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RESEARCH ARTICLE

Macrobenthic fauna of soft-bottom in the eastern sector of the Gulf of Oran (western Algeria, Mediterranean Sea)

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Abstract

Research of benthic macrofauna of the Algerian west coasts is generally rare and mainly concerns a single species. The present work created an inventory of the macrobenthos explaining their distribution in the eastern sector of the Gulf of Oran. A total of 506 individuals sampled at 14 sites in winter 2019 were identified as four main taxa (279 polychaetes, 154 crustaceans, 41 echinoderms, and 32 molluscs). The taxonomic analysis made it possible to inventory 112 species (25 polychaetes, 61 crustaceans, 18 molluscs and 8 echinoderms). Polychaetes were dominant in all stations. Four bio-sedimentary facies (sand, sanded gravel, graveled sand and gravel) were identified by Ascending Hierarchical Classification, diversity indices, and sedimentary analysis and the zoological and ecological characteristics of the main soft-bottom communities of the study area were described.

Keywords: Macrofauna, macrobenthos, softbottom, sedimentary facies, Gulf of Oran, western Algeria

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Introduction

Macroinvertebrates are generally the most representative group among benthic marine organisms and specify the ecological characteristics of a particular study site. In recent years, the increase in economic activities and pollutant flows linked to urban development leads to temporal disturbances of benthic community quantitatively and qualitatively (Rebzani-Zahaf 1992; Rebzani-Zahaf *et al.* 1997). Some results show the response of the benthic communities to different disturbance sources in a simple way, thus some researchers have relied on them as ecological indicators of the health of estuaries and coastal waters (Muxika and Borja 2005; Kies *et al*. 2020).

Most of the previous inventories of the benthic fauna of the western Algerian continental shelf have been being updated (Pallary 1900; 1935; Llabador 1941; Vaissiere and Fredj 1963; Amar 1998; Grimes 2010; Boukhari Benamara 2014; Meziane and Kerfouf 2018*;* Meziane *et al*. 2020). Thus, in the present study, the macrobenthic fauna in the Gulf of Oran were studied, and 14 stations were selected for sampling. The analysis and the inventory of identified species make it possible to define the geographical zoning and the priority habitat types to preserve macroinvertebrates diversity in these coastal areas and to identify its ecological values and disturbances caused by human activities (Benali *et al.* 2017).

Materials and Methods

Study area

The Gulf of Oran is located on the Algerian Mediterranean coast, between the industrial Gulf of Arzew in the east (Cap Carbon) and Cap Falcon in the west. The Atlantic-origin water flows into the Gulf and the circulation seems very turbulent along the African continent. This turbulence favors the eventual pollutant dispersion (Millot 1987; Millot *et al*. 1989, 1990). This coastal water of the Gulf is exposed to different pollution caused by urban concentration and socio-economic development (Remili and Kerfouf 2013; Dilem *et al.* 2014; Guendouzi *et al.* 2021).

Sampling

Following the bathymetry of this zone, 14 stations were proposed along two transects, beginning from the coast to the open water. The station nearest to the coast was at 32 m depth and the farthest one was at 100 m depth (Figure 1). Aberdeen grabs (Smith McIntyre) were used for sediment and macrobenthic fauna sampling in winter 2019. Two grabs were made for an area of 0.2 m^2. The samples were filtrated on a 1mm mesh sieve onboard. Subsamples were picked up in view of the granulometric analysis. After sieving the samples, the residue is fixed with formalin. The samples were also fixed in formalin (10%) and identified in a laboratory according to the references (Fauvel 1923, 1927; Picard 1965;

Fauchald and Rouse 1997; Glémarec and Grall 2000; WORMS 2021). The species inventoried and noted to calculate the abundance and dominance of the species and the diversity index. The collected sediment was physically analyzed to determine the nature of the substrate. The dried sediment (100 g) was sieved through a column of 16 superimposed sieves; 2500, 1600, 1250, 630, 500, 400, 315, 250, 200, 160, 125, 100, 80, 63, 50 and 40 µm. After 15 minutes of sieving using a "Fristch" type vibrator, the residue from each sieve was weighed, then converted into a cumulative percentage (%) by weight, into cumulative masses and into a cumulative percentage (AFNOR 1996).

