season in ecological niches of the different molluscan species. Particular to the undisturbed region of the Cilician shelf, season and depth-wise feeding type distribution pronounced a harmony to make balance in the ecological niches by shifting from filter feeders, herbivorous and carnivorous individuals with high biomass and low abundance or vice versa. Çinar *et al*. [13] showed that the primary factor governing assemblages of the alien macrozoobenthic species in Mersin Bay shelf was the bottom depth, followed by salinity on the first component, and then sand and clay content of the sediment on the second and near-bottom temperature on the third component. That could be reason for the basin to welcome succession of the alien species to fill the gap in the ecological niches of an oligotrophic sea in space and time. Nevertheless, alien species invading oligotrophic seas have brought about some troubles such as disease, gene transfer, food and space competition, long or short term shock on the marine biodiversity [57, 62, 88-89, 93-95].

Mollusc assemblages did not depend on a certain set of prevailing environmental parameters in the present study since hydrographical peculiarities, habitat characteristics and features, and tropical conditions (oligotrophy, eutrophy) of three different areas of the Cilician Basin were distinguished [50, 84]. The assemblage were majorly discriminated and compounded under a geochemical property of the pelagic and benthic environment and sedimentary structures. A community was formed under effect of the terrestrial inputs (Si, SNO_2+NO_3 and NBT, and sand content of the sediment), another assemblage under bottom depth, and fine sediment grains and carbonate fractions, the next communities under increased dissolved oxygen, and the last communities under hydrographical parameters (salinity and density). Mollusc communities did not show any significant differences seasonally in the study area. In a recent study performed in Mersin Bay by Çinar *et al*. [13], it was found that major factors influencing the macrozoobenthic communities were the bottom depth and clay content of the sediment, and the salinity in one directed-way. The silt and sand content as the second component and TOC as the third component were factorized for shaping and structuring the pattern of the communities in Mersin Bay whereas the temperature was a factor for the communities [13]. Mutlu & Ergev [13] found also that the water temperature was ineffective for the mollusc assemblages in Mersin Bay. Depending on the level of nutrient-enrichment level in season the molluscan community could not changes significantly in time. The study region is the most oligotrophic area [2] containing a maximum TOC of 1.4% (average 0.53%) which is a below level of TOC indicated by Koulouri *et al*. [42]. Hyland *et al*. [69] suggested that a TOC concentration < 10 mg g^{-1} could not cause a significant variation in macrozoobenthic communities as observed on no significant seasonal change in the molluscan fauna in the eastern Mediterranean by Evagelopoulos & Koutsoubas [96].

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Appendix I. Maximum abundance (N/bottom depth m) with spatial and temporal distribution of the molluscan species in the Cilician Shelf of the Levantine. Occurrence record of the species were checked referring to a web site, Worldwide Mollusc Species Data Base [53] **Geographical distribution** (***Locality type***) were based on a web site, [97]: M, Mediterranean Sea; A, Atlantic Ocean, H: Indian Ocean or South Africa; P, Pacific Ocean and R, Red Sea. **FD**: Feeding type of the species (DF: Deposit feeder, G: Grazer, SF: Suspension feeder, O: Omnivore; P: Predator; S: Scavenger, H: Herbivore) and nomenclature of the **CLASS** and ***Species*** as well.

