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Benthic communities of the inner Argolikos Bay

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ABSTRACT. Benthic assemblages of the inner Argolikos Bay were investigated as an indication of the quality of the marine environment of the area. Samples were taken with a Ponar grab at 5 and 10 m. The assemblages found corresponded to two communities of the infralittoral (SVMC and SFBC) and one of the circalittoral (VTC). Communities of the two zones were clearly separated. The variety of substrata offered by the presence of plants is the most probable cause for the higher diversity found in the shallower stations. Although diversity is relatively high, the abundance of *Capitella capitata* and *Levinsenia gracilis* indicates that the shallow stations are moderately disturbed, probably due to organic loading.

KEY WORDS: Greece, benthic assemblages, sewage effluent, organic loading.

INTRODUCTION

Argolikos is an open and relatively shallow bay in the southeastern Peloponnese (Fig. 1). It receives the discharges of Argolikos basin, an area of intensive industrial and agricultural activities, as well as sewage from various towns along its shores. The discharge of mainly untreated effluent in the inner bay, in combination with its shallow depth, may have a significant effect on the quality of the marine environment, with severe ecological and financial consequences. The aim of the present study is to investigate the benthic assemblages of the inner Argolikos Bay, as an indication of the quality of the marine environment.

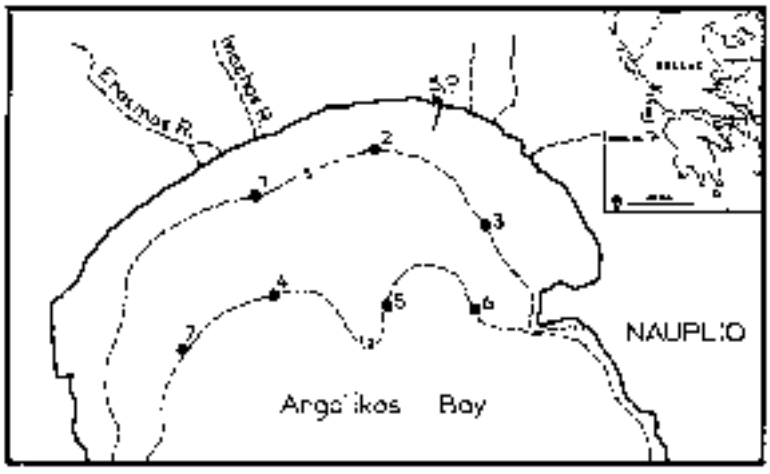

Fig. 1. – Argolikos Bay and the sampling stations

MATERIAL AND METHODS

To study the benthic community of Argolikos Bay, sampling took place in September 1998, a year after the operation of the sewage treatment plant of four main cities of the Argolikos basin, Argos, Nauplio, Nea Kios and Medeia. Three stations were chosen at 5 m (station 1 near the mouth of rivers Inachos and Erasinos, station 2 near the sewage pipe and station 3 on the course of the effluent according to the prevailing currents) and four at 10 m (stations 4, 5, 6 and 7). Three replicate samples were taken at each station using a Ponar grab, which collects 0.05 m^2 of substrate. Each sample was sieved through a 1 mm sieve, fixed in 4% formalin and dyed with Rose Bengal. To assess plant coverage, plants were removed from the samples, washed and then dried to a constant weight at 60° C.

For the mathematical analysis of the samples the Shannon-Wiener Diversity Index (SHANNON & WEAVER, 1968) and the Evenness Index (PIELOU, 1969) were calcu-

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lated. Clustering was calculated with the Bray-Curtis Similarity Index, after a log(x+1) transformation of the data. Classification was performed with the "group average" method and ordination with non-metric Multi-Dimensional Scaling (MDS). To assess differences in ecological parameters (N, S, H' and J) between stations at 5 m and 10 m, a one-way Analysis of Variance (ANOVA) was run between the values of the parameters of stations 1, 2 and 3 at 5 m and 4, 6, and 7 at 10 m. Values of N and S were log transformed to normality [log(x+1)].

RESULTS

The sediment in all sampling stations was mainly muddy. At 10 m (stations 4, 5, 6, 7) shell debris was found deeper within the sediment, while at 5 m (stations 1, 2, 3) there was a distinctive presence of the green algae *Caulerpa prolifera*. Plant biomass was higher at station 2, while at station 3 apart from whole plants there was also a high concentration of plant debris – mainly from *Caulerpa* and possibly from *Posidonia oceanica* – that reached more than 26 gr/0.05 m^2 in sample 3a.