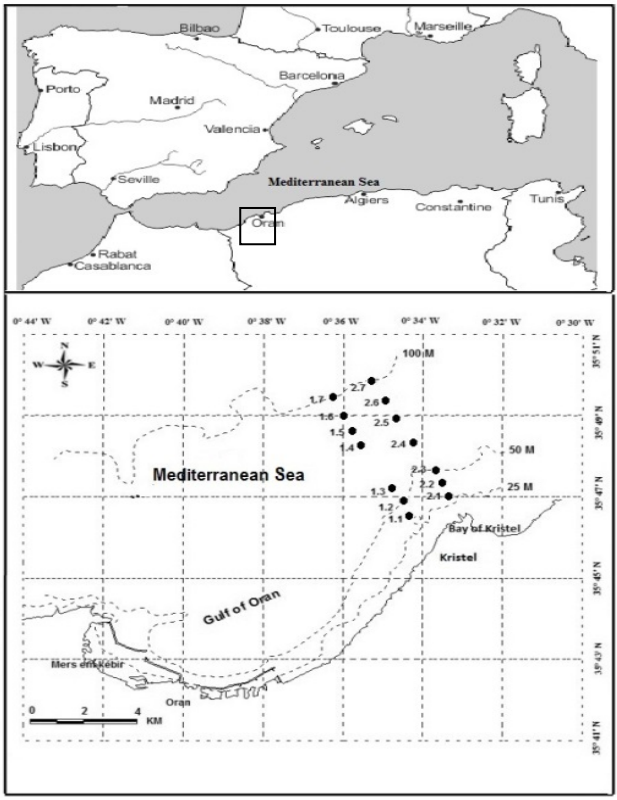

Figure 1. Study area and sampling stations

Data analysis

R software ver.3.5.2 (R Development Core Team 2019) was used to analyze the data. In order to evaluate the distribution and faunal structure such as abundance, species richness and species frequency, the Shannon and Weaver diversity index (H '), equitability index (E), and Simpson index (S) (Shannon and Weaver 1963; Pielou 1966) were calculated with Hmisc R (Harrell 2016) and Vegan (Oksanen *et al.* 2019).

The Ascending Hierarchical Classification (CHA) used in a wide variety of disciplines was adopted in this study. It consists of partitioning the objects (or descriptors) of the study into groups and subgroups, through the condensation of the information provided by the data matrix into a similarity or distance matrix. The latter will then be classified according to different classification algorithms (ward, simple, complete, medium). Each of them will provide a corresponding dendrogram (Herrera and Le Gac 2002).

Results and Discussion

Sediment analysis

Table 1 shows physical characteristics of sediments at each site. The gravel fraction dominated the majority of stations, often associated with sand. The muddy sediment was rarely present due to lack of terrigenous inputs. Coarse sand and gravel were located especially near the offshore capes bordering the gulf. The sand-gravel mixture dominated in all the stations studied, except two stations (1.2 and 1.4) which contained 80.29% and 76.56% fine sand, respectively. The particle size analysis revealed four sedimentary facies: sand, sanded gravel, graveled sand and gravel.

Table 1. Geographical coordinates and physical characteristics of the studied sites

Site	Coordinates		Depth	Median	Gravel	Sand	Mud
	N	E	(m)	(mm)	(%)	(%)	(%)
1.1	35° 46' 38"	0° 34' 14"	40	0.339	73.14	26.43	0.43
1.2	35° 46' 53"	0° 34' 24"	50	0.624	48.29	49.00	2.71
1.3	35° 47' 10"	0° 34' 37"	60	0.372	52.86	47.14	0.00
1.4	35° 48' 20"	0° 35' 27"	70	0.496	77.29	22.70	0.01
1.5	35° 48' 42"	0° 35' 41"	80	0.434	68.54	32.54	1.08
1.6	35° 48' 58"	0° 35' 54"	90	0.400	67.00	32.71	0.29
1.7	35° 49' 24"	0° 36' 12"	100	0.340	67.86	30.29	1.86
2.1	35° 47' 11"	0° 33' 17"	32	0.514	19.43	80.29	0.29
2.2	35° 47' 27"	0° 33' 28"	41	0.521	21.88	76.56	1.56
2.3	35° 47' 40"	0° 33' 36"	49	0.551	80.00	19.14	0.86
2.4	35° 48' 27"	0° 34' 12"	61	0.339	67.00	30.86	2.14
2.5	35° 48' 57"	0° 34' 37"	70	0.414	31.29	67.14	1.57
2.6	35° 49' 20"	0° 34' 49"	80	0.326	54.00	43.43	2.57
2.7	35° 49' 48"	0° 35' 12"	95	0.462	72.86	25.86	1.29

