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Fewer Species but More Existing Individuals: Testing the Hypothesis 'Pessimum Conditions Rule' Based on Long-Term Data of Species Composition of Benthic Fauna and Environmental Variables in the Sea of Marmara, Turkey

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Abstract

The aim of this study is to try to prove the hypothesis that "When species diversity reduced, the survived unit members in the environment would be increased", which named by us as "Pessimum conditions rule" in the scale of the Sea of Marmara.

To prove the hypothesis "Pessimum conditions rule", data from 604 observations both of benthic and oceanographically stations gathered in a 7-year period (2006-2012) were analyzed and compared, and the results used to show the relationship between classic biotic descriptors (e.g. number of species, number of individuals, richness index, dominance index, Shannon/Menhinick diversities) and environmental variables (e.g. Dissolved Oxygen, temperature, Salinity, pH) and depth. Multiple analysis of covariance and multiple linear regressions were used for the statistical analysis of the data.

Correlations between benthic community indices and water quality variables showed that generally might affect community diversity. Besides this, it is clear that variation within benthic habitats in the Sea of Marmara cannot be explained by a single factor, such as uncontrolled overfishing and the revolving changes in the adjacent connected seas or driven by biotic interactions rather than by the water quality.

According to the sample composition of benthic catches and related frequency values, a relative increase in the number of individuals was observed. This is also apparent by the correlation between basic pollution parameters and the community index values regarding long-term data of the present work.

The measured values of the constant environment, created due to the unique structure of the Mediterranean originated lower layer of the Sea of Marmara, and correlated biotic parameters were showing a coherent dispersion in the completely sampling period. However, contrary to this, the values of the number of species were exactly the opposite. In the present study, pessimum conditions rule has been especially distinctive in the Sea of Marmara regarding the long-term data of the benthic catches.

Also, this work report on species composition of the benthic catches in the Sea of Marmara for an assessment of the status of these communities and relation these communities with pollution phenomenon.

Keywords: Diversity; Fauna; New records; Dominance; Species richness; Pessimum rule; Long-term monitoring

Introduction

Anthropogenic impact on marine life has escalated over the last semi centennial and threatened the balance of the ecosystem. Radical ecological changes in a sea can be provided most effectively by monitoring the benthic fauna, as most of the ecological impact and pollution load ultimately will end up on the seabed.

In an inland sea, such as the Sea of Marmara, especially the coastal urban areas are subject to unfavorable ecological changes mainly associated with eutrophication, oxygen deficiency, contaminants and overfishing. The unique water mass of Sea of Marmara has been strongly influenced by anthropogenic activities.

Sea of marmara

The entire system of Turkish Straits and Sea of Marmara extends from the Black Sea to the Aegean Sea through Bosporus (31 km), Sea of Marmara (210 km), and Dardanelles (60 km). The total length of the system is approximately 300 km, with a maximum depth of 1273 m. The maximum depth of the Sea of Marmara is controversial. The most accurate data are obtained by IFREMER [1] during earthquake studies, with a maximum of 1273 m.

Because of the combination of precipitation and runoff exceeds evaporation, relative low salinity and less dense water mass of the Black Sea is entirely different from those of the Mediterranean Sea originated saline and correspondingly dense water mass [2]. Due to the great differences in salinity-based density between the waters of the Black Sea and the Mediterranean Sea, there is a two-layered current system along the Turkish Straits and the Sea of Marmara, flowing in opposite directions [3]. In addition, there are serious vertical mixing points along those waterways especially in narrow and shallow straits and it tends to reduce the density of the deeper surface layer (approx. 200 m). Therefore, the deeper surface layer of the Sea of Marmara has a lower density than that of the water in the Aegean Sea at the equal depth [4].

As the connection between the Mediterranean Sea *via* Dardanelles and the Black Sea *via* Bosporus, the Sea of Marmara is a two-layered water mass with unique circumstances and attributes that determine its biological and ecological characteristics. The Sea of Marmara is situated between these two different ecosystems and serves as a sheltering, feeding and nesting area for both the Mediterranean Sea and the Black Sea originated forms, constituting a biological corridor [3].

Collectively, the two Straits and the Sea of Marmara provide an important "acclimatization zone" for transiting species during their migration from the Black Sea to the Aegean Sea and *vice versa* [5]. In addition, because of this, the increasing manner of Lessepsian invasion began to strongly affect to the Sea of Marmara as a result of decreased competition due to the reduction in species diversity [6].

Previous benthic studies in the Sea of Marmara

The first benthic study on the Sea of Marmara was carried out by Ostroumoff, et al. [7,8]. Following benthic and biological studies were by Marion (1898), Demir (1954), Tortonese (1959), Caspers (1968), Ünsal (1988), Balkıs (1992), Eryılmaz (1997), Uysal et al., (2002), Artüz et al., (2007, 2008, 2009,2011a, 2011b, 2012, 2013) [3,4,9-21]. In addition to benthic studies, there were some specific works that partly discussed the benthic fauna of the Sea of Marmara and Turkish Strait System [22-31]. Biodiversity studies were very limited and inadequate for studying this unique water mass, which was considered as a passageway or biological corridor.

Over the years, the Sea of Marmara has been under pressure in terms of pollution from domestic and industrial wastewater sources. Therefore, water quality has degraded significantly and biodiversity has been compromised in the Sea of Marmara. The current study presents literality of the pollution-based theory "When species diversity reduced, the survived unit members in the environment would be increased" for Sea of Marmara, that first proposed by Artüz, et al, 2007 regarding long-term data between years 2006 and 2012.

Materials and Methods

Rationale

In this study, Sea of Marmara is particularly selected as an appropriate model to test the "Pessimum conditions rule" because of providing the following conditions; i) presence of long-term and regular benthic and chemical-physical oceanographic data; ii) the sub-thermocline water mass carrying the Mediterranean water mass properties, particularly; iii) is relatively small in size and easily controllable in terms of pollution parameters; iv) as a suitable model for testing the hypothesis that species are biologically close to the Mediterranean in terms of diversity.

Study area and location of sampling stations

A series of samples were taken at annually at periodic intervals at same localities in Sea of Marmara from August 2006 to August 2012. The study was conducted at 61 stations (Figure 1) in the Sea of Marmara, between 15/08/2006 and 30/07/2012 (Table 1). Locations were determined by MAP 330GPS as part of the project MAREM (Marmara Environmental Monitoring Project) entitled, "Changing Oceanographic Conditions of the Sea of Marmara", Istanbul.

Macrofauna sampling and sample processing

A twin beam trawler 'Oktay 4' (length overall, 28 m; gross tonnage, 142 GT; main engine, 735 kW) was used for the study. The vessel was rigged for twin 3,75 m beam trawls with 18 and 3,6 mm stretched

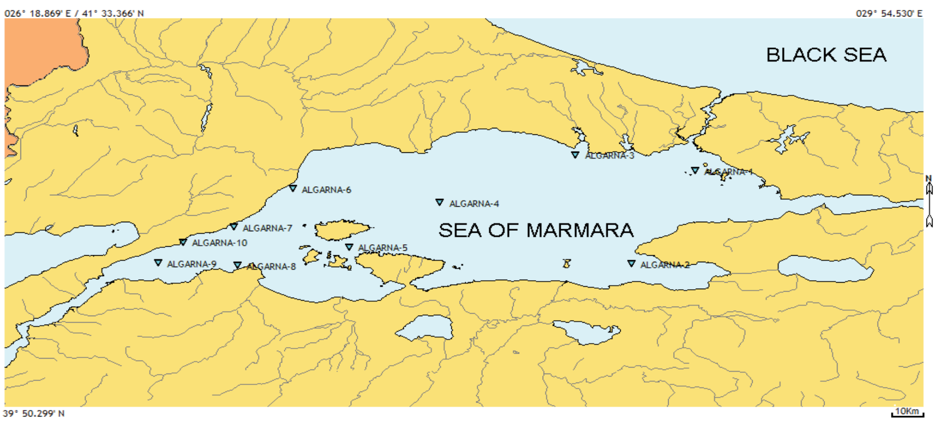

Figure 1: Survey area map of the MAREM (Marmara Environmental Monitoring) project, showing the 10 fixed beam-trawl sampling stations (▼) for each year.

Table 1: Location table with the beginning and ending coordinates of hauls, depth, and working date for each station.