A total of 3062 animals were counted, belonging to 151 species. Polychaetes were the dominant phylum (57 % of all taxa), while 16 % were mollusks, 14 % crustaceans, 3% echinoderms and 10% of all taxa belonged to minor phyla. Total abundance (N) and number of species (S) for each station are shown in Fig. 2, while Diversity (H') and Evenness (J) indices for each station are shown in Fig. 3. Station 3 had the highest number of species and individuals and the highest Diversity Index. High diversity was also found at station 5, which should be attributed not so much to its high species number as to its high Evenness. The lowest number of species was observed at station 6, which also had the lowest Diversity (Figs 2-3).

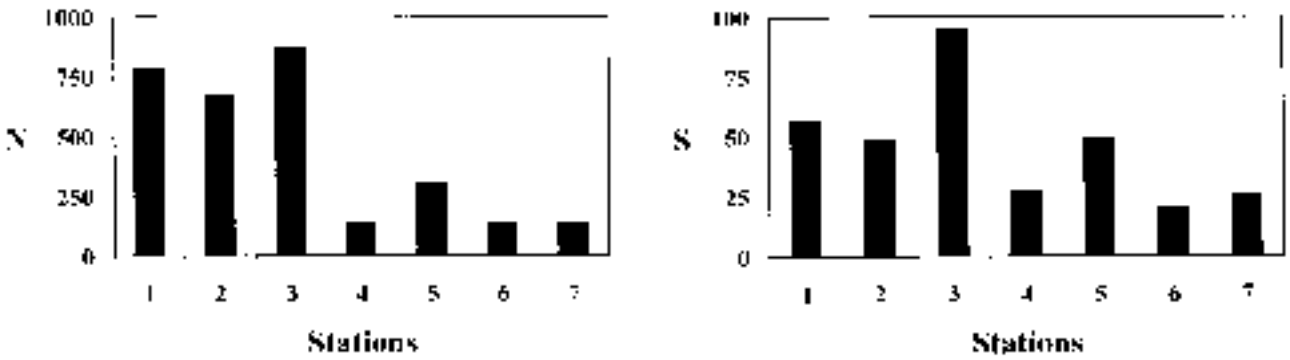

Fig. 2. – Total abundance (N) and total number of species (S) for each sampling station