Zoological analysis

The sampling campaign identified (506) macroinvertebrates, including 279 polychaetes, 154 crustaceans, 41 echinoderms, and 32 molluscs in Annex.

The stations 1.2, 1.3, 2.1, 2.2, and 2.3 near the coast presented the most diverse communities (Figures 2 and 3).

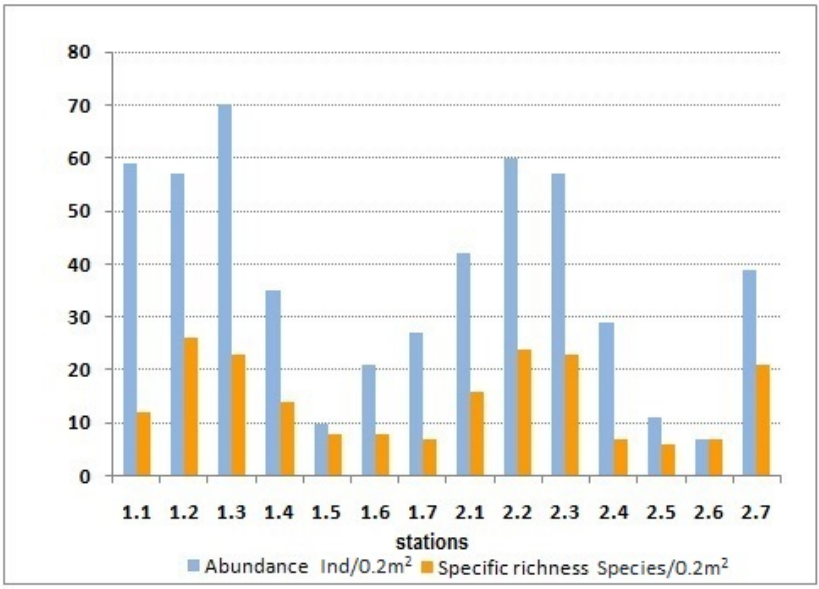

Figure 2. Abundance and specific richness of the studied benthic communities in the Gulf of Oran

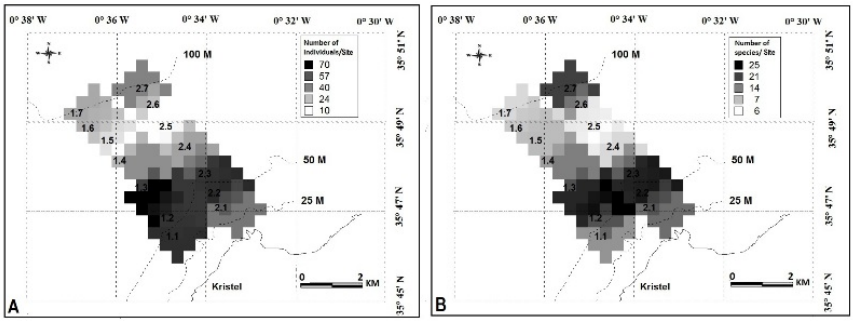

Figure 3. Spatial distribution of (A) abundance and (B) specific richness of benthic communities in the Gulf of Oran

Polychaetes were dominant in all stations except station 1.2, where crustaceans were dominant, and station 1.5 dominated by molluscs. Echinoderms were the least represented zoological group. Molluscs were also poorly represented in the samples (Table 2). Polychaetes showed the highest abundance (41) at station 1.3 due to the presence of a species with wide ecological distribution *Aponuphis bilineata* (33 individuals). Polychaetes were also dominant at stations 1.3, 1.4, 1.6, 1.7, 2.1, 2.2, 2.3, and 2.4. The highest abundance of crustaceans were noted at station 1.2 (35), with 22 species evenly distributed. Another polychaete species,

Eunice vittata, dominated at station 1.1 with an abundance of 17 individuals. All the other polychaete species identified were represented by only one or two individuals, except for *Syllis amica* and *Neanthes acuminata* (pollution indicator) with 6 and 4 individuals, respectively.