Station №	Beginning coordinate	Ending coordinate	Depth (m)	Date
ALGARNA-1	40° 38.167' N : 027° 12.100' E	40° 38.667' N : 027° 12.450' E	23	15/08/2006
ALGARNA-2	40° 36.067' N : 027° 10.750' E	40° 36.000' N : 027° 10.183' E	70	15/08/2006
ALGARNA-3	40° 33.850' N : 027° 00.867' E	40° 33.233' N : 027° 00.983' E	15	15/08/2006
ALGARNA-4	40° 27.500' N : 027° 13.050' E	40° 27.667' N : 027° 12.333' E	32	19/08/2006
ALGARNA-5	40° 27.217' N : 027° 06.750' E	40° 27.233' N : 027° 06.167' E	35	19/08/2006
ALGARNA-1	40° 52.583' N : 028° 59.650' E	40° 52.750' N : 028° 59.833' E	40	03/08/2007
ALGARNA-2	40° 28.150' N : 028° 45.850' E	40° 27.733' N : 028° 45.133' E	60	03/08/2007
ALGARNA-3	40° 56.650' N : 028° 33.517' E	40° 56.617' N : 028° 33.100' E	56	04/08/2007
ALGARNA-4	40° 32.800' N : 027° 41.283' E	40° 32.217' N : 027° 40.717' E	50	05/08/2007
ALGARNA-5	40° 56.150' N : 027° 37.583' E	40° 56.133' N : 027° 38.567' E	75	06/08/2007
ALGARNA-6	40° 38.167' N : 027° 12.250' E	40° 37.733' N : 027° 11.550' E	45	07/08/2007
ALGARNA-7	40° 32.917' N : 027° 12.500' E	40° 32.733' N : 027° 13.000' E	74	07/08/2007
ALGARNA-8	40° 33.317' N : 027° 00.367' E	40° 33.700' N : 027° 00.800' E	33	09/08/2007
ALGARNA-9	40° 27.017' N : 027° 13.200' E	40° 27.067' N : 027° 13.900' E	27	09/08/2007
ALGARNA-10	40° 27.150' N : 027° 06.067' E	40° 27.017' N : 027° 05.383' E	40	09/08/2007
ALGARNA-2	40° 28.700' N : 028° 45.683' E	40° 28.267' N : 028° 45.950' E	53	07/08/2008
ALGARNA-3	40° 56.517' N : 028° 32.333' E	40° 56.200' N : 028° 31.383' E	56	08/08/2008
ALGARNA-4	40° 32.417' N : 027° 41.317' E	40° 32.583' N : 027° 40.300' E	60	09/08/2008
ALGARNA-5	40° 45.900' N : 027° 25.150' E	40° 45.133' N : 027° 25.550' E	650	11/08/2008
ALGARNA-6	40° 44.300' N : 027° 26.150' E	40° 44.067' N : 027° 26.833' E	500	11/08/2008
ALGARNA-8	40° 33.383' N : 027° 00.867' E	40° 33.767' N : 027° 01.467' E	26	12/08/2008
ALGARNA-9	40° 27.000' N : 027° 12.600' E	40° 26.867' N : 027° 11.867' E	40	11/08/2008
ALGARNA-10	40° 27.133' N : 027° 05.967' E	40° 27.450' N : 027° 04.800' E	39	11/08/2008
ALGARNA-1	40° 52.217' N : 029° 00.100' E	40° 51.633' N : 029° 00.950' E	96	01/08/2009
ALGARNA-2	40° 28.550' N : 028° 46.033' E	40° 28.083' N : 028° 46.717' E	59	04/08/2009
ALGARNA-3	40° 57.150' N : 028° 32.567' E	40° 57.267' N : 028° 31.717' E	56	05/08/2009
ALGARNA-4	40° 44.700' N : 027° 50.800' E	40° 44.667' N : 027° 59.500' E	950	06/08/2009
ALGARNA-5	40° 32.400' N : 027° 40.767' E	40° 31.917' N : 027° 40.167' E	60	07/08/2009
ALGARNA-6	40° 48.233' N : 027° 27.550' E	40° 46.767' N : 027° 26.983' E	1100	11/08/2009
ALGARNA-7	40° 38.400' N : 027° 12.617' E	40° 37.783' N : 027° 11.350' E	28	12/08/2009
ALGARNA-8	40° 27.250' N : 027° 13.417' E	40° 26.650' N : 027° 11.800' E	45	12/08/2009
ALGARNA-9	40° 27.833' N : 026° 55.000' E	40° 27.617' N : 026° 53.417' E	43	12/08/2009
ALGARNA-10	40° 33.333' N : 027° 00.500' E	40° 33.717' N : 027° 01.133' E	27	13/08/2009
ALGARNA-1	40° 52.267' N : 029° 00.867' E	40° 52.033' N : 029° 01.500' E	81	08/08/2010
ALGARNA-2	40° 27.517' N : 028° 45.900' E	40° 26.850' N : 028° 45.967' E	63	11/08/2010
ALGARNA-3	40° 56.483' N : 028° 32.817' E	40° 56.133' N : 028° 31.900' E	64	12/08/2010
ALGARNA-4	40° 43.800' N : 028° 00.967' E	40° 43.667' N : 028° 01.783' E	900	13/08/2010
ALGARNA-5	40° 31.983' N : 027° 39.667' E	40° 31.267' N : 027° 39.000' E	58	13/08/2010
ALGARNA-6	40° 47.483' N : 027° 26.450' E	40° 47.600' N : 027° 27.117' E	1100	15/08/2010
ALGARNA-9	40° 27.767' N : 026° 54.900' E	40° 27.800' N : 026° 54.150' E	42	15/08/2010
ALGARNA-7	40° 37.300' N : 027° 12.617' E	40° 37.950' N : 027° 11.900' E	30	15/08/2010
ALGARNA-8	40° 27.217' N : 027° 13.533' E	40° 27.083' N : 027° 11.867' E	45	15/08/2010
ALGARNA-10	40° 33.333' N : 027° 00.767' E	40° 33.817' N : 027° 01.450' E	22	16/08/2010
ALGARNA-1	40° 52.483' N : 029° 00.267' E	40° 53.033' N : 029° 01.183' E	74	31/07/2011
ALGARNA-2	40° 27.050' N : 028° 45.633' E	40° 26.783' N : 028° 46.433' E	65	02/08/2011
ALGARNA-3	40° 58.417' N : 028° 07.483' E	40° 58.467' N : 028° 06.517' E	40	04/08/2011
ALGARNA-4	40° 45.050' N : 027° 58.300' E	40° 44.550' N : 027° 58.317' E	900	05/08/2011
ALGARNA-5	40° 33.467' N : 027° 43.450' E	40° 33.183' N : 027° 42.533' E	65	06/08/2011
ALGARNA-6	40° 48.850' N : 027° 29.167' E	40° 48.317' N : 027° 28.483' E	1000	07/08/2011
ALGARNA-7	40° 27.950' N : 027° 08.367' E	40° 27.850' N : 027° 07.533' E	32	08/08/2011
ALGARNA-8	40° 26.467' N : 026° 50.067' E	40° 26.767' N : 026° 50.800' E	31	09/08/2011
ALGARNA-9	40° 33.950' N : 027° 01.100' E	40° 33.500' N : 027° 00.917' E	23	09/08/2011
ALGARNA-1	40° 52.500' N : 029° 00.333' E	40° 52.067' N : 029° 01.117' E	64	24/07/2012
ALGARNA-2	40° 27.217' N : 028° 45.667' E	40° 26.667' N : 028° 45.500' E	65	26/07/2012
ALGARNA-3	40° 57.450' N : 028° 31.617' E	40° 57.617' N : 028° 30.400' E	53	22/07/2012
ALGARNA-4	40° 44.567' N : 028° 01.200' E	40° 44.500' N : 028° 02.017' E	1000	27/07/2012
ALGARNA-5	40° 32.733' N : 027° 43.117' E	40° 32.383' N : 027° 42.067' E	64	28/07/2012
ALGARNA-6	40° 49.400' N : 027° 29.133' E	40° 50.583' N : 027° 29.333' E	1000	21/07/2012
ALGARNA-7	40° 27.800' N : 027° 07.183' E	40° 27.017' N : 027° 05.917' E	49	29/07/2012
ALGARNA-8	40° 27.167' N : 026° 51.100' E	40° 26.950' N : 026° 50.350' E	30	29/07/2012
ALGARNA-9	40° 33.533' N : 027° 00.650' E	40° 33.850' N : 027° 01.283' E	18	30/07/2012

mesh sizes at the cod-ends. Hauls were conducted once at each station with a quarter-hour duration and boat speed of 2 mph.

All captured material was retained for species identification, and then each species was weighed (wet weight) to the nearest 0,01 g and the number of individuals from each species was determined. Also, attached invertebrates on the captured various kind and sizes hard substrate are also collected and added to catch composition.

Thereafter, the collected species were fixed in 10% buffered formalin-seawater and then were taken to the laboratory for closer examination. Samples were rinsed with formalin after about a week and transferred to 70% isopropyl alcohol.

Mainly the most abundant species was *Spatangus purpureus* and was hauled at some stations in large quantities, more than 4 MT in each haul. In this case, the number of individuals is calculated using a random sampling method with 25 replicates, and numbers of individuals are submitted as an average value. Also in station ALGARNA-2, on August 2008, the mass aggregates of *Phyllochaetopterus socialis*, with a total wet weight of 58 kg, are not counted in the individual basis and are not added to calculations.

Diversity measurements

Several catch parameters were estimated in this study: the species richness index according to the equation of the Shannon-Weiner index [32-36] and the evenness index according to Pielou, et al. [37]; the number of species and dominance index thereof Simpson, et al. [38]. In text and tables, the calculation results of indices are given as rounded upwards to two decimal places. Because of, values below the 0,01 were assigned as (: $<e^{-2}$).

Statistical analyses

MANCOVA was performed (multiple analysis of covariance) to test if there is a significant difference in the centroid of the means of the multiple dependent variables for East and West regions of the Sea of Marmara. The reason for this distinction is the examination of pollution based apparent effect of the external factor on the distribution and diversity of species between the eastern region (Algarna 1; 2; 3) under heavy pollution load and the western region (Algarna 4; 5; 6; 7; 8; 9; 10) under relatively less pollution load which are in the same water mass.

The dependent variables were "the number of species (S)", "the number of individuals (**Nº**)" and "dissolved oxygen (DO)" where the factor variable was "the region". MANCOVA is a statistical method which allows using continuous control variables as covariates when dealing with analyses where there is more than one outcome variable explained by one or more independent variables. "The year" was used as the covariate to control the dependent variables' values for the year they were collected.

A post-hoc comparison has also been performed, using Bonferroni adjustment [39] for multiple comparisons, to test the mean differences between East and West regions for each dependent variable individually. Statistical analyses were carried out using the Statistical Package for the Social Sciences (SPSS) version 20,0 (IBM SPSS Statistics for Windows, Version 20,0; IBM Corp., Armonk, New York, USA).

Water quality data

All oceanographical parameters were measured in situ with a CTD YSI 6600 V2 multi-parameter data sonde and MIDAS ECM along with the water column with 1 sec duration (approximately 10 cm intervals) from the surface (0,5 m) to the deepest section of the station. The mean values of the water mass of 1 m in height from the bottom are used in the calculations.

Bottom type data

The analysis for the bottom type regarding Wenworth, et al. [40] was carried two replicates on the samples of gravity-corer from the upper 2 cm layer of sediment. Small Stones and shell parts were removed before drying and the residue of the first replicate was sieved on a mechanical shaker through six sieves (mesh size of 2 mm-0,004 mm) for 60 min, and the sediment present in each sieve was weighed. The second replicate was burned on 400 °C for the organic ingredient.

The basic bottom types (Sand: 2 mm to 0,59 mm; Silt: 0,6 mm to 0,004 mm; Clay: <0,004 mm; Muddy: mixture of sand+silt+clay; Detritus: ≥ 50% of the weight lost when burned) are given in Table 2.

Availability of material and data

The material is deposited in the collection of the MAREM project, and all data were recorded stored and processed in the Hidro- QL version 2012.9.2. [41]. The datasets generated and/or analyzed during the current study are not publicly available due http://prog.marem.org. Login requires membership and registration, and the owner of the work needs to share it according to the database rules.