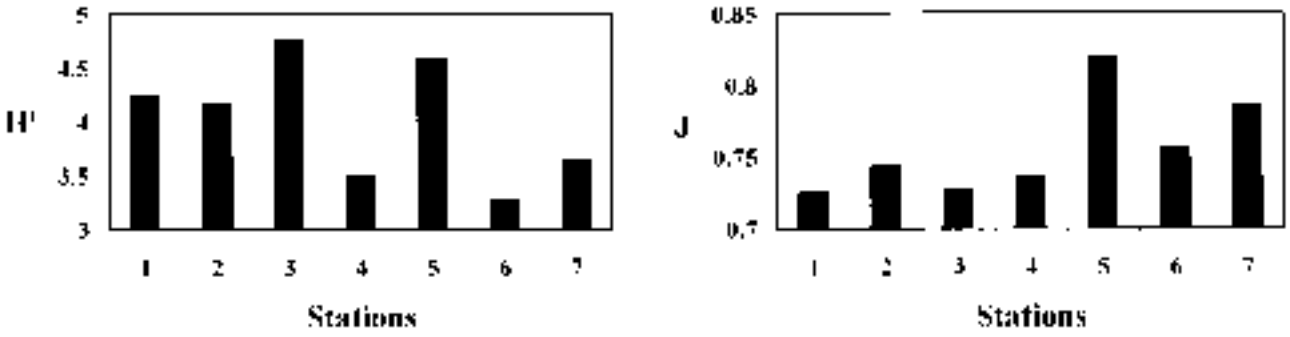

Fig. 3. – Diversity (H') and Evenness (J) Indices for each sampling station

Many of the species identified characterise Mediterranean benthic communities, as these were described by Peres (1967). In the Infralittoral, the bivalve *Loripes lacteus* and the polychaete *Paradoneis lyra*, abundant in stations 1, 2 and 3, are characteristic of the Biocoenosis of Muddy Sand in Sheltered Areas (SVMC). The bivalves *Tellina pulchella* and *T. fabula* and the polychaete *Prionospio malmgreni*, found in relative abundance in stations 1, 2, 3 and 5, are characteristic of the Biocoenosis of Fine, Well Sorted Sand (SFBC). In stations 4, 6 and 7 we observed the polychaetes *Nephthys hystricis* and *Sternaspis scutata*, the bivalve *Abra nitida* and the crab *Goneplax rhomboides*, which are characteristic of the Biocoenosis of Terrigenous Mud (VTC) of the Circalittoral Zone.

The polychaete *Capitella capitata*, which indicates organic enrichment and/or environmental disturbance (Peres, 1967; Pearson & Rosenberg, 1978), was abundant in stations 1, 2, 3 and 5. Its highest number (108 per 0.15 m^2) was observed in station 2 and its lowest (30 per 0.15 m^2) in station 5. The ascidian *Clavellina lepadiformis*, a species of hard substrata, which also appears in eutrophic areas (Tursi, 1980), was also found in stations 1 to 3. Further, the polychaete *Levinsenia gracilis*, which is also

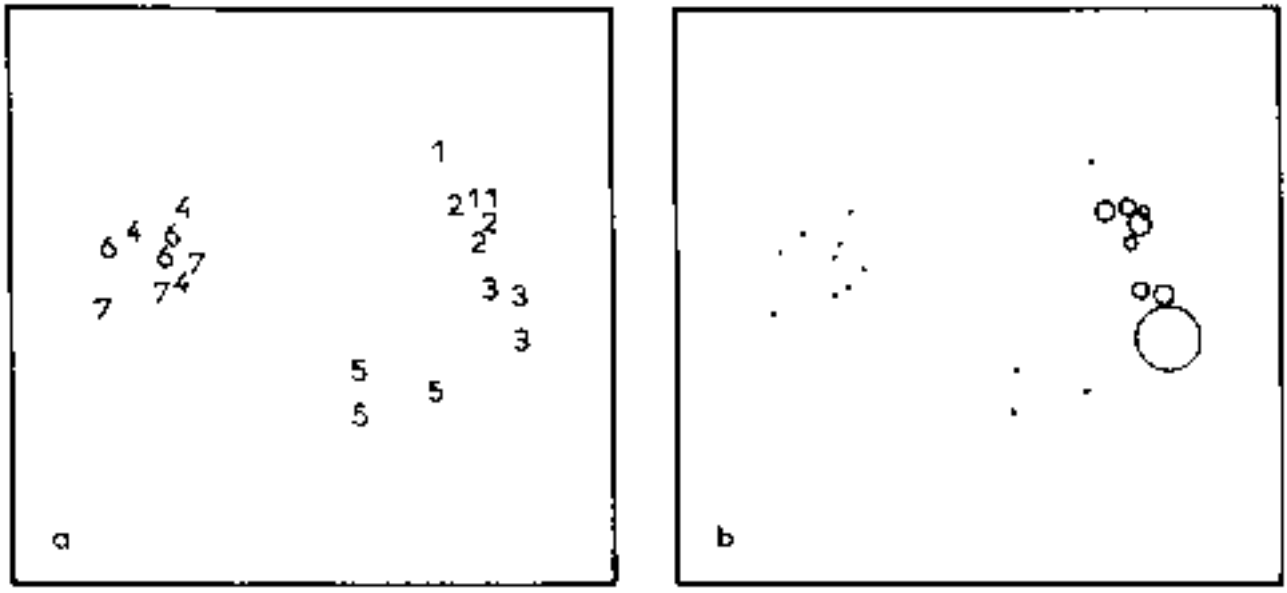

Fig. 4. – a.Ordination of samples with Multi-Dimensional Scaling (MDS). b. Schematic representation of dried plant biomass superimposed on the MDS results.

considered resistant to most pollutants (Chang *et al*., 1992), was found in relative abundance in stations 2 and 3.

Ordination of the samples (Fig. 4a) showed two groups according to depth: one with stations 4, 6 and 7 (10 m depth) and one with stations 1 to 3 (5 m depth). The three samples of station 5 were placed in between but closer to the 5 m stations although taken at 10 m. The dried plant biomass superimposed on the MDS results (Fig. 4b), shows that the presence of plants is most probably the factor separating stations 1 to 3 from the rest.