The best represented crustacean species were the amphipods *Urothoe elegans* (6) and the decapod *Galathea intermedia* (5). Molluscs were less present in the soft bottoms of the stations sampled. Amar (1998) noted the highest number of molluscs (66) in the Gulf of Arzew, which has the bottom of pure silt. Echinoderms were absent at five stations (1.2, 1.3, 1.5, 2.1, 2.5), and the highest value (14) at station 1.1 was dominated by green sea urchin *Psammechinus microtuberculatus.* This species is known to live in a coastal gravel habitat. Echinoderms are more common on the rocky substrates of the Algerian west coast (Allaili and Kerfouf 2015).

Qualitatively, polychaetes dominated many stations and constitute the most diverse animal group. Crustaceans with the highest species richness values predominated at six stations near the coast: 1.2, 1.3, 1.4, 2.1, 2.2, and 2.3.

Table 2. Zoological composition of each station (A: abundance, D: dominance %)

Stations	Polychaetes		Crustaceans		Molluscs		Echinoderms		Total
	A	D	A	D	A	D	A	D	
1.1	40	67.79	0	0	5	8.47	14	23.71	59
1.2	2	35.08	35	61.38	2	3.50	0	0	39
1.3	41	58.54	29	41.46	0	0	0	0	70
1.4	20	57.08	11	34.30	3	8.57	1	2.86	35
1.5	3	30	1	10	6	60	0	0	10
1.6	16	76.18	0	0	1	4.76	4	19.5	21
1.7	20	74.07	5	18.52	0	0	2	7.40	27
2.1	21	50.46	17	40.45	4	9.52	0	0	42
2.2	27	45	20	33.10	4	6.66	9	14.99	60
2.3	33	57.89	15	26.31	5	8.77	4	7.02	57
2.4	27	93.09	0	0	0	0	2	6.90	29
2.5	7	63.63	4	36.36	0	0	0	0	11
2.6	2	28.58	4	56.16	0	0	1	14.29	7
2.7	20	51.20	13	33.28	2	5.13	4	10.24	39
Total	279		154		32		41		506

Specific richness analysis

There are three indicators calculated based strictly on species diversity: the Shannon–Weaver index, Pielou's evenness (J'), and Simpson index (Figure 4). The analysis of data for each station of the diversity indices integrating the specific richness and the relative abundance of the different taxa showed that the values of Shannon index (H') and Pielou's evenness (J') were between a maximum (H'= 3.91) recorded at station 2.7 and (J '= 1) recorded at station 2.6. A minimum

value of H'= 2.09 was noted at station 2.4 and J'=0.71 at station 1.3. The highest values of H' and J' were noted in stations 1.2, 2.2, 2.3, 2.7 and 1.5, 2.5, 2.6, 2.7 respectively. These stations presented a well-diversified population where several taxa were well represented. The lowest values of H' and J' were recorded at stations 1.6, 1.7, 2.4, and 1.3, 1.6, 2.1, respectively. For the other stations, the values of H' and J' showed an average diversity of the macrobenthic communities, however, a good representation of a few taxa. The highest values of the Simpson index were noted in stations 1.6 and 2.4.