Results

Faunal communities

Three hundred and sixty benthic and benthopelagic species representing 21 taxa were collected and identified from the Sea of Marmara between years 2006 and 2012 during MAREM Beam-Trawl surveys, including 52 species that are new records for the Sea of Marmara. Individual numbers of species and total wet weight with respect to each species are given in Table 3.

In the Beam-Trawl surveys, 1356624 specimens representing 360 species with the total wet weight of 21616108,28 g were collected. With regard to the percentage of total weight, *Spatangus purpureus* was the dominant species (96,7%) followed by *Parapenaeus longirostris* (0,32%) in total. The frequency tables and graphs in annual basis are given in Supplementary File 1.

Diversity composition

Four indices (diversity, species richness, evenness, and dominance) were calculated according to the sampling stations (Table 2).

The diversity index (*H'*) showed the maximum value at the year 2009 (*H'*: 3,72) with the maximum at the station ALGARNA-9 (*H'*: 3,31), and the minimum value at year 2012 (*H'*: 0,06) with the minimum at the station ALGARNA-1 (*H'*: $<e^{-2}$). The species composition of the regarding station was: Echinodermata community with Nº of species 2 and Nº of individuals of 858038 with the frequency of 0,9999; Osteichthyes community with Nº of species 5 and Nº of individuals 29; Decapoda community with Nº of species 2 and Nº of individuals 23; Ascidiacea community with Nº of species 1 and Nº of individuals 18 (Tables 3,4).

Richness index (D_{Mg}) did not display a clear trend on the yearly basis. The richness index showed the maximum value at the year 2009 (D_{Mg}: 17,10) with the maximum at the station ALGARNA-9 (D_{Mg}: 8,63), and the minimum value at the year 2006 (D_{Mg}: 7,75) with the minimum at the station ALGARNA-1 (D_{Mg}: 1,76) (Tables 2,4).

Evenness *(J')* displayed quite different values at all years and shows a proportional decrease in year basis between 2006 and 2012. The Evenness index *(J')* showed the maximum value at the year 2009

Table 2: Station based Depth (m), type of sea bottom, Station richness (S= Number of Species; *N*°=Number of Individuals) and index values (D_{Mg} =Margalef richness index; D_{Mn}=Menhinick diversity index; *H'*= Shannon-Weiner diversity index*; J'*= Pielou's evenness index).

			Station richness		*Index values*			
Station	**Depth (m)**	**Bottom**	**S**	***Nº***	D_{Mg}	D_{Mn}	*H'*	*J'*
2006								
ALGARNA-1	23	Silt/Clay	10	166	1,76	0,78	1,91	0,83
ALGARNA-2	70	Clay	14	307	2,27	0,80	1,93	0,73
ALGARNA-3	15	Detritus	10	73	2,10	1,17	2,01	0,87
ALGARNA-4	32	Detritus	15	360	2,38	0,79	1,93	0,71
ALGARNA-5	35	Silt	17	159	3,16	1,35	2,63	0,93
2007								
ALGARNA-1	40	Silt/Clay	9	533	1,27	0,39	0,69	0,31
ALGARNA-2	60	Clay	25	1867	3,19	0,58	2,18	0,68
ALGARNA-3	56	Detritus	15	1266	1,96	0,42	1,28	0,47
ALGARNA-4	50	Detritus	25	369	4,06	1,30	2,93	0,91
ALGARNA-5	75	Silt	18	875	2,51	0,61	1,85	0,64
ALGARNA-6	45	Muddy	19	464	2,93	0,88	2,54	0,86
ALGARNA-7	74	Sandy clay	27	498	4,19	1,21	2,58	0,78
ALGARNA-8	33	Sandy clay	23	467	3,58	1,06	2,59	0,83
ALGARNA-9	27	Silt/Clay	28	491	4,36	1,26	2,80	0,84
ALGARNA-10	40	Clayed sand	27	810	3,88	0,95	2,46	0,75
2008								
ALGARNA-2*	53	Clay	43	1872	5,57	0,99	1,99	0,53
ALGARNA-3	56	Detritus	22	1421	2,89	0,58	1,35	0,44
ALGARNA-4	60	Detritus	41	968	5,82	1,32	2,59	0,70
ALGARNA-5	650	Silt	1	16	$< e^{-2}$	0,25	$< e^{-2}$	$< e^{-2}$
ALGARNA-6	500	Muddy	4	3939	0,36	0,06	0,13	0,09
ALGARNA-8	26	Sandy clay	32	648	4,79	1,26	3,06	0,88
ALGARNA-9	40	Silt/Clay	19	213	3,36	1,30	2,63	0,89
ALGARNA-10	39	Clayed sand	28	2264	3,50	0,59	1,10	0,33
2009								
ALGARNA-1	96	Silt/Clay	13	6808	1,36	0,16	0,13	0,05
ALGARNA-2	59	Clay	22	658	3,24	0,86	1,85	0,60
ALGARNA-3	56	Detritus	19	132456	1,53	0,05	0,02	0,01
ALGARNA-4	950	Muddy	6	134	1,02	0,52	1,25	0,70
ALGARNA-5	60	Silt	36	556	5,54	1,53	2,65	0,74
ALGARNA-6	1100	Muddy	10	130	1,85	0,88	1,93	0,84
ALGARNA-7	28	Sandy clay	24	987	3,34	0,76	1,98	0,62
ALGARNA-8	45	Sandy clay	28	482	4,37	1,28	2,38	0,71
ALGARNA-9	43	Silt/Clay	61	1049	8,63	1,88	3,34	0,81
ALGARNA-10	27	Clayed sand	42	551	6,50	1,79	3,03	0,81
2010								
ALGARNA-1	81	Silt/Clay	10	21628	0,90	0,07	0,07	0,03
ALGARNA-2	63	Clay	23	115429	1,89	0,07	0,02	0,01
ALGARNA-3	64	Detritus	30	151457	2,43	0,08	0,05	0,01
ALGARNA-4	900	Muddy	10	212	1,68	0,69	1,41	0,61
ALGARNA-5	58	Silt	26	389	4,19	1,32	2,52	0,77
ALGARNA-6	1100	Muddy	4	65	0,72	0,50	0,78	0,57
ALGARNA-7	30	Sandy clay	16	272	2,68	0,97	2,07	0,75
ALGARNA-8	45	Sandy clay	24	534	3,66	1,04	2,14	0,67
ALGARNA-9	42	Silt/Clay	89	1300	12,27	2,47	3,98	0,89
ALGARNA-10	22	Clayed sand	68	803	10,02	2,40	3,31	0,79
2011								
ALGARNA-1	74	Silt/Clay	20	30168	1,84	0,12	0,04	0,01
ALGARNA-2	65	Clay	20	148	3,80	1,64	2,35	0,78
ALGARNA-3	65	Detritus	8	558	1,11	0,34	0,67	0,32
ALGARNA-4	900	Muddy	8	155	1,39	0,64	1,66	0,80
ALGARNA-5	65	Silt	39	1254	5,33	1,10	2,23	0,61
ALGARNA-6	1000	Muddy	13	997	1,74	0,41	0,49	0,19

ALGARNA-7	29	Sandy clay	61	594	9,39	2,50	3,24	0,79
ALGARNA-8	31	Sandy clay	48	348	8,03	2,57	2,74	0,71
ALGARNA-9	23	Silt/Clay	14	86	2,92	1,51	2,32	0,88
ALGARNA 10	40	Clayed sand	23	1472	3,02	0,60	1,20	0,38
2012								
ALGARNA-1	64	Silt/Clay	10	858108	0,66	0,01	$< e^{-2}$	$< e^{-2}$
ALGARNA-2	65	Clay	32	518	4,96	1,41	2,61	0,75
ALGARNA-3	53	Detritus	15	698	2,14	0,57	1,89	0,70
ALGARNA-4	1000	Muddy	22	644	3,25	0,87	1,63	0,53
ALGARNA-5	64	Silt	38	746	5,59	1,39	2,99	0,82
ALGARNA-6	1000	Muddy	15	167	2,74	1,16	2,25	0,83
ALGARNA-7	49	Sandy clay	39	711	5,79	1,46	2,25	0,62
ALGARNA-8	30	Sandy clay	58	798	8,53	2,05	3,33	0,82
ALGARNA-9	18	Silt/Clay	11	1636	1,35	0,27	1,20	0,50

*In that station was landed 58 kg of *Phyllochaetopterus socialis* aggregates, individuals cannot be counted individually and are not included in the calculations.

(*J'*:0,83) with the maximum at the station ALGARNA-5 (*J'*:0,93), and the minimum value at year 2012 (*J'*:0,01) with the minimum at the station ALGARNA-1 (*J'*: $<e^{-2}$) (Tables 2,4).

The most dominant community was for the year 2006 Osteichthyes with regional frequency of 0,2486; for year 2007 Decapoda with regional frequency of 0,3654; for year 2008 Echinodermata with regional frequency of 0,4157; for year 2009 Echinodermata with regional frequency of 0,9689; for year 2010 Echinodermata with regional frequency of 0,9851; for year 2011 Echinodermata with regional frequency of 0,9118 and for year 2012 Echinodermata with regional frequency of 0,9950 respectively. In addition, the overall most dominant species was *Spatangus purpureus* (Supplementary File 1).

Measured environmental parameters

Dissolved oxygen (DO) concentration, salinity, temperature, and pH of seawater at the stations were determined during the investigations. Temperatures in the deeper water masses below the thermocline (30 m) showed virtually no changes, fluctuating by only 1,2°C (14,2-15,4°C) throughout the entire sampling period (Supplementary File 2).

Also, salinity measurements showed the two-layer structure of Sea of Marmara clearly and in all stations below thermocline layer Mediterranean environmental conditions with the salinity range between 21,81 and 39,46 Sal (mean) were obtained. The in-and out-flowing water masses in the system were separated by a well-defined transition layer, which oscillated up and down according to contours of the bottom. This transition layer also represents the discontinuity layer for temperature and salinity (thermo-halocline layer). The intersection of thermocline and pycnocline layers, as a unique characteristic of the Sea of Marmara, was clearly traceable from measurement results (Supplementary File 2).