Comparing the ecological parameters between stations 1, 2, 3 (5 m) and 4, 6, 7 (10 m) showed significant differences in all but Evenness (Table 1). Thus, the number of species (S), abundance (N) and Diversity Index (H') were significantly higher for stations taken at 5 m (1-3), while Evenness Index was marginally lower for stations taken at 10 m (4, 6, 7).

TABLE 1

One-way ANOVA results between stations of 5 and 10 m for the parameters S, N, H' and J

	R_a^2	F	df	p	5 m mean ± s.d.	10 m mean ± s.d.
S	0.971	34.10	1, 16	0.000	35.444 ± 13.380	13.667 ± 2.828
N	0.978	44.61	1, 16	0.000	211.33 ± 101.59	46.00 ± 14.12
H'	0.943	16.45	1, 16	0.001	3.877 ± 0.516	3.097 ± 0.259
J	0.834	5.03	1, 16	0.039	0.768 ± 0.062	0.829 ± 0.053

DISCUSSION

Results of the present study show that the benthic fauna of inner Argolikos Bay does not correspond to only one of the communities described by PERES (1967) for the Mediterranean. In stations 1 to 3 there are species that characterise two communities of the Infralittoral Zone, that of Muddy Sand in Sheltered Areas (SVMC) and that of Fine, Well Sorted Sand (SFBC). In this area we also find species characteristic of disturbance and/or eutrophication. In stations 4, 6 and 7 we find characteristic species of the Biocoenosis of Terrigenous Mud (VTC) of the Circalittoral Zone. Both classification and ordination, as well as the ecological parameters N, S, H' and J show that there are two distinctly separate benthic assemblages, one at 5 m and one at 10 m.

It is interesting to note that station 5, although it was taken at 10 m, is placed –in both clustering and the MDS- closer to the group of stations taken at 5 m, i.e. stations 1, 2 and 3. Further, the presence of species *Tellina fabula*, *T. pulchella* and *Prionospio malmgreni*, which are characteristic of the Biocoenosis of Fine, Well Sorted Sand (PERES, 1967) in relative abundance in station 5, also places it at the Infralittoral Zone. It is thus possible that station 5 represents an intermediate situation between the more sheltered inner stations 1, 2 and 3 at 5 m, and the more exposed outer stations 4, 6 and 7 at 10 m.

An examination of the values of N, S and H' per sample shows that they are significantly higher for samples taken at 5 m, while Evenness J is slightly higher for samples at 10 m. The presence of *Caulerpa prolifera* and of a significant amount of dried plant biomass at 5 m appears to be responsible for the increased number of species and animals and the high Diversity. It is possible that the rhizomes of *Caulerpa* act as hard substrate for many organisms, as is proved by the presence of species like the ascidian *Clavellina lepadiformis* and various polychaetes of the

family Syllidae that are characteristic of hard substrata (Tursi, 1980 and Simboura et al., 1995, respectively). This variety of available substrata results in an increase of microniches, and thus of Diversity at the shallower stations, while the homogeneity of the substrate at 10 m could be responsible for the lower Diversity and higher Evenness found at the deeper stations (Gray, 1974). Therefore, station 3, which had the highest amount of dried plant biomass (app. 40 gr.), showed the highest number of species and individuals, the highest Diversity and the lowest Evenness.

Although diversity is high, the abundance of polychaete species *Capitella capitata* and *Levinsenia gracilis* indicate that the shallow stations 1, 2 and, in a lesser degree, 3 show some signs of environmental disturbance. On the contrary, no such signs are obvious in any of the deeper stations (4-7). This disturbance is most probably due to organic loading from the two small rivers Inachos and Erasinos (station 1) and a sewage pipe outlet (station 2), in addition to the presence of an important amount of plants and plant debris (station 3). The Diversity values of these stations (H' = 3.4-4.4) vary within the limits of other Greek areas with moderate disturbance. For example, in Atalanti Bay (Central Greece) diversity ranged from 2.8 to 4.5 (Bei et al., 1990), while in Geras Bay (Mytilini, E. Aegean) the values were 4.4 to 5.3 (Zenetos & Papathanassiou, 1989). On the contrary, diversity of the highly polluted area near the mouth of the sewage pipe of Athens at Saronikos Bay (30 m), was 0.93 (Nicolaidou et al., 1993).

