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Diversity of benthic macroinvertebrates in the Algerian East Coast

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ABSTRACT Marine biodiversity play a fundamental role in the ecology and functioning of benthic communities. The study of the structure of benthic macroinvertebrate peoples is an excellent tool for evaluating the impact of human activities on the ecological quality of lotic environments. However, little data is available on the diversity, structure and ecology of benthic macroinvertebrates of the Algerian east coast. The main purpose of this work is to present an inventory of the current faunistic data general at three sites of study in Algerian east coastline: El-Kala, Annaba and Skikda. After doing the morphometric analysis of all the individuals, this study allowed to the identification of several species of macroinvertebrates. The variations in the distribution of these macroinvertebrates at different sites are related to external factors (temperature, salinity, dissolved O_2), that would have an impact on the abundance of the species of marine fauna of the Algerian east coastline.

KEY WORDS Biodiversity; Ecological indices; Macroinvertebrate; Macrofauna taxa; Algerian east coast.

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INTRODUCTION

The marine environment constitutes a precious capital. Seas and oceans represent 99% of the living space available on our planet, nearly 71% of the earth's surface and contain 90% of the biosphere; they therefore contain more biological diversity than terrestrial and freshwater ecosystems. The marine environment is an essential element for life on earth because it represents a main source of oxygen and plays a determining role on the climate. It is also an important factor in economic prosperity, social well-being and quality of life. One of the great marine ecosystems on the planet is the Mediterranean Sea. It is of major ecological interest, in particular a specific richness which places it immediately after tropical ecosystems in terms of biodiversity (Ramade, 2003; Coll et al., 2012; Gerovasileiou & Voultsiadou, 2012). This represents 4% to 18% of the world's marine biodiversity, despite its estimated area of 0.82%. The Mediterranean Sea represents a complex reserve of biological energy, ensuring important processes, and therefore provide humanity with a wide variety of resources and services (Liquete et al., 2016). They are in fact invisible animal organisms with an internal bony skeleton, visible to the naked eye, which carry out part or all of their life cycle in an aquatic environment (Tachet et al., 2010). They are present at different levels of the food web, and relatively easy to sample and store, and their collection has little effect on the remaining biocenosis (Moisan & Pelletier, 2008). The present study was carried out during the year 2019 aimed generally at determining the composition and structure of populations of benthic macroinvertebrates.

MATERIAL AND METHODS

Study area

Three sites of northeastern of the Algeria were chosen to collect specimens. The first site was located at El-Kala (La Montagne station). It was located on a latitude 36°53’53.33”N and a longitude 08°27′3.28″W. The second site was located at Annaba (Rezgui Rachid station). It was located at latitude 36°91’67.70”N and a longitude 07°76’81.70”W. The third site was located at Skikda (Bikini Beach). It was located at latitude 36°52’18.86”N and a longitude 06°54’3.28”W (Fig. 1).

Sampling

Macroinvertebrates were collected from three sites in the northeastern of Algeria during 2019 (El-Kla, Annaba and Skikda). Sampling is carried out in rocky and sandy substrates covered with algae. At each site, one replicate of sampling were performed each month by using 25 cm × 25 cm quadrate and 0.5 m depth by using a scraper. In the laboratory, the macroinvertebrates were fixed in the field with at 4% formaldehyde formalin solution, and then preserved in 70% ethanol.

Physico-chemical parameters

The physico-chemical parameters represented by Salinity (mg/l), Dissolved oxygen (mg/l), pH and Temperature (C°) can influence the dynamics of the macroinvertebrate, that is why we measured them at the three study sites: El-Kala (La Montagne), Annaba (Rezgui Rachid) and Skikda (Bikini) using a “Thermo” multi-parameter scientific Orien 5-star multi-parameter portable.