Dissolved oxygen concentrations were variable and fluctuating depending on two main factors in the Sea of Marmara, especially below the thermocline layer. The main factor was the previously higher DO of inflowing Mediterranean water, which was over 5 mg/l at the entrance of Dardanelles. DO decrease gradually to 3,5 mg/l with the distance travelled in the Sea of Marmara along the pycnocline layer, which was isolated by the low density, the Black Sea originated water mass that covered the entire surface and sealed the oxygen transfer from the atmosphere. This decrease was a function of the distance travelled by the water. In addition, regarding our measurements, anoxic and hypoxic areas have been widely observed in benthic regions >200 m depth of Sea of Marmara over the past fifteen decades. In contrast, DO concentrations in the super stratum exceeded as a mean value of 4 mg/l throughout most of the water mass between surface and pycnocline interface, restricting vertical re-aeration across this strong pycnocline, in the Sea of Marmara.

pH values were recorded between a minimum of 7,06 and maximum of 8,88 during the sampling period (Supplementary File 2) with the average value in the Black Sea originated upper layer of pH 7,84 ± 0,03 and with the average value in the Mediterranean Sea originated layer below the pycnocline of pH 7,86 ± 0,09. Across the Sea of Marmara are seasonal intense and successive blooms of phytoplankton [42]. As a result, the phytoplankters uses more CO_2 during the photosynthesis activity in the course of blooming period and decomposes the bicarbonate in the environment into neutral carbonates. This event causes to increase the basicity of the environment.

Observed changes in the chemical environmental variables (Supplementary File 2) such as pH might be due to increasing amounts of chlorine and/or increasing pesticide concentration [43] in the Sea of Marmara. Chlorine was used as an anti-fouling agent in cleaning the direct discharge pipes of sewage and intake pipes of cooling systems for industrial facilities. When discharged directly to the water column, chlorine might be one of the causes of current acidification.

Relation between fauna and the environmental variables

The measured environmental parameters (pH; DO; Sal; T˚C) provide a consistent appearance with the indices values (D_{Mn}, D_{Mg}, H', J') each other. In addition, the correlation between the number of species (S) and numbers of individuals (N) with the measured environmental parameters (DO and pH) that directly related to pollution, shows a significant dispersion against each other.

In the last fifty years, the pollution has been dramatically increased in the east part of the Sea of Marmara. The increase in heavy industry and connected urbanization in the area also been the leading cause of that increased pollution. Owing to the connection via Dardanelles and because of the water exchange with the Aegean Sea, the western part is exposed to a relatively less pollution load [42].

There were 19 observations from East and 43 observations from the West Regions of the Sea of Marmara. According to Multivariate Test Results (Table 5), there is a significant difference (significance 0,008<0,05) between the East and West regions of Sea of Marmara.

Pairwise comparison results from (Supplementary 5) indicate that there is a difference in the number of individuals (significance 0,031). There are averagely a 65450 number of individuals more in East than in the West. On the contrary, there is averagely an 8 number of species more in West than in East as the number of individuals' increases, the number of species decreases, and *vice versa*; as trying to be proven as "pessimum conditions rule". Beside this, it is seen there is nearly one unit less dissolved oxygen in East than in the West.

The result of comparisons shows conformity to the theory if the diversity reduces, the increase in the number of survived members in these two regions, thus under heavy pollution pressure and with relatively less pollution load.

Since MANCOVA analysis results have given some insights that there is a negative relationship between the number of species and the number of individuals multiple linear regression analysis to model the relationship for all data is also used. The regression model was estimated as;

$$Individual = constant - 1739 \times species - 82 \times depth + 17867 \times year$$

According to the regression model as the number of species increase for one unit, the number of individuals decreases averagely for 1739 units. As the depth increase for one unit (meter) the number of individuals decreases averagely for 82 units, and as the year increase for one unit (year) the number of individuals increases averagely for 17867 units. This means that there is an increase in the number of individuals while the numbers of species are decreasing every year in the Sea of Marmara.

All the relevant values are given in Supplementary File 2 and Supplementary File 3. The analysis results are given in Supplementary File 4 and Supplementary File 5.

Bottom type

There were no significant differences in the bottom types between the studied stations. The predominant sediment components at the station are the silts and clays, mixed with detritus material (Table 2). The main structure was a soft bottom type with the varying the particle size between 1,9 to 0,001 mm. This situation does not appear to be a factor to influence the diversity of species. In fact, the species components of the benthic fauna in Sea of Marmara constitute a relative continuum, despite the indefinite change in sediment composition.

Discussion

The present study was conducted between the years 2006 and 2012, being the longest run study on the Sea of Marmara. The aim was to investigate biodiversity under changing environmental conditions, specifically due to increasing pollution load.

Correlations between benthic community indices and water quality variables showed that generally might affect community diversity. Besides this, it is clear that variation within benthic habitats in the Sea of Marmara cannot be explained by a single factor, such as uncontrolled overfishing and the revolving changes in the adjacent connected seas or driven by biotic interactions rather than by the water quality.

As most of the environmental parameters are closely related to each other, it is difficult to segregate the effect of each one on the distribution of benthic fauna elements, especially in a highly eutrophic ecosystem.

However, the environmental measurement results (Supplementary File 2), changes in indices values over time (Table 2) and related correlation values show that the predominant effect of pollution preponderates over all other factors in that aquatic medium.

There should be normally the decline by natural way of species diversity and consequently number of individuals depending on the depth, but contrary in present work, according to the sample composition (Table 3) and frequency values (Supplementary File 1), besides of a decrease of the species diversity, a relative increase of number of individuals was observed. This is also apparent by the correlation between basic pollution parameters DO and pH and the community index values regarding long-term data of the present work.

As stated above, the measured values of the constant environment, created due to the unique structure of the Mediterranean originated lower layer of the Sea of Marmara, and correlated biotic parameters were showing a coherent dispersion in the completely sampling period. However, contrary to this, the values of the number of species (N) was exactly the opposite. The main reason of this was the variable structure of the echinoderm communities and huge fluctuations in general numbers of species, based on species densities of echinoderm communities, especially due to the *S. purpureus* individuals abundance in the hypoxic depth and areas (e.g. the N values was between a range of 18 and 858,108)

Probably, low diversity and consequent irregularity of the survived number of individuals may be a result of the variable environmental conditions, benthic species are more exposed to environmental variation, and therefore some macrofaunal community patterns may reflect species adaptations to those environmental conditions. However, it is clear, that point and non-point pollution sources affect macrobenthos communities shifting their composition to taxa that are more tolerant.

It shall also be noted that since the Sea of Marmara is connected to the Mediterranean Sea and the Black Sea and considering the heavy maritime traffic, it is open to any kind of species transportation. Therefore, the occurrence of various types and numbers of species can be observed naturally in the Sea of Marmara, increasing its biodiversity. However, due to the effects of continuous untreated wastewater discharge and intermittent transportation of invader species, biodiversity in the Sea of Marmara has been observed to decrease.

Conclusion

In this study, we have investigated the hypothesis "Pessimum conditions rule" data from 604 observations both of benthic and oceanographical stations gathered in a 7-year period (2006-2012). Our results suggest conformity to the theory "When species diversity reduced, the survived unit members in the environment would be increased".

Artüz, et al. [29] previously discussed that the Sea of Marmara used to have high biodiversity before the major urbanization and industrialization that has been going on since the 1970's. Unplanned urbanization and industrialization brought about many environmental issues, a major one being large quantities of domestic and industrial wastewater. The most economical solution to this massive wastewater problem was seen as to discharge it to the Sea of Marmara, which became a dumping ground over the years. Prior to intense unplanned urbanization and industrialization, the Sea of Marmara was hosting various and numerous organisms in its discrete two-layered system. In addition, Dardanelles and Bosporus Straits constitute biological corridors/barriers for different species with their narrow and relatively shallow structures.

On the other hand, the Sea of Marmara has been receiving heavy inputs of municipal and industrial wastewater from Istanbul and

Table 3: List of landed species between years 2006 and 2012 (number of individuals/wet weight as g).

↓ List of species Years →	2006	2007	2008	2009	2010	2011	2012	Total
Porifera								
Acanthella acuta Schmidt, 1862	-	-	-	-	-	22/179	-	22/179
Ancorina cerebrum Schmidt, 1862	-	-	-	11/1450	-	1/3	16/1600	28/3053
Axinella damicornis (Esper, 1794)	-	-	-	-	-	1/31	-	1/31
Axinella polypoides Schmidt, 1862	-	-	-	-	3/15	3/67	-	6/82
Axinella rugosa (Bowerbank, 1866)	-	-	-	-	-	9/126	-	9/126
Axinella verrucosa (Esper, 1794)	-	-	-	-	-	3/24	-	3/24
Chondrosia reniformis Nardo, 1847	-	-	-	-	-	1/73	-	1/73
Cliona celata Grant, 1826	-	-	1/110	-	-	-	-	1/110
Corticium candelabrum Schmidt, 1862 *	-	-	-	-	-	1/98	-	1/98
Dysidea tupha (Martens, 1824)*	-	-	-	-	-	3/23	-	3/23
Geodia barretti Bowerbank, 1858	-	-	-	6/13,5	-	-	-	6/13,5
Geodia cydonium (Jameson, 1811)	3/1510	-	-	8/22000	-	1/22	9/15025	21/38557
Geodia hentscheli Cárdenas, Rapp, Schander & Tendal, 2010 *	-	-	-	-	-	41/29230	4/2560	84/31790
Halichondria (Halichondria) panicea (Pallas, 1766)	-	-	-	-	-	1/115	-	1/115
Haliclona (Haliclona) simulans (Johnston, 1842)	-	-	-	-	21/670	-	-	21/670
Haliclona (Reniera) mediterranea Griessinger, 1971	-	-	-	-	-	-	22/95	22/95
Hemimycale columella (Bowerbank, 1874)*	-	-	-	-	-	1/96	-	1/96
Leucosolenia sp.	-	-	-	-	-	-	11/135	11/135
Pheronema carpenteri (Thomson, 1869)*	-	-	-	1/63	-	3/29,34	-	4/92,34
Raspaciona aculeata (Johnston, 1842)*	-	-	-	1/19	-	-	-	1/19
Raspailia (Clathriodendron) hispida (Montagu, 1814)*	-	-	-	-	1/16	-	-	1/16
Rhizaxinella pyrifera (Delle Chiaje, 1828)	-	-	9/223	5/22	5/25	1/6	2/30	22/306
Spongia (Spongia) officinalis Linnaeus, 1759	-	-	-	1/335	-	-	-	1/335
Suberites domuncula (Olivi, 1792)	-	22/85	22/1442	18/113	11/270	32/965	7/1464	140/4339
Tethya aurantium (Pallas, 1766)	-	-	14/127	17/244	19/292	-	-	50/663
Tethya citrina Sarà & Melone, 1965 *	-	-	-	-	-	-	11/1290	11/1290
Tethya sp.	-	-	-	1/31	-	-	-	1/31
Thenea muricata (Bowerbank, 1858)	-	-	-	3/23	-	-	-	3/23
Timea unistellata (Topsent, 1892)	-	-	-	18/210	-	-	-	18/210
Hydrozoa								
Antenella sp.	-	-	-	1/11	-	-	-	1/11
Bougainvillia muscus (Allman, 1863)	-	-	-	-	-	5/0,19	-	5/0,19
Eudendrium racemosum (Cavolini, 1785)*	-	-	-	-	-	4/1	-	4/1
Lytocarpia myriophyllum (Linnaeus, 1758)	-	-	-	4/9	-	-	-	4/9
Nausithoe marginata Kölliker, 1853 *	-	-	-	19/4	-	11/4	17/20	47/28
Pennaria disticha Goldfuss, 1820*	-	-	-	1/3	-	-	-	1/3
Sertularella sp.	-	-	-	4/5	1/10	-	-	5/15
Anthozoa								
Actinia cari Delle Chiaje, 1822*	-	-	-	-	10/133	6/11	-	16/144
Adamsia palliata (Fabricius, 1779)*	-	6/25	-	-	-	-	-	6/25