	Stations						
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Porifera							
Craniella cranium (Muller)	0	0	1	0	0	0	0
Polychaeta							
Amphiglena mediterranea Leidig, 1851	0	0	2	0	0	0	0
Amphinomidae sp.	0	1	0	0	0	0	0
Aonides oxycephala (Sars, 1862)	15	30	41	0	0	0	0
Aphroditidae sp.	0	0	0	0	1	0	0
*Aphylochaeta marioni (*Saint-Joseph, 1894)	4	15	13	1	1	0	1
Arabella iricolor (Montagu, 1804)	0	0	1	0	0	0	0
Aricidea capensis Day, 1965	1	0	2	0	0	0	0
Aricidea fauveli Hartman, 1957	13	7	9	4	9	4	7
Axiothella constricta (Claparede 1868)	0	0	0	0	10	0	0
Capitella capitata (Fabricius, 1780)	78	55	94	0	30	0	2
Capitomastus minimus (Langerhans, 1880)	181	119	0	6	0	0	2
Cauleriella bioculatus (Keferstein, 1862)	0	1	0	0	0	0	0
Chaetopterus variopedatus (Renier, 1804)	0	0	0	1	0	0	0
Chaetozone cf setosa (Malmgren, 1867)	3	1	0	0	2	0	0
Chone collaris Langerhans, 1880	0	2	0	0	0	0	0
Cirratulus filiformis Keferstein, 1862	1	0	8	0	5	0	0
Clymenura clypeata (Saint-Joseph 1894)	5	8	0	2	4	0	0
Cossura coasta (Kitamori, 1960)	0	0	0	3	2	8	8
Ctenodrilus serratus (O.Schmidt)	1	17	21	0	0	0	0
Drilonereis filum (Claparede 1868)	0	0	1	0	0	0	1
Euchone rosea Langerhans, 1884	0	0	6	0	0	0	0
Euclymene oerstedii (Claparede, 1863)	44	0	4	0	2	0	0
Eunice harassii Audouin & M.-Edwards, 1834	4	0	0	0	0	0	0
Eunice oerstedii Stimpson, 1854	0	0	5	0	9	0	0
Eunice pennata (O.F.Muller, 1776)	0	0	4	0	2	0	0
Exogone verrugera (Claparede, 1868)	0	0	1	0	0	0	0
Glycera alba (Muller, 1788)	1	0	1	0	0	1	0
Glycera rouxii Audouin & M.-Edwards, 1834	4	9	1	0	1	0	0
Goniada emerita Audouin & M.-Edwards, 1834	0	2	0	0	0	0	0
Grubeosyllis limbata (Claparede, 1868)	**0**	**0**	**1**	**0**	**0**	**0**	**0**
Harmothoe lunulata (Delle Chiaje, 1841)	0	1	4	1	8	0	3
Harmothoe sp.1	0	0	2	0	0	0	0
Harmothoe sp.2	0	0	1	0	0	0	0
Inermonephthys inermis (Ehlers, 1887)	0	1	0	0	0	0	0
Kefersteinia cirrata (Keferstein, 1863)	1	0	1	0	0	0	0
Lanice conchilega (Pallas, 1778)	0	0	2	0	0	0	0
Levincenia gracilis (Hartman, 1965)	10	82	53	0	3	2	0