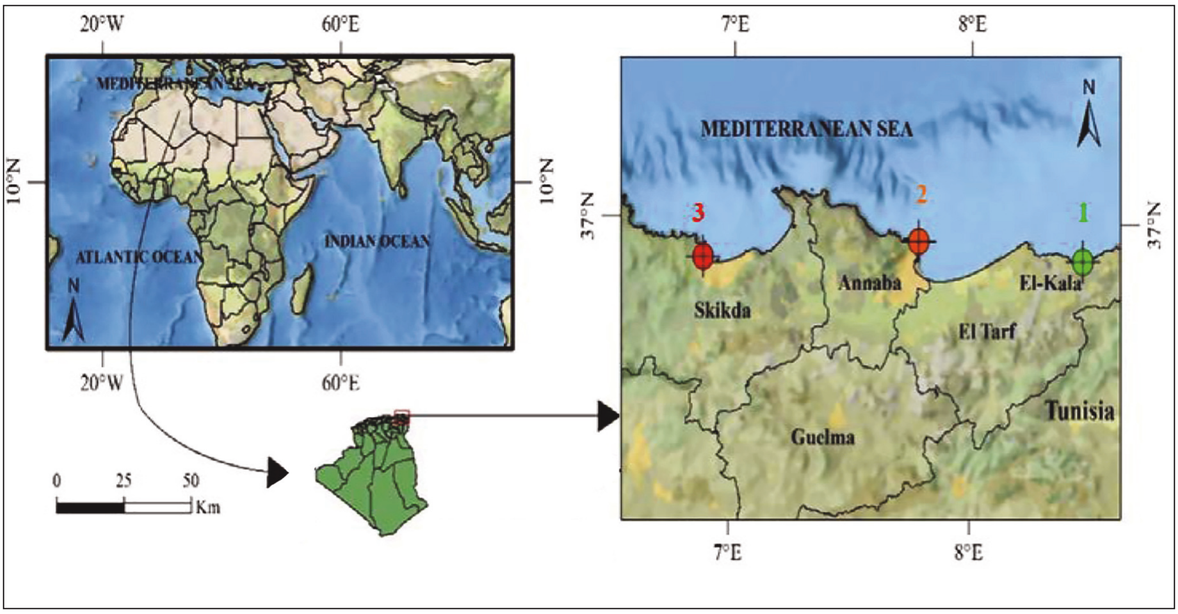

Figure 1. Location of sampling area.

Ecological indices

To determine the general structure of the communities of the macroinvertebrates, the following descriptive parameters were determined: the specific richness (S), abundance (A), or the total number of individuals per unit area (Ind.m-2), occurence frequency (F), diversity of Shannon - Weaver (H'), Piélou equitability index (J') and Sörensen similarity coefficient.

RESULTS

Physico-chemical parameters

The physico-chemical parameters were measured throughout the duration of the study at the three study sites: El-Kala, Annaba and Skikda. We did not observe any significant differences between the study sites for seawater temperature, pH and salinity (Fig. 2). For dissolved O_2, a very highly significant effect was recorded at El-Kala site.

During this study, the physicochemical quality of the water did not vary significantly between the three study sites for the three parameters (temperature, pH and salinity) except for the dissolved oxygen parameter ($P < 0.05$) (Table 1) analyzed by ANOVA single controlled factor variance analysis.

Structure of benthic macroinvertebrate populations - Diversity and distribution of taxa

We carried out an inventory of aquatic macroinvertebrates present at three sites on the East Algerian coast (El-Kala, Annaba and Skikda) during the year 2019 (Table 2). We proceed to the identification and classification of the different species according to the zoological group.