Aiptasia diaphana (Rapp, 1829)	-	-	-	-	-	2/14	3/14	5/28
Alcyonium acaule Marion, 1878	-	-	-	-	-	1/6	-	1/6
Alcyonium coralloides (Pallas, 1766)	-	-	-	3/19	-	-	-	3/19
Alcyonium palmatum Pallas, 1766	8/180	368/5224	24/746	43/502	26/570	4/36	243/2080	716/9338
Antipathella subpinnata (Ellis & Solander, 1786)	-	-	-	4/97	-	-	-	4/97
Aulactinia verrucosa (Pennant, 1777) *	-	-	-	-	2/11	-	-	2/11
Calliactis parasitica (Couch, 1842)*	-	-	2/21	1/14	5/45	-	2/22	10/102
Caryophyllia (Acanthocyathus) grayi (Milne Edwards & Haime, 1848)*	-	-	8/48	-	-	-	-	8/48
Caryophyllia (Caryophyllia) inornata (Duncan, 1878)*	-	-	-	12/29	6/36	-	11/40	29/105
Caryophyllia (Caryophyllia) smithii Stokes & Broderip, 1828	6/25	41/70	27/96	38/146	20/154	-	-	132/491
Cladocora caespitosa (Linnaeus, 1767)	-	-	-	-	-	1/18	-	1/18
Funiculina quadrangularis (Pallas, 1766)	55/110	59/665	-	8/98	10/340	8/104	10/100	150/1417
Isidella elongata (Esper, 1788)*	-	12/75	-	-	1/6	6/9,5	3/33	22/123,5
Paramuricea clavata (Risso, 1826)	-	6/75	-	-	-	-	2/21	8/96
Parazoanthus axinellae (Schmidt, 1862)	-	18/47	-	-	55/890	-	-	73/937
Pennatula phosphorea Linnaeus, 1758	-	359/1291	3/11	13/55	28/120	-	90/178	493/1655
Pennatula rubra (Ellis, 1761)	-	24/75	5/15	19/71	41/213	7/18	-	96/392
Pteroeides spinosum (Ellis, 1764)	-	-	-	9/79	22/337	12/150	25/389	68/955
Sagartia elegans (Dalyell, 1848)	-	-	-	1/6	-	-	-	1/6
Savalia savaglia (Bertoloni, 1819)	-	-	1/22	1/22	-	2/57	-	4/101
Veretillum cynomorium (Pallas, 1766)	16/820	211/2846	-	312/3889	241/16445	-	55/630	835/24630
Virgularia mirabilis (Müller, 1776)	-	-	-	-	-	-	3/24	3/24
Plathelminthes								
Drepanonema inarimense Panceri, 1876 *	-	-	-	-	4/30	-	-	4/30
Aschelmintes								
Nectonema agile Verrill, 1879*	-	-	-	-	-	-	3/14	3/14
Echiurida								
Bonellia viridis Rolando, 1821	2/80	-	-	-	-	-	-	2/80
Sipunculida								
Sipunculus (Sipunculus) nudus Linnaeus, 1766	-	-	-	-	-	3/30	-	3/30
Placophora								
Chiton (Rhyssoplax) olivaceus Spengler, 1797	-	-	-	-	2/15	-	-	2/15
Gastropoda								
Aegires sp.	-	-	2/29	-	-	-	-	2/29
Aplysia depilans Gmelin, 1791	-	-	-	-	-	-	2/10	2/10
Aplysia punctata (Cuvier, 1803)	-	17/205	-	36/610	16/235	1/17	7/69	77/1136
Aplysia sp.	-	-	-	52/350	-	-	-	52/350
Aporrhais pespelecani (Linnaeus, 1758)	-	-	-	18/92	1/12	-	-	19/104
Aporrhais serresianus (Michaud, 1828)	-	-	-	-	-	-	19/91	19/91
Armina maculata Rafinesque, 1814 *	-	-	-	-	2/15	-	-	2/15
Armina tigrina Rafinesque, 1814	-	-	-	-	1/32	-	-	1/32
Berghia coerulescens (Laurillard, 1832)	-	-	2/56	-	-	-	-	2/56
Calliostoma conulus (Linnaeus, 1758)	-	4/15	-	-	-	-	-	4/15

Calliostoma granulatum (Born, 1778)	-	-	11/174	-	19/159	1/4	14/74	45/411
Cerithium vulgatum Bruguière, 1792	-	-	54/379	20/185	8/50	11/34	18/82	111/730
Charonia lampas (Linnaeus, 1758)	-	1/75	-	-	-	1/8	-	2/83
Epitonium tenuicostatum (G. B. Sowerby, 1844) *	-	-	-	-	-	9/35	-	9/35
Euspira guilleminii (Payraudeau, 1826)	-	7/63	-	4/21	-	1/21,87	37/192	49/297,87
Euthria cornea (Linnaeus, 1758)	-	3/15	4/43	-	-	-	-	7/58
Fusinus rostratus (Olivi, 1792)	-	-	-	1/5	-	-	-	1/5
Galeodea echinophora (Linnaeus, 1758)	-	-	3/42	-	-	-	-	3/42
Gibbula albida (Gmelin, 1791)	-	-	-	10/68	-	-	-	10/68
Gibbula magus (Linnaeus, 1758)	-	-	-	-	-	1/4	-	1/4
Littorina obtusata (Linnaeus, 1758)	-	31/205	-	-	1/5	-	-	32/210
Marionia blainvillea (Risso, 1818)	-	-	-	-	-	1/9	-	1/9
Melarhaphe neritoides (Linnaeus, 1758)	-	12/54	-	-	-	-	-	12/54
Nassarius reticulatus (Linnaeus, 1758)	-	-	-	55/188	-	-	-	55/188
Nassarius sp.	-	15/35	-	-	9/130	-	-	24/165
Naticarius hebraeus (Martyn, 1786)*	-	-	-	31/146	20/156	10/26	3/30	64/358
Philine angulata Jeffreys, 1867*	-	-	-	22/91	-	-	-	22/91
Philine aperta (Linnaeus, 1767)	-	142/980	2027/6012	233/873	256/730	68/310	66/265	2792/9170
Phorcus turbinatus (Born, 1778)	-	-	31/165	-	-	15/6	-	46/171
Pneumoderma mediterraneum Van Beneden, 1838*	-	-	-	-	-	-	3/110	3/110
Rapana venosa (Valenciennes, 1846)	11/950	-	-	-	-	-	-	11/950
Raphitoma bicolor (Risso, 1826) *	-	-	-	3/8	-	-	-	3/8
Trophonopsis muricata (Montagu, 1803)	-	-	-	1/2	-	-	-	1/2
Turbella sp.	-	-	-	-	-	-	2/7	2/7
Turritella communis Risso, 1826	-	72/167	27/47	84/66	67/110	17/49	8/24	275/463
Scaphopoda								
Antalis dentalis (Linnaeus, 1758)	-	24/60	-	-	97/138	3/4	111/373	235/575
Antalis inaequicostata (Dautzenberg, 1891)	-	-	-	9/10	18/23	-	34/136	61/169
Antalis panorma (Chenu, 1843) *	-	33/15	-	62/177	-	-	-	95/192
Antalis vulgaris (da Costa, 1778)	-	-	-	14/12	12/18	-	-	26/30
Entalina tetragona (Brocchi, 1814)	-	-	-	6/5	-	-	-	6/5
Fustiaria rubescens (Deshayes, 1825)	-	-	-	-	-	-	12/31	12/31
Bivalvia								
Abra alba (W. Wood, 1802)	-	-	-	-	-	-	10/42	10/42
Acanthocardia aculeata (Linnaeus, 1758)	-	-	-	-	-	5/20	-	5/20
Acanthocardia echinata (Linnaeus, 1758)	-	-	-	2/5	-	-	-	2/5
Acanthocardia tuberculata (Linnaeus, 1758)	-	-	-	-	6/95	-	3/90	9/185
Aequipecten opercularis (Linnaeus, 1758)	-	-	-	1/16	-	-	3/15	4/31
Anadara gibbosa (Reeve, 1844)	-	-	98/1975	340/3166	21/547	6/11	132/960	597/6659
Cerastoderma edule (Linnaeus, 1758)	-	-	-	-	-	1/9	-	1/9
Chamelea gallina (Linnaeus, 1758)	-	-	-	-	1/10	11/61	23/115	35/186
Cuspidaria japonica Kuroda, 1948 *	-	-	-	-	-	5/2,2	63/189	68/191,2
Cuspidaria sp.	-	-	-	-	-	4/7	-	4/7