CLASS/***Species***/**Geographical distribution/ (FD)**	**Transect**			**Months in 2005-2007**			
	Mersin	**Iskenderun**	**Anamur**	**November**	**March**	**July**	**January**
PLACOPHORA							
Hanleya hanleyi (Bean in Thorpe *1844*) **MA (DF,G)**	ND	ND	10/21,	ND	10/21,	ND	ND
Leptochiton cimicoides (di Monterosato, 1879) **A (DF,G)**	ND	ND	10/54,	ND	ND	ND	10/54,
Lepidochitona cinerea (Linnaeus, 1767) **MA (DF,G)**	ND	ND	10/12,	ND	ND	ND	10/12,
BIVALVIA							
Abra alba (Wood W. 1802) **MA (DF)**	20/11,	20/11,	ND	20/11	ND	ND	I10/10,
Abra nitida (Müller O.F. 1776) **MA (DF, G, SF)**	50/12,	ND	ND	ND	50/12,	ND	ND
Abra prismatica (Montagu 1808) **MA (DF)**	50/26,	10/203,207,	10/95,	10/50,203,	20/12,	50/26,	10/29,207,
Acanthocardia sp.	ND	10/11,	ND	10/11,	ND	ND	ND
Anadara natalensis (Krauss, 1848) **HR (DF, SF)**	10/150,	ND	ND	10/150,	ND	ND	ND
Anomia ephippium Linnaeus, 1758, MA (SF)	ND	ND	10/26,	ND	ND	10/26,	ND
Arca noae Linné 1758 **MAH (SF)**	ND	ND	10/12,	ND	ND	ND	10/12,
Arca tetragona Poli 1795 **MA (SF)**	ND	ND	130/12,	ND	10/21,	ND	130/12,
Arcopagia crassa (Pennant 1777) **MA (DF,G,SF)**	ND	ND	20/32,	ND	ND	ND	20/32,
Barbatia barbata (Linné 1758) **MA (SF)**	20/10,216,	ND	10/95,	ND	ND	10/95,	20/10,216,
Bathyarca pectunculoides (Scacchi, 1835) **MA (SF)**	20/10,216,	ND	10/95,	ND	ND	10/95,	20/10,216,
Bathyarca philippiana (Nyst 1848) **MA (SF)**	ND	ND	40/95,	ND	ND	40/95,	ND
Cardiomya costellata (Deshayes 1835) **MA (O,P,S)**	ND	10/101,	ND	ND	ND	ND	10/101,
Centrocardita aculeata (Poli, 1795) **MA (SF)**	ND	ND	40/12,	20/113,	ND	ND	40/12,
Corbula gibba (Olivi 1792) **MA (SF)**	20/50,10,51,	30/14,	10/31,8,	20/50,	I30/14,	10/100,	20/10,51,
Dosinia exoleta (Linné 1758) **MA (SF)**	ND	30/14,	10/32,	ND	I30/14,	ND	10/32,
Dosinia lupinus (Linné 1758) **MA (SF)**	ND	ND	10/119,	ND	ND	ND	10/119,
Dosinia sp. juvenile	ND	10/153,	ND	I10/153,	ND	ND	ND
Glans trapezia (Linné 1767) **MA (SF)**	ND	ND	150/12,	ND	ND	ND	150/12,
Glycymeris sp.	ND	ND	10/12,	ND	ND	ND	10/12,
Goodallia triangularis (Montagu 1803) **MA (SF)**	**ND**	ND	10/54,78,	ND	ND	ND	10/54,78,
Hiatella arctica **MA (SF)**	ND	ND	10/75,78,	ND	ND	10/75,	10/78,
Kellia sp.	10/51,	ND	ND	ND	ND	ND	10/51,
Kellia suborbicularis (Montagu, 1803) **MA (SF)**	20/11,	130/11,	ND	130/11,	ND	ND	ND
Musculus costulatus (Risso, 1826) **MA (SF)**	ND	ND	10/12,	ND	ND	ND	10/12,
Musculus subpictus (Cantraine, 1835) MA (SF)	ND	ND	20/12,	ND	ND	ND	20/12,
Myrtea spinifera (Montagu 1803) **MA (SF)**	10/10,	ND	ND	ND	ND	ND	10/10,
Nucula nitidosa Winckworth, 1930 **MA (DF)**	30/79,	20/101,207,	30/75,95,	20/53,	ND	30/75,95,	30/79,
Nuculana pella (Linné 1767) **MA (DF,SF)**	ND	ND	10/108,	ND	10/108,	ND	ND
Paphia sp.	10/12,	ND	ND	ND	10/12,	ND	ND
Paphia textile (Gmelin 1791) **MRH (SF)**	10/12,25,	ND	ND	ND	10/12,25,	ND	ND
Parvicardium pinnulatum (Conrad 1831) **MA (SF)**	ND	ND	10/113,	10/113,	ND	ND	ND
Parvicardium sp.	30/12,	ND	ND	ND	30/12,	ND	ND
Petricola fabagella Lamarck, 1818 **R (SF)**	ND	ND	40/95,	ND	ND	40/95,	ND
Pinctada imbricata radiata (Leach, 1814) **MARH (SF)**	ND	ND	10/12,	ND	ND	ND	10/12,
Pitar rudis (Poli 1795) **MA (SF)**	ND	ND	10/176,	ND	10/176,	ND	ND
Saccella commutata (Philippi 1844) **MA (DF,SF)**	ND	ND	100/95,	ND	ND	100/95,	20/119,