In all three stations studied, we obtained 5226 individuals. These individuals are divided into 6 branches (Annelids, Arthropods, Cnidarians, Echinoderms, Molluscs and Sipuncula), 9 classes (Polychaetes, Malacostraces, Anthozoa, Echinoderms, Holothurians, Bivalves, Gastropods, Polyplacophores, Phascolosomatidea), 14 orders and 25 fami-

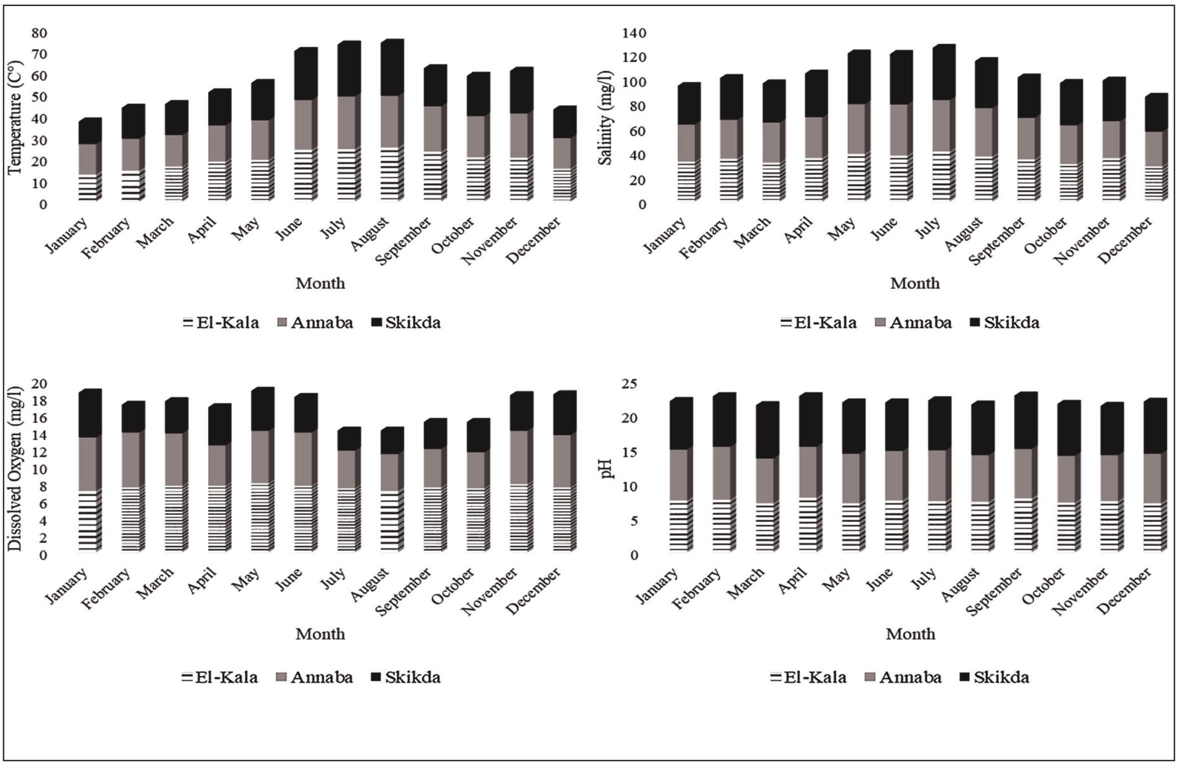

Figure 2. Monthly variations of the mean physico-chemical parameters of seawater for individuals collected in El-Kala, Annaba and Skikda from January to December 2019. Each data point represents mean ± standard deviation (n = 3).

lies, taxa identified at the rank of genus and/or species, 1 at the rank of order and 1 at the rank of family (Table 2). The Annelids have the greatest specific richness of the stand with a value of 33.33% of the total specific richness and an abundance of 45.44%. This phylum is best represented with 1 class, 1 order, 1 family and 9 morphotypes. They are followed by Molluscs representing 25.92% of the total specific richness and an abundance of 45.16%. This branch is divided into 3 classes, 5 orders, 5 families and 7 genera. Arthropods represent 22.22% of the total specific richness and an abundance of 6.81%. They have 1 class, 3 orders, 5 families and 5 genera, then the Sipuncula and the Cnidaria which each contain only one class, an order, a family and a single morphotype represent 3.7% of the total specific richness and an abundance of 1.76% and 0.13% respectively. Finally, the Echinoderms which have 2 classes, 3 orders, 3 families, and 2 genera record 11.11% of the total specific richness and an abundance of 0.56%.