Cyclochlamys mestayerae (Dell, 1956) *	-	-	-	-	-	2/1	-	2/1
Donax trunculus Linnaeus, 1758	-	-	-	-	49/276	43/94,03	-	92/370,03
Dosinia lupinus (Linnaeus, 1758)	-	-	31/335	-	-	-	-	31/335
Ensis ensis (Linnaeus, 1758)	-	-	-	-	3/65	-	-	3/65
Flexopecten flexuosus (Poli, 1795)	-	-	-	2/21	-	3/32,96	5/73	10/126,96
Flexopecten glaber (Linnaeus, 1758)	-	-	-	-	7/155	-	5/40	12/195
Kellia suborbicularis (Montagu, 1803)	-	-	-	16/82	-	-	5/35	21/117
Limaria hians (Gmelin, 1791)	-	-	10/94	-	12/125	-	4/44	26/263
Loripes lucinalis (Lamarck, 1818)	-	-	-	-	8/15	-	11/39	19/54
Lucinoma borealis (Linnaeus, 1767)	-	-	-	-	13/25	-	-	13/25
Mactra sp.	-	-	-	-	-	-	5/22	5/22
Mimachlamys crassicostata (Sowerby II, 1842)*	-	-	-	-	-	-	5/33	5/33
Mimachlamys varia (Linnaeus, 1758)	-	-	-	-	-	1/2	2/14	3/16
Moerella distorta (Poli, 1791)	-	-	-	-	-	-	37/180	37/180
Moerella donacina (Linnaeus, 1758)	-	-	-	11/29	-	-	62/310	73/339
Mya arenaria Linnaeus, 1758	-	110/990	-	-	-	-	-	110/990
Mytilaster minimus (Poli, 1795)	-	-	-	-	-	-	23/160	23/160
Mytilus galloprovincialis Lamarck, 1819	-	-	-	27/200	5/110	60/484	-	92/794
Nucula dorsocrenata (Habe, 1977) *	-	-	-	-	-	23/120	-	23/120
Nucula nucleus (Linnaeus, 1758)	-	86/740	-	-	-	-	-	86/740
Nucula sulcata Bronn, 1831	-	-	-	-	38/298	-	-	38/298
Ostrea edulis Linnaeus, 1758	66/1230	-	-	-	-	163/13887,8	-	229/15117,8
Papillicardium papillosum (Poli, 1791)	-	-	-	-	1/19	-	-	1/19
Parvicardium exiguum (Gmelin, 1791)	-	-	-	7/50	-	1/143	-	8/193
Pecten jacobaeus (Linnaeus, 1758)	-	-	-	-	-	1/9	-	1/9
Pinna nobilis Linnaeus, 1758	-	2/185	-	-	-	-	1/35	3/220
Pitar rudis (Poli, 1795)	-	-	-	-	-	-	22/244	22/244
Polititapes aureus (Gmelin, 1791)	-	-	-	-	-	-	9/70	9/70
Pseudamussium clavatum (Poli, 1795)	-	-	-	-	-	-	1/20	1/20
Pteria hirundo (Linnaeus, 1758)	-	-	23/215	-	-	3/21,92	-	26/236,92
Rocellaria dubia (Pennant, 1777)	-	-	-	1/4	-	-	-	1/4
Solemya togata (Poli, 1791)	-	-	-	-	6/80	-	-	6/80
Solen marginatus Pulteney, 1799	-	-	-	-	1/25	-	1/25	2/50
Talochlamys multistriata (Poli, 1795)	-	-	-	-	-	-	7/85	7/85
Tellina serrata Brocchi, 1814	-	-	-	-	-	4/32	20/100	24/132
Tellina tenuis da Costa, 1778	-	-	-	-	1/10	-	-	1/10
Teredo navalis Linnaeus, 1758	-	-	-	-	-	-	6/30	6/30
Venus casina Linnaeus, 1758	-	-	-	-	-	1/4	-	1/4
Cephalopoda								
Loligo vulgaris Lamarck, 1798	-	-	-	1/55	-	1/110	-	2/165
Octopus vulgaris Cuvier, 1797	-	1/300	-	-	3/510	1/250	5/810	10/1870
Rossia macrosoma (Delle Chiaje, 1830)*	19/450	13/125	-	-	-	24/271	6/133	62/979
Sepia elegans Blainville, 1827	3/550	4/110	13/187	4/210	4/55	1/54	3/950	32/2116
Sepia officinalis Linnaeus, 1758	1/600	-	3/976	7/426	19/1450	8/442	-	38/3894
Sepia orbignyana Férussac, 1826	-	5/72	21/478	-	6/40	-	-	32/590
Sepietta oweniana (d'Orbigny, 1841)	22/480	10/120	-	-	-	-	-	32/600
Sepiola affinis Naef, 1912*	-	15/195	-	5/55	-	-	-	20/250

Sepiola rondeletii Leach, 1817	12/198	8/95	-	-	-	-	2/33	22/326
Todarodes sagittatus (Lamarck, 1798)	-	-	-	-	-	2/155	-	2/155
Polychaeta								
Amphictene auricoma (O.F. Müller, 1776)	-	-	-	1/2	-	-	-	1/2
Aphrodita aculeata Linnaeus, 1758	10/220	19/330	26/513	18/396	10/275	4/41	65/613	152/2388
Chaetopterus variopedatus (Renier, 1804)	4/18	1/5	19/175	-	14/285	-	-	38/483
Dasybranchus caducus (Grube, 1846)	-	5/17	-	9/21	-	37/204,11	11/75	62/317,11
Euclymene lombricoides (Quatrefages, 1866)	-	-	-	2/7	-	-	-	2/7
Eulalia viridis (Linnaeus, 1767)	-	-	-	1/3	-	-	-	1/3
Eunice aphroditois (Pallas, 1788) *	-	-	-	-	-	2/5	-	2/5
Glycera unicornis Savigny in Lamarck, 1818	-	-	21/276	-	-	2/6	3/19	26/301
Harmothoe extenuata (Grube, 1840)	-	-	-	-	-	2/9	26/210	28/219
Hesione pantherina Risso, 1826	-	-	71/329	-	-	1/2	-	72/331
Nephtys hombergii Savigny in Lamarck, 1818	-	-	-	-	1/6	-	-	1/6
Nephtys hystricis McIntosh, 1900*	-	-	-	-	-	-	2/22	2/22
Phyllochaetopterus socialis Claparède, 1869	-	-	100/58115	133/125	-	-	32/1878	265/60118
Protula tubularia (Montagu, 1803)*	-	9/40	-	4/19	-	1/14	-	14/73
Sabella spallanzanii (Gmelin, 1791)	-	-	-	-	-	3/4	-	3/4
Serpula vermicularis Linnaeus, 1767	-	-	-	-	-	3/7,08	-	3/7,08
Sternaspis scutata Ranzani, 1817	-	-	-	-	16/155	1/7	24/88	41/250
Oligochaeta								
Marionina subterranea (Knöllner, 1935) *	-	-	-	-	-	3/1	-	3/1
Hirudinea								
Pontobdella muricata (Linnaeus, 1758) ∆	-	16/110	3/43	2/18	5/35	3/11	-	29/217
Decapoda								
Aegaeon cataphractus (Olivi, 1792)	-	-	4/16	5/12	2/27	14/18	5/35	30/108
Calocaris macandreae Bell, 1853	-	-	7/29	32/61	-	-	3/28	42/118
Carcinus aestuarii Nardo, 1847	37/770	5/30	-	-	-	-	-	42/800
Clibanarius erythropus (Latreille, 1818)	-	18/30	-	-	5/24	-	-	23/54
Crangon crangon (Linnaeus, 1758)	-	-	20/190	-	-	-	-	20/190
Dardanus arrosor (Herbst, 1796)	6/220	-	-	-	6/20	-	-	12/240
Dardanus calidus (Risso, 1827)*	-	-	-	2/9	-	-	-	2/9
Diogenes pugilator (Roux, 1829)	14/97	-	1/11	-	5/22	-	3/28	23/158
Eriphia verrucosa (Forskål, 1775)	9/387	44/15	-	-	-	-	-	53/402
Ethusa mascarone (Herbst, 1785)	-	-	-	-	1/165	-	-	1/165
Galathea strigosa (Linnaeus, 1761)	-	-	-	-	-	-	4/39	4/39
Gennadas elegans (Smith, 1882)	-	-	-	-	22/185	-	-	22/185
Gnathophyllum elegans (Risso, 1816)	-	-	-	-	3/18	-	-	3/18
Goneplax rhomboides (Linnaeus, 1758)	-	-	12/860	-	1/55	11/155	-	24/1070
Homarus gammarus (Linnaeus, 1758)	-	-	1/2600	-	-	-	-	1/2600
Inachus dorsettensis (Pennant, 1777)	8/20	2/10	13/44	-	3/13	7/23	-	33/110