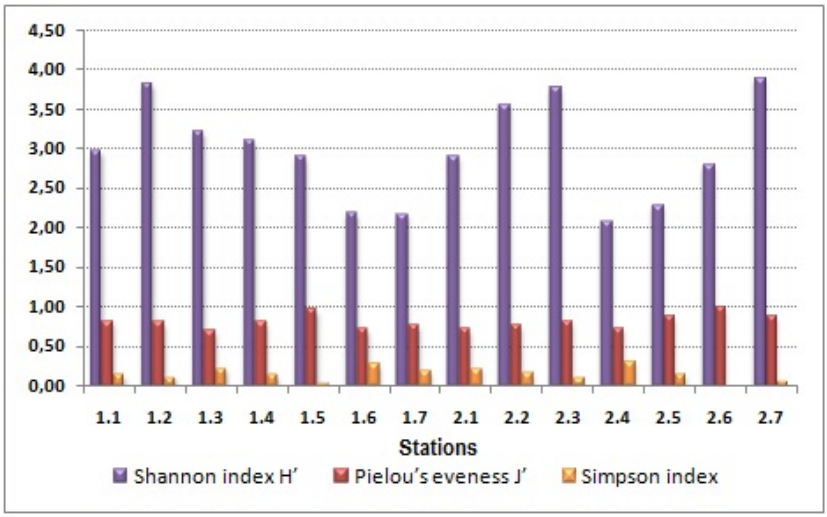

Figure 4. Diversity index and specific richness of sampled stations in the Gulf of Oran

Ecological Analysis

Using Ascending Hierarchical Classification (CHA), the stations were regrouped according to the faunal composition and the substrate nature (Glémarec and Grall 2000; Hilly 1985). The communities identified in the eastern sector of the Gulf of Oran (and in most studies concerning the Mediterranean Sea) were organized following the classification of biocoenoses (Pérès and Picard 1964; PNUE, PAM, CAR/ASP 2006).

All stations were classified based on the CHA dendrogram structure (Figure 5) according to the χ^2 criterion into four sets of stations and the sediment's criterion (Cabioch *et al.* 1978). Set (A) made up of four gravel stations (1.1, 1.4, 2.3, 2.7). Set (B) included four sandy gravel stations (1.5, 1.6, 1.7, 2.4). Set (C) included three sand and gravel stations (1.2, 1.3, 2.6). The fine sand set (D) included three sand stations (2.1, 2.2, 2.5) (Figure 6).

Group (A) located on gravel bottoms characterized by the dominance of species with a wide ecological distribution (*Aponuphis bilineata* and *Eunice vittata*). The substrate of group (B), consisted mainly of gravel, dominated by the polychaete *A. bilineata* and and a mixticole species, *Saccella commutata*. Group (C), where the sand were more important than gravels, were characterized by high abundance of *A. bilineata* in stations 1.2 and 1.3. Group (D) contained only species with wide ecological distribution and sandy species.

Quantitatively, benthic communities of sanded gravel were the most important (116 individuals), followed by fine sands (113 individuals). Polychaetes dominated the whole macrobenthic communities of the Gulf of Oran (Grimes 2010; Kerfouf *et al.* 2021). Qualitatively, the polychaetes were, also, the most diversified zoological group in all the stations, followed by crustaceans. Thus, there was high diversity in stations near the coast, where the sediment fraction was heterogeneous. The most important ecological group composing these communities was the group of species with wide ecological distribution represented by *A. bilineata* and *E. vittata*, those of the exclusive gravel species of the coastal detritic represented by *Psammechinus microtuberculatus*, and *Urothoe elegans*.

Most studies in the Mediterranean Sea were organized following the classification of biocoenoses proposed by Pérès and Picard (1964). Picard (1965) and Guille (1970, 1971) described the benthic communities in the Gulf of Marseille and the French Catalan coast, respectively. Desbruyères *et al.* reported (1973) on the Spanish Catalan coast. The distribution of marine macrobenthic depends on the nature of the substrate, its composition of organic matter, and the quality of the environment, as reported by the work on the Algerian coast (Kies et *al.* 2020; Bakalem *et al.* 2020).

This study area is the poorest in abundance of species in the Eastern sector of the Gulf of Oran, compared to similar sites across the Mediterranean (Bakalem *et al.* 2020; Belhadj Tahar *et al.* 2021; Kerfouf *et al.* 2021). This gulf is subject to human activity due to the proximity of the port of Oran and urban wastewater discharges (Remili and Kerfouf 2013; Dilem *et al.* 2014). From the coastal area of Oran to Paloma Island in the west, the richness of soft-bottom species is higher than that of rock substrates, with 100 species of soft-bottom macrobenthos and 65 species of rock bottom macrobenthos (Haddou *et al.* 2019). On the Algerian coast, the Bay of Bou-Ismail presents the most diverse macrobenthic community with 723 species (Bakalem *et al.* 2020). Dauvin *et al.* (2013) reported a specific richness of 642 species from a total sampling surface area for soft-bottom communities along the Algerian coast. The Bay of Marseille and the French Catalan coast (both in the western basin of the Mediterranean Sea) also show high diversity (Dauvin *et al.* 2017).