Species	Stations						
	1	2	3	4	5	6	7
Levincenia oculata Hartman, 1957	0	0	13	0	3	0	0
Lumbrineris coccinea (Renieri, 1804)	1	1	1	0	0	0	0
Lumbrineris gracilis (Ehlers, 1868)	5	8	23	1	29	5	0
Lumbrineris impatiens (Claparede, 1868)	1	1	4	1	5	0	0
Lumbrineris latreilli Audouin & M.-Edwards, 1834	86	29	20	46	42	47	37
Magelona cincta Ehlers1908	0	0	0	0	2	0	0
Maldane sarsi Malmgren, 1865	0	0	0	0	3	0	0
Marphysa bellii Audouin & M.-Edwards, 1834	4	5	6	0	0	0	0
Melinna palmata Grube, 1870	6	12	2	0	8	1	2
Mysta siphonodonta (Delle Chiaje, 1822)	0	0	2	0	0	0	0
Nematonereis unicornis Schmarda, 1861	11	18	16	0	1	0	0
Nephthys hombergii (Savigny, 1820)	3	2	1	0	3	0	0
Nephthys hystricis (Mc Intosh, 1908)	0	0	1	20	0	21	25
Nephthys incisa (Malmgren, 1865)	0	0	2	0	0	0	0
Nereis sp.	0	0	6	0	3	0	0
Nicomache lumbricalis (Fabricius, 1780)	0	0	0	0	3	0	0
Notomastus latericeus Sars, 1851	37	33	50	5	10	4	2
Owenia fusiformis Delle Chiaje, 1844	0	4	3	0	2	0	0
Paradoneis armata Glemarec, 1967	4	2	0	0	0	0	0
Paradoneis lyra Southern, 1914	59	76	96	0	2	0	0
Perinereis cultrifera (Grube, 1840)	0	0	0	1	0	0	1
Pilargis verucosa Saint-Joseph, 1899	0	0	1	0	0	0	0
Pisione remota (Southern, 1914)	0	0	0	1	0	0	0
Pista cristata (Muller, 1776)	0	0	1	0	0	0	0
Polycirrus medusa Grube 1855	0	0	0	5	0	7	0
Polydora ciliata (Johnston, 1838)	0	0	0	0	0	0	6
Polydora hoplura Claparede, 1870	0	0	2	0	0	0	0
Polynoe sp.	0	0	1	0	0	0	0
Polyophthalmus pictus (Dujardin, 1893)	0	2	0	0	0	0	0
Prionospio cirrifera Wiren, 1883	8	1	1	0	0	0	0
Prionospio malmgreni Claparede, 1870	15	0	3	0	3	0	0
Protodorvillea kefersteini (McIntosh, 1869)	0	0	11	0	0	0	0
Psammolyce articulata Day, 1960	0	0	1	0	0	0	0
Pseudocapitella incerta Fauvel, 1913	0	1	0	0	0	0	0
Pseudopolydora antennata Claparede, 1870	4	0	1	0	0	0	0
Sabella sp.	0	1	0	0	0	0	0
Schistomeringos rudolphi (Delle Chiaje, 1828)	3	8	6	0	0	0	0
Schistomeringos sp.	0	0	1	0	0	0	0
Scoloplos armiger (O.F.Muller, 1776)	0	0	5	0	0	0	0
Serpula vermicularis L.,1767	0	1	0	0	0	0	0
Sigambra parva Day, 1963	2	1	8	4	3	1	1
Sphaerosyllis pirifera Claparede, 1868	0	0	7	0	0	0	0
Spio filicornis Southern, 1914	20	1	0	0	0	0	0
Spiochaetopterus typicus Sars, 1856	0	0	0	0	1	0	0
Spiophanes bombyx (Claparede, 1870)	0	0	0	1	0	0	0
Sternaspis scutata Renier, 1807	0	1	0	5	1	16	8
Syllidae sp.	0	0	1	0	0	0	0
Syllis cirropunctata Michel, 1909	0	0	1	0	0	0	0
Syllis sp.	0	0	3	0	0	0	0
Trichobranchus glacialis Malmgren, 1866	0	0	0	2	0	7	5
Mollusca							
Abra alba (W.Wood, 1802)	29	7	1	0	3	0	0
Abra prismatica (Montagu, 1808)	0	0	1	18	0	2	12
Cerastoderma glaucum (Poiret, 1789)	0	0	0	0	1	0	0
Corbulla gibba (Olivi, 1792)	0	0	1	3	1	0	1
Cylichna cylindracea (Pennant, 1777)	1	0	0	0	0	0	0
Fasciolaria lignaria (L., 1758)	0	0	1	0	0	0	0
Gastrochaena dubia (Pennant, 1777)	0	0	1	0	0	0	0