Distribution of taxa by site

The beach of La Montagne (El-Kala) has the greatest taxonomic wealth with a total of 26 morphotypes (96.29% of the overall taxonomic wealth) distributed in 17 families (it represents 100% of families), 14 orders (100 % of orders), 9 classes (Polychaeta, Malacostraca, Anthozoa, Echinoidea, Holothuroidae, Bivalvia, Gastropoda, Polyplacophora, phascolosomatidea) and 6 Phylum (Annelida, Arthropoda, Cnidaria, Echinodermata, Mollusca, Sipuncula) (Table 2). The Polychaeta class dominates the population with 1 order, 1 family and 8 morphotypes. This class is followed by Mollusc which has 5 orders, 5 families and 4 species. Arthropods are represented by 5 families and 5 taxa, while Echinoderms are made up of 3 families and 2 taxa. The orders of Cnidaria and Sipuncula record a single order and a single family and a single taxon for each one. Twenty-six (26) species are recorded only at the El-Kala site during the entire study period (2019), where we have found *Perinereis oliveirae, Platynereis dumerilii*, *Pisa* sp., *Maja* sp., *Paracentrotus lividus* and *Acanthochitona* sp.

The beach of Rezgui-Rachid (Annaba), in total 11 orders (64.28% of orders), 11 families (64.70% of families) and 19 morphotypes (70.37% of the overall taxonomic richness). Annelida and Molluscs predominate with 1 order for Annelids and 4 orders for Molluscs, 1 family for Annelids and 4 families for Molluscs and 6 taxa for Annelida and 4 taxa for Molluscs, followed by Cnidaria, Echinodermata and Sipuncula made up of 1 species each one.

The beach of Bikini (Skikda), a total of 10 families (71.42% of families) and 16 morphotypes (59.25% of the overall taxonomic richness) are identified. Molluscs are the most represented families with 5 orders, 5 families and 6 taxa, followed by Annelids made up of 1 order, 1 and 5 species. Arthropods with 3 identified families and 4 taxa, followed by Sipuncula (a single species). *Pseudonereis anomala* is the only species found at the Skikda site.

Sites	**Temperature (C°)**	**Salinity (mg/l)**	**Dissolved O_2(mg/l)**	**pH**
El-Kala	19.43 ± 3.43	34.58 ± 2.66	7.54 ± 0.21	7.4 ± 0.2
Annaba	18.83 ± 3.26	34.59 ± 4.17	5.45 ± 0.85	7.12 ± 0.28
Skikda	17.65 ± 3.54	35.14 ± 3.59	3.8 ± 0.71	7.33 ± 0.18
P	0.574**NS**	0.911 **NS**	**0.000*****	0.060 **NS**

Table 1. Statistical analysis of physicochemical parameters seawater collected at the three study sites (El-Kala, Annaba and Skikda) from January to December 2019. NS = not significant (P>0.05); * = very significant (P<0.05); ** = highly significant (P<0.01); *** = very highly significant (P<0.001).