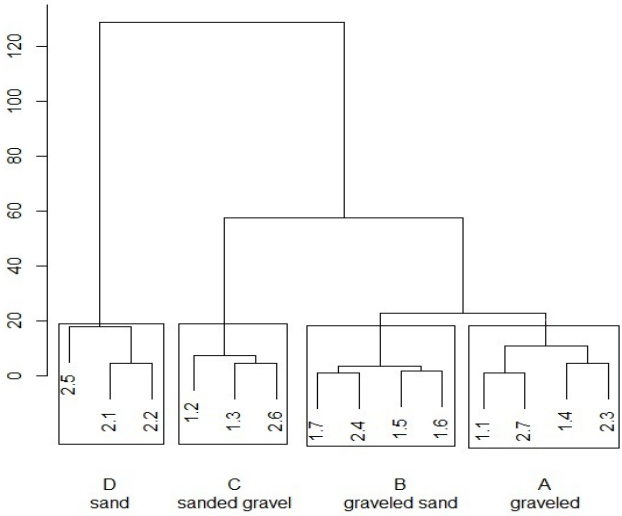

Figure 5. Dendrogram of Ascending Hierarchical Classification of the benthic communities in the Gulf of Oran

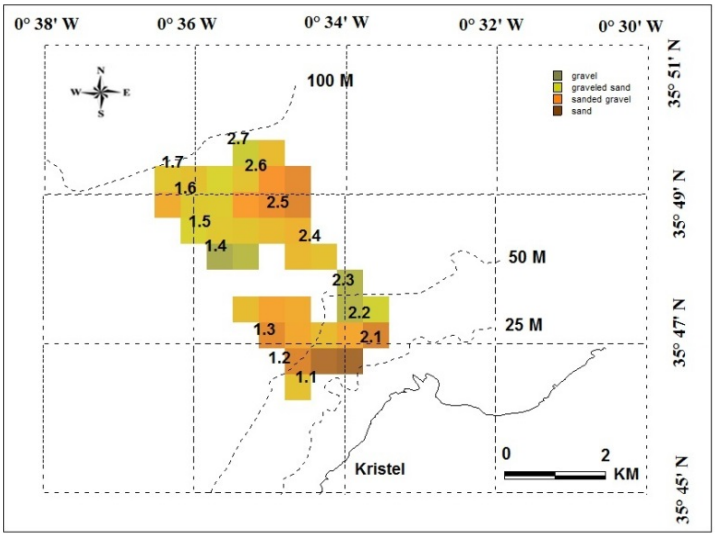

Figure 6. Spatial distribution of the benthic communities in the Gulf of Oran

Conclusion

It is necessary to establish inventories of marine invertebrates as a prerequisite for biodiversity and ecological studies (Ferrario *et al.* 2016). Several studies (Dauvin *et al.* 2013; Allaili and Kerfouf 2015; Bakalem *et al.* 2020) had indicated that the taxonomic richness depends on the sampling method (tools and sampling

frequency), and the nature of the substrate in each area. Whilst numerous local and regional studies carried out on benthic communities across the Mediterranean Sea, there had been in the Algerian west coast, in particular, few studies with a small quantitative sampling of soft-bottom communities. In the inventory of the benthic fauna, sampled in 14 sites located in the eastern sector of the Gulf of Oran, 506 individuals were divided into four main zoological groups of 279 polychaetes, 154 crustaceans, 41 echinoderms, and 32 molluscs. The calculation of the diversity indices highlighted the quantitative and qualitative importance of polychaete annelids in most stations. Molluscs were the least represented group.