Species	Stations						
	1	2	3	4	5	6	7
Glans trapezia (L., 1767)	4	2	2	0	0	0	0
Gouldia minima (Montagu, 1803)	0	0	1	0	0	0	0
Hemilepton nitidum (Turton, 1822)	1	0	9	0	0	0	0
Limatula subauriculata (Montagu, 1808)	0	0	1	0	0	0	0
Loripes lacteus (L., 1758)	26	15	18	0	0	0	0
Lucinoma boreale (L., 1767)	0	0	1	0	0	0	0
Mangillella multilineolata (Deshayes, 1835)	0	1	0	0	0	0	0
Modiolus barbatus (L.1758)	0	0	1	0	0	0	0
Musculus costulatus (Risso, 1826)	1	0	0	0	0	0	0
Mysella bidentata (Montagu, 1803)	2	0	11	0	0	0	0
Natica hebraea (Martin, 1784)	0	0	0	0	0	1	0
Neverita josephinia Risso, 1876	4	0	0	0	0	0	0
Rissoa monodonta Philippi, 1836	0	10	0	0	0	0	0
Tellina fabula Gmelin, 1791	0	0	1	0	0	0	0
Tellina pulchella Lamarck, 1818	9	0	1	1	10	1	0
Tricolia pullus (L., 1758)	5	0	0	0	0	0	0
Venus verrucosa (L., 1758)	0	0	1	0	0	0	0
Decapoda							
Alpheus glaber (Olivi, 1792)	1	0	0	0	0	0	0
Anapagurus hyndmanii (Bell, 1845)	0	0	1	0	0	0	0
*Athanas nitescens (*Leach, 1814)	0	2	2	0	0	0	0
Goneplax rhomboides (L., 1758)	0	0	0	1	0	1	1
Inachus dorsettensis (Pennant, 1777)	0	0	1	0	0	0	0
Leiocarcinus arquatus (Leach, 1814)	0	1	0	0	1	0	0
Upogebia tipica (Nardo, 1869)	1	0	0	0	1	0	1
Amphipoda							
Ampelisca tenuicornis Liljeborg, 1855	2	1	1	1	0	0	1
Bathyporeia sp.	0	0	1	0	0	0	0
Caprella linearis (L.)	0	0	2	0	0	0	0
Erichthonius brasiliensis (Dana, 1855*)*	3	0	8	0	0	0	0
Leucothoe incisa (Robertson, 1892)	2	0	0	0	0	0	0
Oedicerotidae sp.	0	0	1	0	0	0	0
Isopoda							
Arctruropsis rudis	0	0	1	0	0	0	0
Tanaidacea							
Apseudes latreilli (M. Edwards, 1828)	1	0	0	0	0	0	0
Cumacea							
Iphinoe sp.	0	0	0	0	2	0	0
Pycnogonida							
Nymphon gracile (Leach)	2	0	0	0	1	0	0
Echinodermata							
Amphiura chiajei Forbes, 1843	0	0	6	1	24	0	4
Holothuria tubulosa Gmelin,1788	1	0	0	0	0	0	0
*Leptopenctata elongata (*Duben & Koren, 1844)	0	0	0	0	1	0	0
Phoronida							
Phoronis sp.	0	0	0	2	0	6	4
Sipuncula							
Aspidosiphon mulleri Diesing, 1851	0	0	0	0	2	0	0
Phascolion strombi (Montagu, 1804)	0	0	2	0	2	0	0
Tunicata							
Clavellina lepadiformis (Muller)	50	70	160	0	32	0	2
Tunicata sp. (juveniles)	0	0	3	0	0	0	0
Nemertea							
Carcinonemertes sp.	0	0	1	0	0	0	0

Species	Stations						
	1	2	3	4	5	6	7
Cerebratulus fuscus (McIntosh, 1873-74)	1	0	8	0	6	0	1
Micrura fasciolata (Ehrenb)	0	0	3	0	0	0	0
Micrura purpurea (Dal)	5	5	1	0	0	0	0
Micrura sp.	0	5	1	0	0	2	0
Poliopsis lacazei	0	0	0	0	0	1	0
Turbelaria							
Leptoplana alcinoi	1	0	0	0	0	0	0
Leptoplana tremellaris	0	0	1	0	0	0	0
Miscellanea							
Calanoidea sp.	0	0	0	0	1	0	0
Mysidacea	1	0	0	0	0	0	0
Nematoda sp.	1	1	2	0	0	0	0
Oligochaeta sp.	0	0	41	0	0	0	0
Ostracoda	0	0	0	0	1	0	0
Peachia cylindrica (Reid)	0	0	0	1	0	0	0

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