Inachus leptochirus Leach, 1817	-	-	-	6/18	-	1/2	9/37	16/57
Inachus thoracicus Roux, 1830	-	-	-	-	-	3/7	2/10	5/17
Jaxea nocturna Nardo, 1847	-	-	-	29/49	126/195	69/163	30/147	254/554
Liocarcinus corrugatus (Pennant, 1777)	-	-	2/10	-	-	-	-	2/10
Liocarcinus depurator (Linnaeus, 1758)	67/910	680/10494	51/898	536/6455	139/2273	572/3613	1259/15274	3304/39917
Macropodia longirostris (Fabricius, 1775)	-	14/30	-	1/6	-	7/25	7/19	29/80
Macropodia rostrata (Linnaeus, 1761)	-	19/55	-	-	-	-	-	19/55
Maja crispata Risso, 1827	4/105	5/300	-	-	1/40	-	-	10/445
Medorippe lanata (Linnaeus, 1767)	-	-	-	-	1/30	-	2/55	3/85
Monodaeus couchii (Couch, 1851)	-	-	-	-	-	3/19	-	3/19
Monodaeus guinotae Forest, 1976	-	-	11/143	-	-	6/38	-	17/181
Paguristes eremita (Linnaeus, 1767)	7/40	33/70	-	-	8/95	-	7/33	55/238
Pagurus cuanensis Thompson, 1844	-	-	17/50	-	-	2/5	18/126	37/181
Pagurus forbesii Bell, 1846	-	-	4/62	-	-	-	-	4/62
Pagurus prideaux Leach, 1815	-	-	8/81	-	-	-	-	8/81
Palaemon adspersus Rathke, 1837	-	-	15/43	5/22	4/25	3/10	7/43	34/143
Palaemon elegans Rathke, 1837	-	28/90	-	-	-	-	-	28/90
Palaemon serratus (Pennant, 1777)	7/5	59/180	26/122	-	21/102	4/10	-	117/419
Palaemon xiphias Risso, 1816	-	5/22	-	7/33	-	-	-	12/55
Pandalina brevirostris (Rathke, 1843)	-	6/20	3/20	1/4	5/41	-	-	15/85
Parapenaeus longirostris (Lucas, 1846)	36/360	2155/20130	1665/15701	469/2962	1489/12506	1022/14612	312/3047	7148/69318
Parasergestes vigilax (Stimpson, 1860)*	-	-	-	-	-	-	2/5	2/5
Pasiphaea sivado (Risso, 1816)	-	-	16/99	-	-	25/155	-	41/254
Periclimenes scriptus (Risso, 1822)	-	-	-	-	4/11	-	-	4/11
Pestarella tyrrhena (Petagna, 1792)	-	-	-	-	-	-	4/19	4/19
Pilumnus hirtellus (Linnaeus, 1761)	5/10	-	9/55	14/118	14/129	10/51	11/75	63/438
Pisa nodipes (Leach, 1815)	-	-	-	-	-	1/6	-	1/6
Pisidia longicornis (Linnaeus, 1767)	2/20	5/5	-	-	1/11	-	-	8/36
Plesionika martia (A. Milne-Edwards, 1883)*	-	-	41/335	-	-	2/22	-	43/357
Porcellana platycheles (Pennant, 1777)	3/40	-	-	-	-	-	-	3/40
Solenocera membranacea (Risso, 1816)	-	-	23/192	10/76	-	11/70	26/230	70/568
Stereomastis artuzi Artüz Kubanç & Kubanç, 2014	-	-	-	-	-	4/44	-	4/44
Stereomastis nana (Smith, 1884) *	-	-	-	-	-	1/18	-	1/18
Typton spongicola O.G. Costa, 1844	-	-	-	-	1/5	-	1/4	2/9
Upogebia pusilla (Petagna, 1792)	-	24/56	15/55	-	20/130	2/9	-	61/250
Xantho hydrophilus (Herbst, 1790)	-	-	-	-	6/400	-	-	6/400
Xantho poressa (Olivi, 1792)	-	-	3/22	-	-	-	-	3/22
Isopoda								
Nerocila bivittata (Risso, 1816)#	-	14/35	-	5/35	1/8	-	-	20/78
Rocinela dumerilii (Lucas, 1849)*	-	-	-	-	-	-	1/4	1/4
Echinodermata								
Amphipholis squamata (Delle Chiaje, 1828)	-	-	5/21	33/51	-	-	-	38/72
Amphiura chiajei Forbes, 1843	-	-	-	-	19/32	-	-	19/32

Amphiura filiformis (O.F. Müller, 1776)	-	-	5/27	44/40	97/217	-	-	146/284
Anseropoda placenta (Pennant, 1777)	-	2/24	10/121	84/457	28/135	8/90	38/590	170/1417
Antedon bifida (Pennant, 1777)*	-	-	-	2/9	-	11/18	-	13/27
Antedon mediterranea (Lamarck, 1816)	14/35	21/75	11/49	24/85,5	67/200	33/96	90/371	260/911,5
Asterias amurensis Lutken, 1871	63/1530	102/1700	-	1/38	-	-	-	166/3268
Astropecten bispinosus (Otto, 1823)	-	-	20/255	70/422	-	73/160	14/80	177/917
Astropecten irregularis (Pennant, 1777)	-	-	18/101	18/43	6/157	7/65	-	49/366
Astropecten spinulosus (Philippi, 1837)	5/610	135/1025	63/580	58/298	364/3075	47/60	139/1440	811/7088
Brissus unicolor (Leske, 1778)	-	19/340	-	-	-	-	-	19/340
Echinaster (Echinaster) sepositus (Retzius, 1783)	-	-	10/67	21/93	51/745	8/85	26/295	116/1285
Echinus melo Lamarck, 1816	7/180	-	-	-	-	-	5/95	12/275
Genocidaris maculata A. Agassiz, 1869	-	-	-	7/740	-	-	-	7/740
Holothuria (Holothuria) tubulosa Gmelin, 1791	-	-	-	-	11/950	-	-	11/950
Holothuria (Panningothuria) forskali Delle Chiaje, 1823*	-	10/225	-	-	-	-	9/44	19/269
Holothuria (Rowethuria) poli Delle Chiaje, 1824*	-	-	-	-	6/850	-	-	6/850
Labidoplax buskii (McIntosh, 1866)*	-	-	-	-	-	-	4/65	4/65
Leptometra phalangium (Müller, 1841)	-	-	-	-	-	2/9	-	2/9
Leptopentacta elongata (Düben & Koren, 1846)	-	4/20	13/80	27/152	8/55	-	7/39	59/346
Leptopentacta tergestina (M. Sars, 1857)	-	34/165	3/24	-	18/108	9/74	26/179	90/550
Marthasterias glacialis (Linnaeus, 1758)	20/345	131/2940	114/2882	84/1305	232/2860	76/1608	673/7495	1330/19435
Molpadia musculus Risso, 1826*	-	-	-	-	5/135	-	-	5/135
Ocnus planci (Brandt, 1835)	-	80/544	11/140	1/21	6/55	3/46	16/195	117/1001
Ocnus syracusanus (Grube, 1840) Panning, 1949*	-	31/250	-	-	18/115	1/11	90/685	140/1061
Ophiacantha setosa (Bruzelius, 1805)	-	-	15/64	-	-	2/5	-	17/69
Ophioderma longicauda (Bruzelius, 1805)	16/22	28/70	-	24/185	8/14	-	29/39	105/330
Ophiomyxa pentagona (Lamarck, 1816)	-	-	14/68	-	51/65	9/6	-	74/139
Ophiopsila aranea Forbes, 1843	11/18	-	-	-	-	9/1	18/21	38/40
Ophiothrix fragilis (Abildgaard, in O.F. Müller, 1789)	-	-	-	11/16	29/36	13/13	-	53/65
Ophiothrix quinquemaculata (Delle Chiaje, 1828)	-	-	-	1/0	34/49	18/25	-	53/74
Ophiura ophiura (Linnaeus, 1758)	-	142/564	261/806	112/119	35/79	7/23	58/80	615/1671
Paracentrotus lividus (Lamarck, 1816)	5/270	15/210	-	-	-	-	5/42	25/522
Parastichopus regalis (Cuvier, 1817)	15/975	80/4180	57/5810	14/4020	119/15650	-	82/7935	367/38570
Peltaster placenta (Müller & Troschel, 1842)	-	-	-	1/21	-	-	-	1/21
Phyllophorus (Phyllophorus) urna Grube, 1840	-	-	-	5/44	3/85	1/8	6/59	15/196
Psammechinus microtuberculatus (Blainville, 1825)	-	-	25/613	2/12	-	-	130/1560	157/2185
Spatangus purpureus O.F. Müller, 1776	121/2420	458/7320	4037/194272	138701/8300689	286513/4801900	31965/1598850	858438/6004077	1320233/20909528
Thyone fusus (O.F. Müller, 1776)	-	-	-	-	-	13/100	18/231	31/331

Ascidiacea								
Aplidium proliferum (Milne Edwards, 1841)*	-	-	3/39	5/15	-	-	-	8/54
Aplidium turbinatum (Savigny, 1816)	-	-	11/369	-	-	-	-	11/369
Ascidia conchilega Muller, 1776*	-	-	-	2/14	-	-	-	2/14
Ascidia mentula Müller, 1776	-	-	-	33/321	-	1/8	12/1200	46/1529
Ascidia virginea Müller, 1776	-	144/1914	78/3057	36/377	135/1675	276/1642,4	402/5885	1071/14550,4
Ascidiella aspersa (Müller, 1776)	-	-	-	5/43	-	-	-	5/43
Ciona intestinalis (Linnaeus, 1767)	-	-	71/1100	-	38/410	-	34/161	143/1671
Clavelina lepadiformis (Müller, 1776)*	-	-	-	23/34	56/65	9/99	7/84	95/282
Corella parallelogramma (Müller, 1776)	-	15/45	36/360	-	27/98	3/55	-	81/558
Microcosmus claudicans (Savigny, 1816)*	-	-	3/27	-	-	-	-	3/27
Microcosmus vulgaris Heller, 1877	-	-	-	-	-	7/236	-	7/236
Molgula appendiculata Heller, 1877	-	-	4/115	-	-	-	-	4/115
Polycarpa pomaria (Savigny, 1816)	-	9/170	-	-	-	-	-	9/170
Pycnoclavella nana (Lahille, 1890)	-	-	48/649	-	-	-	-	48/649
Rhodosoma turcicum (Savigny, 1816) *	-	-	-	-	-	-	19/100	19/100
Rhopalaea neapolitana Philippi, 1843	-	-	8/97	2/19	19/120	-	-	29/236
Styela canopus (Savigny, 1816)	-	-	7/63	-	9/65	-	-	16/128
Chondrichthyes								
Acipenser gueldenstaedtii Brandt	1/1322	-	-	-	-	-	-	1/1322
Galeus melastomus Rafinesque, 1810	-	-	-	-	-	-	1/1085	1/1085
Oxynotus centrina (Linnaeus, 1758)	-	-	-	-	-	-	1/2600	1/2600
Raja asterias Delaroche, 1809	5/340	1/160	-	1/240	-	4/430	-	11/1170
Raja brachyura Lafont, 1871	-	-	-	1/100	-	-	-	1/100
Raja clavata Linnaeus, 1758	5/950	37/34531	13/10760	3/3490	8/18740	4/1976	3/6720	73/77167
Raja miraletus Linnaeus, 1758	-	-	-	-	1/80	-	1/100	2/180
Raja radula Delaroche, 1809	-	-	1/700	-	-	-	-	1/700
Scyliorhinus canicula (Linnaeus, 1758)	-	1/80	1/100	2/380	4/535	5/1450	5/3900	18/6445
Torpedo marmorata Risso, 1810	-	-	1/200	-	-	-	-	1/200
Torpedo torpedo (Linnaeus, 1758)	3/210	-	-	1/40	-	-	-	4/250
Osteichthyes								
Arnoglossus laterna (Walbaum, 1792)	-	-	-	3/109,9	-	-	11/159,5	14/269,4
Blennius ocellaris Linnaeus, 1758	-	14/130	11/470	2/31	8/100	1/40	7/0	43/771
Buglossidium luteum (Risso, 1810)	-	3/20	1/190	-	3/15	-	-	7/225
Callionymus lyra Linnaeus, 1758	7/90	55/805	10/150	43/420	7/82	3/80	9/303	134/1930
Carapus acus (Brünnich, 1768)	-	-	2/65	-	6/120	-	7/205	15/390
Centracanthus cirrus Rafinesque, 1810	-	-	-	-	-	-	1/41	1/41
Chelidonichthys cuculus (Linnaeus, 1758)	-	-	-	16/280	12/180	-	11/505	39/965
Chelidonichthys lucerna (Linnaeus, 1758)	-	9/1130	-	48/1430	34/2480	50/1800	14/1285	155/8125
Citharus linguatula (Linnaeus, 1758)	-	-	15/400	77/948	99/1355	61/740	44/14811	296/18254
Coelorinchus caelorhincus (Risso, 1810)	-	-	24/1100	18/270	33/690	41/630	34/9670	150/12360
Eutrigla gurnardus (Linnaeus, 1758)	13/110	-	-	4/42,5	-	-	2/320	19/472,5
Gaidropsarus mediterraneus (Linnaeus, 1758)	-	6/95	1/40	-	-	-	-	7/135
Gobius cruentatus Gmelin, 1789	-	42/380	117/1130	170/1885	-	-	6/110	357/3613
Gobius niger Linnaeus, 1758	32/620	72/905	4/100	8/135	6/75	23/300	8/45	165/2405,5
Gymnammodytes cicerelus (Rafinesque, 1810)	-	3/20	-	-	-	-	-	3/20