Multivariate analysis (CHA) revealed four communities according to their abundance and the nature of the substrate: sand, sanded gravel, graveled sand and gravel. Sedimentary gravel facies and low terrigenous contribution characterized the Gulf of Oran, related to the presence of two major ecological stocks, composed of species with a wide ecological distribution and sand species. Most of the species found in the area originated from the Mediterranean or northeastern Atlantic. The study in this sector of the Gulf of Oran aims to build a database of sampled species, to describe the mainly macrozoobenthos communities and their ecological features. Comparatively, to the other coastal areas of Algeria which have been studied: Alger, Bou Ismail, Arzew, and Skikda (Rebzani *et al.* 1997; Grimes 2010; Amar *et al. 2*014; Bakalem *et al.* 2020; Belhadj Tahar *et al.* 2021), and to the other Mediterranean coast (Baldó *et al.* 1999) the area of Oran is the poorest both in quality and quantity.

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Annex. Species abundance of each station (number of individuals/0.2 m²)

Stations	1.1	1.2	1.3	1.4	1.5	1.6	1.7	2.1	2.2	2.3	2.4	2.5	2.6	2.7
Polychaetes														
Amphitrite gracilis (Grube, 1860)							1							1
Amphitrite edwardsii (Quatrefages, 1866)										2				
Chloeia venusta Quatrefages, 1866		1								1				1
Eulymene lombricoides (Quatrefages, 1866)						1								
Eteone picta Quatrefages, 1866														1
Eunice vittata (Delle Chiaje, 1828)	17		3	5			7			6	3	3	1	5
Harmothoe longisetis (Grube, 1863)			1	2	1	1								
Harmothoe spinifera (Ehlers, 1864)									2					
Aponuphis bilineata (Baird, 1870)	12	19	33	13	1	11	12	20	25	18	16	4	1	9
Hyalinoecia fauveli Rioja, 1918											3			
Leanira hystricis Ehlers, 1874					1									
Lepidasthenia maculata Potts, 1910														1
Lumbrineris fragilis (O.F. Müller, 1776)										1				
Lysidice ninetta Audouin & H Edwards, 1833						1				1				
Marphysa bellii oculata Treadwell, 1921										1				
Neanthes acuminata (Ehlers, 1868)	4													
Phyllodoce laminosa brevis Zachs, 1933						1								
Pista cristata (Müller, 1776)			1			1					2			1
Polynoe scolopendrina Savigny, 1822	1									1				
Sigalion squamatum Delle Chiaje, 1830								1						
Sthenelais boa (Johnston, 1833)														1
Sylidae not identified			1											
Syllis prolifera Krohn, 1852			2											
Syllis amica Quatrefages, 1866	6									2	3			

Annex. Continued

Stations	1.1	1.2	1.3	1.4	1.5	1.6	1.7	2.1	2.2	2.3	2.4	2.5	2.6	2.7
Crustaceans														
Alpheus glaber (Olivi, 1792)		1												
Ampelisca brevicornis (Costa, 1853)														1
Ampelisca diadema (Costa, 1853)									1					
Ampelisca ledoyeri Bellan-Santini & Kaim-Malka, 1977														3
Ampelisca multispinosa Bellan-Santini & Kaim-Malka, 1977								2						
Ampelisca provincialis Bellan-Santini & Kaim-Malka, 1977				1									1	
Ampelisca pseudosarsi Bellan-Santini & Kaim-Malka, 1977			1											1
Ampelisca sp.			2	1										
Ampelisca spinipes (Boeck, 1861)								1		1				
Ampelisca tenuicornis (Liljeborg, 1856									2	3				
Ampelisca typica (Spence Bate, 1856)		3		3					1					
Ampelisca vervecei Bellan-Santini & Kaim-Malka, 1977									1			1		
Anapagurus laevis (Bell, 1845)									2					
Anapagurus petiti Dechancé & Forest, 1962									2					
Anonyx sarsi Steele & Brunel, 1968								1		2				
Apseudes holthuisi (Bacescu, 1961)														2
Apseudes spinosus (M. Sars, 1858)														2
Athanas nitescens (Leach, 1814)		1								1				
Atylus guttatus (Costa, 1851)		4												
Atylus swammerdamei (H. Milne Edwards, 1830)		1							1					
Bathyporeia guilliamsoniana (Spence Bate, 1857)								2						
Ceradocus semiserratus (Spence Bate, 1862)			2											
Cirolana borealis Lilljeborg, 1851		1					3							1
Corophium rotundirostre Stephensen, 1915		1												