CLASS/***Species***/**Geographical distribution/ (FD)**	**Transect**			**Months in 2005-2007**			
	Mersin	**Iskenderun**	**Anamur**	**November**	**March**	**July**	**January**
Septifer cumingii Récluz, 1849 **MP (SF)**	ND	ND	130/12,	10/31,	ND	ND	130/12,
Sphenia binghami Turton, 1822 **MA (SF)**	ND	ND	40/12,	ND	ND	ND	40/12,
Solemya togata Poli, 1795 **MAH (SF)**	ND	10/11,	ND	10/11,	ND	ND	ND
Tellina albicans Gmelin, 1791 **MA (DF)**	ND	50/203,	ND	50/203,	ND	ND	ND
Tellina tenuis da Costa 1778 **MA (DF)**	ND	20/153,	ND	20/153,	ND	ND	ND
Thracia phaseolina (Lamarck, 1818) **MA (DF)**	ND	10/101,	ND	ND	ND	ND	10/101,
Thyasira flexuosa (Montagu 1803) **MA (DF,SF**	10/11,	10/207,	10/119,	10/11,	ND	ND	10/207,119,
Timoclea ovata (Pennant 1777) **MA (SF)**	ND	10/101,	ND	ND	ND	ND	10/101,
GASTROPODA							
Alvania testae (Aradas & Maggiore 1844) **MA (DF,G)**	30/150,	ND	ND	30/150,	ND	ND	ND
Bittium reticulatum (da Costa 1778) **MA (DF,G)**	50/29,	ND	ND	ND	ND	ND	50/29,
Eulimella acicula (Philippi 1836) **MA**	ND	10/51,	ND	10/51,	ND	ND	ND
Liostomia sp.	ND	10/77,	ND	10/77,	ND	ND	ND
Monia sp.	ND	ND	10/95,	ND	ND	10/95,	ND
Neverita josephinia Risso, 1826 **MA**	ND	10/51,	ND	10/51,	ND	ND	ND
Philine aperta (Linnaeus, 1767) **HA (O,P,S)**	10/12,	ND	10/54,	ND	10/12,	ND	10/54,
Pseudorhaphitoma iodolabiata (Hornung & Mermod, 1929) **R**	ND	ND	10/12,	ND	ND	ND	10/12,
Pseudominolia nedyma (Melvill 1897) **MRA (C, DF)**	ND	ND	10/31,	10/31,	ND	ND	ND
Retusa truncatula (Bruguière, 1792) **MA (O,P,S)**	ND	ND	10/119,	ND	ND	ND	10/119,
Strombus persicus (Swainson, 1821) **M*H* (H)**	10/12,	ND	ND	ND	10/12,	ND	ND
Tricolia pullus pullus (Linnaeus, 1758) **M (H, SuF)**	ND	ND	20/12,	ND	ND	ND	20/12,
Williamia gussoni (Costa O. G., 1829) **AM (DF)**	ND	ND	10/12,	ND	ND	ND	10/12,

Appendix II. Environmental characters as physical, chemical and sedimentary parameters measured at the sampling stations and abbreviations of the parameters used in the analyses [50].

Physical parameters in Surface (SSx) and Near Bottom water (NBx)	**Chemical parameters (µM) in** Surface (SSx) and Near Bottom water (NBx)	**Sedimentary parameters in** Superficial sediment
Temperature (°C); SST and NBT	Dissolved oxygen (Winkler); SSO and NBO	Gr; Gravel (%)
Salinity (PSU); SSS and NBS	PO_4; $SSPO_4$ and $NBPO_4$	Snd; Sand (%)
Density, Sigma-t; SSD and NBD	NO_2+NO_3; $SSNO_2$+NO_3 and $NBNO_2$+NO_3	Mud (%)
Oxygen (mg $^{-}$l); SSOx and NBOx	Si; SSSi and NBSi	Slt; Silt (%)
		Cly; Clay (%)
		CaCO3; Total carbonate (%)
		TOC; Total organic carbon (%)