Hippocampus guttulatus Cuvier, 1829	-	-	-	-	-	-	8/43	8/43
Hippocampus hippocampus (Linnaeus, 1758)	-	9/30	-	2/7	1/4	-	-	12/41
Iniistius pavo (Valenciennes, 1840)	-	10/340	-	-	-	-	-	10/340
Lepidotrigla cavillone (Lacepède, 1801)	-	-	3/210	-	-	-	-	3/210
Lesueurigobius friesii (Malm, 1874)	-	-	-	10/10	-	-	-	10/10
Lesueurigobius suerii (Risso, 1810)	-	-	-	-	5/17	-	-	5/17
Merlangius merlangus (Linnaeus, 1758)	22/300	120/1337	73/5975	447/8965	3/70	14/185,04	4/435	683/17267,04
Merluccius merluccius (Linnaeus, 1758)	62/1850	118/4330	48/1468	149/7070	40/4460	83/5000	41/2400	541/26578
Microchirus variegatus (Donovan, 1808)	-	18/564	-	-	-	-	-	18/564
Microlipophrys dalmatinus (Steindachner	-	18/75	-	-	-	-	-	18/75
Molva macrophthalma (Rafinesque, 1810)	-	-	-	1/60	8/54	-	2/35	11/149
Monochirus hispidus Rafinesque, 1814	-	4/30	-	-	-	-	-	4/30
Mullus barbatus barbatus Linnaeus, 1758	-	-	-	5/140	-	-	10/303	15/443
Mullus surmuletus Linnaeus, 1758	10/90	93/1490	45/598	21/840	44/1770	8/180	92/1845	313/6813
Ophidion barbatum Linnaeus, 1758	-	-	-	2/10	-	-	-	2/10
Parablennius gattorugine (Linnaeus, 1758)	-	-	1/40	-	-	-	-	1/40
Pegusa lascaris (Risso, 1810)	-	-	-	-	1/30	-	2/300	3/330
Platichthys flesus (Linnaeus, 1758)	1/350	6/240	-	1/510	-	-	-	8/1100
Pomatoschistus marmoratus (Risso, 1810)	-	-	-	-	202/1205	105/435	38/335	345/1975
Sciaena umbra Linnaeus, 1758	3/80	-	-	-	-	-	-	3/80
Scorpaena notata Rafinesque, 1810	1/130	-	-	-	-	-	-	1/130
Scorpaena porcus Linnaeus, 1758	-	-	-	-	-	1/80	-	1/80
Scorpaena scrofa Linnaeus, 1758	-	-	-	1/280	-	-	2/155	3/435
Serranus hepatus (Linnaeus, 1758)	9/100	231/2240	193/2150	241/2961	229/2997	305/4416	335/3253	1543/18117
Solea solea (Linnaeus, 1758)	1/80	31/1620	-	8/200	2/100	8/1335,48	4/315	54/3650,48
Spicara smaris (Linnaeus, 1758)	152/2800	268/5580	67/820	67/1920	52/870	59/1465	51/1189	716/14644
Symphodus cinereus (Bonnaterre, 1788)	-	-	-	-	1/15	-	-	1/15
Symphodus ocellatus (Linnaeus, 1758)	-	10/105	-	-	-	-	1/20	11/125
Symphodus rostratus (Bloch, 1791)	-	-	-	2/110	-	-	-	2/110
Syngnathus phlegon Risso, 1827	-	-	-	-	-	-	1/14,7	1/14,7
Syngnathus taenionotus Canestrini, 1871	-	12/55	-	-	1/5	-	1/10	14/70
Thorogobius macrolepis (Kolombatovic, 1891)	-	8/60	-	-	-	-	-	8/60
Trachinus draco Linnaeus, 1758	-	-	4/200	1/60	2/130	1/50	-	8/440
Trachurus mediterraneus (Steindachner, 1868)	-	-	-	-	-	8/98,76	-	8/98,76
Trachurus trachurus (Linnaeus, 1758)	-	33/200	24/200	2/40	26/510	15/285	219/1498	319/2733
Trigla lyra Linnaeus, 1758	18/370	28/860	8/550	19/335	38/556	18/602,5	5/80	134/3353,5
Trigloporus lastoviza (Bonnaterre, 1788)	-	-	3/210	-	-	-	2/150	5/360
Uranoscopus scaber Linnaeus, 1758	-	-	3/210	-	1/200	2/90	-	6/500
Zebrus zebrus (Risso, 1827)	-	12/60	-	-	-	-	-	12/60
Zeus faber Linnaeus, 1758	-	1/80	-	-	-	-	-	1/80

*New record for Sea of Marmara; ΔFound on host *Raja clavata*; #Found on host *Spicara smaris*.

Table 4: Station richness and indices in the annual basis.

	Station richness		Index values			
Year	S	Nº	D_{Mg}	D_{Mn}	H'	J'
2006	55	1065	7,75	1,69	3,31	0,83
2007	105	7640	11,63	1,20	3,24	0,70
2008	111	10341	11,90	1,09	2,33	0,49
2009	147	5117	17,10	2,05	3,72	0,74
2010	144	292089	11,36	0,27	0,16	0,03
2011	151	35981	14,30	0,80	0,71	0,14
2012	142	864026	10,32	0,15	0,06	0,01

*(S=Number of Species; *Nº*=Number of Individuals; D_{Mg}=Margalef richness index; D_{Mn}=Menhinick diversity index; *H'*=Shannon-Weiner diversity index; *J'*= Pielou's evenness index).

Table 5: Pairwise comparison results from MANCOVA. The related data and calculations are given as supplementary file (Supplementary File: 3; 4; 5)

Dependent Variable	Mean Difference (East-West)	Sig.[b]
Species	-8,077	0,079
Individuals	65450,014*	0,031
DO	-,997*	0,006

*The mean difference is significant at the, 05 level.
[b]Adjustment for multiple comparisons: Bonferroni.

adjacent populated areas. Significant amounts of industrial wastewater and municipal wastewater are still discharged following primary treatment, which is comprised of screening and grit removal. Critical areas in need of stronger pollution control measures include the vicinity of Istanbul, İzmit Bay, and Gemlik Bay due to heavy domestic and industrial pollution loads. A major pollution source is the release of wastewaters with limited or no treatment via "deep sea discharges", which is based on the principal to use the below water mass, that flows from the Aegean Sea to the Black Sea, as a conveyor.

If significant stress in the living world occurs by moving away from the normal ambient environmental conditions, this can be described as a valid rule and can be named as "Pessimum conditions rule". According to this rule, depending on the degree of divergence from normal conditions, numbers of living species that share the same ecosystem are reduced due to stress. However, the adapted species groups, which can resist the stress opportunistically, multiply their own number of individuals. With the disappearance of regressive species in the ecosystem, species with wider borders against limiting ecological factors begin to proliferate relatively; these can be the organisms that share the same environment with the lost species previously or any new species in the ecosystem.

In the present study, pessimum conditions rule has been especially distinctive in the Sea of Marmara regarding the echinoderm community structure. As long-term data were studied, the increasing abundance of *S. purpureus* species was an indicator of this situation.

Meantime regarding the most common community position of echinoderms in present work, it seems occurred a variable composition in the Sea of Marmara. Öztoprak, et al. [28] are denoted the echinoderms *Hymenodiscus coronata*, *Amphiura chiajei*, *Ophiura ophiura*, *Brissopsis lyrifera*, *Cidaris cidaris*, *Psammechinus microtuberculatus*, *Ocnus koellikeri*, and *Oestergrenia digitata* as the species that inhabited the deepest parts of the areas (>600 m) in the Turkish coasts. Likewise, regarding reports of Hydrobiological Research Institute on 1968 [44] *Echinocyamus pusillus* and *Stylocidaris affinis* are reported from the Sea of Marmara.

However, during the present work, living specimens aside from *A. chiajei*, *O. ophiura* and *P. microtuberculatus* are not observed in the Sea of Marmara. Nevertheless, regarding Artüz, et al. [29] in the sediment samples, in the sediment core material, a dense occurrence of the spins of family Cidaridae are reported.

The reason of this exchange of the echinoderm community composition can be depends possibly to the actual DO level (mean 0,98 mg/l) of the depths of >600 m in the Sea of Marmara, due to the minimum survive limit range related the dissolved oxygen concentrations of *B. lyrifera* and *C. cidaris* that 2,17 mg/l and 2,27 mg/l [45] respectively.

Especially, the growing trend of the echinoderm communities showed us the typical reflection of "Pessimum conditions rule" compared with environmental oceanographical parameters such as decreasing DO and fluctuating pH levels, which is indicative of pollution.

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Highlights

- Biodiversity studies were conducted in the Sea of Marmara.
- The relationship between species diversity and number of individuals was examined.
- The data based on the long-term field measurements were evaluated.
- The case, which appears to be the result of measurements, is defined as a hypothesis.

The hypothesis "Pessimum conditions rule" was proposed.

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