Annex. Continued

Stations	1.1	1.2	1.3	1.4	1.5	1.6	1.7	2.1	2.2	2.3	2.4	2.5	2.6	2.7
Cymodoce truncata Leach, 1814										1		1		
Cypridina mediterranea Costa, 1845		1	2					2						
Ebalia edwardsii O.G. Costa, 1838		1												
Eurydice affinis (Hansen, 1905)				1										
Eurydice cf pulchra				1	1					3				
Eurydice pulchra (Leach, 1815)		2	2	1			2		1					3
Eurydice sp.		1												
Galathea intermedia (Lilljeborg, 1851)		5	2						2					
Gammarus crinicornis (Stock, 1966)			1											
Gammarus sp.		1												
Gastrosaccus sanctus (Van Beneden, 1861)								1						
Gastrosaccus sp.													1	
Haplostylus normani (G.O. Sars, 1877)								1						
Harpinia crenulata (Boeck, 1871)				2										
Hippomedon denticulatus (Spence Bate, 1857)									2			1		
Idothea neglecta (G. O. Sars, 1897)			1											
Inachus communissimus (Rizza, 1839)			1											
Isopode not identified			1											
Leptocheirus bispinosus (Norman, 1908)									2	2				
Leucothoë lilljeborgii (Boeck, 1861)		1												
Lysianassa ceratina (Walker, 1889)			1							1				
Lysianassidae indéterminé										1				
Macropipus corrugatus (Pennant, 1777)			1											
Maera grossimana (Montagu, 1808)		3	2											
Maera knudseni (Reid, 1951)		1												
Maera othonis (H. Milne Edwards, 1830)			1											
Maera shieckei (Karaman & Ruffo, 1971)								1						
Maera grossimana (Montagu, 1808)									2					

Annex. Continued

Stations	1.1	1.2	1.3	1.4	1.5	1.6	1.7	2.1	2.2	2.3	2.4	2.5	2.6	2.7
Nebalia bipes (Fabricius, 1780)		1												
Paguristes oculatus (Fabricius, 1775)			2											
Procersa parva (Holthuis, 1951)		1												
Rocinella danmoniensis Leach, 1818		1												
Socarnopsis crenulatus Chevreux, 1911		1	1						1					
Sophrosyne robertsoni Stebbing & Robertson, 1891		1											1	
Urothoe brevicornis Spence Bate, 1862								5				1	1	
Urothoe elegans Spence Bate, 1857		2	6					1						
Urothoe sp.				1										
Molluscs														
Amygdalum phaseolinum Philippi, 1844														1
Callochiton septemvalvis (Montagu, 1803)									1					
Corbula gibba (Olivi, 1792)								1						
Euthria cornea (Linnaeus, 1758)									1					
Gari costulata (W. Turton, 1822)								1						
Gonilia calliglypta (Dall, 1903)										1				
Saccella commutata (Philippi, 1844)					2	1								
Limatula subauriculata (Montagu, 1808)	1	1						1						
Nassa limata (Chemnitz, 1795)														1
Nucula sulcata Bronn, 1831	4				1				1	3				
Nucula turgida Gould, 1846		1												
Papillicardium papillosum (Poli, 1791)				1										
Parvicardium scabrum (Philippi, 1844)					1									
Pitaria sp.								1						
Saxicarva arctica (Linnaeus, 1767)					2									
Tellina donacina Linnaeus, 1758				2										
Uncidens arupinensis Coen, 1934										1				
Venus ovata Pennant, 1777									1					

Annex. Continued

Stations	1.1	1.2	1.3	1.4	1.5	1.6	1.7	2.1	2.2	2.3	2.4	2.5	2.6	2.7
Echinoderms														
Amphiura chiajei Forbes, 1843	2						1							1
Amphiura filiformis (O.F. Müller, 1776)						4								1
Amphiura mediterranea Lyman, 1882	3								2					1
Astropecten irregularis (Pennant, 1777)											1			
Echinocyamus pusillus (O.F. Müller, 1776)									2				1	
Ophiopsila aranea Forbes, 1843	1								2	2				
Ophiura albida Forbes, 1839	1			1					1		1			1
Psammechinus microtuberculatus (Blainville, 1825)	7						1		2	2				