Phylum	Classes	Orders	Families	Genus/Species	K	A	S	Total
Annelida	Polychaeta	Phyllodocida	Nereididae	*Perinereis cultrifera*	763	550	409	**1722**
				Perinereis floridana	81	32	0	**113**
				Perinereis oliveirae	14	0	0	**14**
				Perinereis macropus	26	3	1	**30**
				Perinereis marionii	16	10	0	**26**
				Pseudonereis anomala	0	0	30	**30**
				Platynereis dumerilii	19	0	0	**19**
				Nereis falsa	48	203	108	**359**
				Perinereis sp.	46	13	5	**64**
Arthropoda	Malacostraca	Amphipoda	nd	nd	91	67	60	**218**
		Decapoda	Epialtidae	*Pisa* sp.	4	0	0	**4**
			Eriphiidae	*Eriphia verrucosa*	16	5	3	**24**
			Grapsidae	*Pachygrapsus marmoratus*	23	14	10	**47**
			Majidae	*Maja* sp.	2	0	0	**2**
		Isopoda	Cirolanidae	*Eurydice pulchra*	31	27	5	**63**
Cnidaria	Anthozoa	Actiniaria	Actiniidae	*Anemonia viridis*	5	2	0	**7**
Echinodermata	Echinoidea	Arbacioida	Arbaciidae	*Arbacia lixula*	15	3	0	**18**
		Camarodonta	Parechinidae	*Paracentrotus lividus*	9	0	0	**9**
	Holothuroidae	Holothuriida	Holothutiidae	nd	3	0	0	**3**
Mollusca	Bivalvia	Mytilida	Mytilidae	*Mytilus* sp.	586	651	525	**1762**
	Gastropoda	Archaeogastropoda	Trochidae	*Gibbula* sp.	119	45	20	**184**
		Neogastropoda	Muricidae	*Stramonita haemastoma*	45	25	17	**87**
		Patellogastropoda	Patellidae	*Cymbula safiana*	16	10	22	**48**
				Patella caerulea	26	15	17	**58**
				Patella rustica	84	51	47	**182**
	Polyplacophora	Chitonida	Acanthochitonidae	*Acanthochitona* sp.	41	0	0	**41**
Sipuncula	Phascolosomatidea	Phascolosomatida	Phascolosomatidae	*Phascolosoma* sp.	51	30	11	**92**
Totals	**9**	**14**	**17**	**27**	**2180**	**1756**	**1290**	**5226**

Table 2. List of aquatic macrofauna taxa collected at the different sampling stations of the three sites studied (K: El-Kala, A: Annaba, S: Skikda) during the study period (2019); nd = taxon not determined.

Frequency of occurrence of taxa at different sampling sites

The analysis of the benthic macrofauna collected in all 3 sampling sites (El-Kala, Annaba and Skikda) during the study period (2019) shows that the ubiquitous taxa are the most represented with a frequency of occurrence of 100% followed by accessory taxa (33.33%) and constant taxa (66.66%) (Table 3).

Phylum	Classes	Orders	Families	Genus / Species	F	Qualification
Annelida	Polychaeta	Phyllodocida	Nereididae	*Perinereis cultrifera*	100	*****
				Perinereis floridana	66,67	***
				Perinereis oliveirae	33,33	**
				Perinereis macropus	100	*****
				Perinereis marionii	66,67	***
				Pseudonereis anomala	33,33	**
				Platynereis dumerilii	33,33	**
				Nereis falsa	100	*****
				Perinereis sp.	100	*****
Arthropoda	Malacostraca	Amphipoda	nd	nd	100	*****
		Decapoda	Epialtidae	*Pisa* sp.	33,33	**
			Eriphiidae	*Eriphia verrucosa*	100	*****
			Grapsidae	*Pachygrapsus marmoratus*	100	*****
			Majidae	*Maja* sp.	33,33	**
		Isopoda	Cirolanidae	*Eurydice pulchra*	100	*****
Cnidaria	Anthozoa	Actiniaria	Actiniidae	*Anemonia viridis*	66,67	***
Echinodermata	Echinoidea	Arbacioida	Arbaciidae	*Arbacia lixula*	66,67	***
		Camarodonta	Parechinidae	*Paracentrotus lividus*	33,33	**
	Holothuroidae	Holothuriida	Holothutiidae	nd	33,33	**
Mollusca	Bivalvia	Mytilida	Mytilidae	*Mytilus* sp.	100	*****
	Gastropoda	Archaeogastropoda	Trochidae	*Gibbula* sp.	100	*****
		Neogastropoda	Muricidae	*Stramonita haemastoma*	100	*****
		Patellogastropoda	Patellidae	*Cymbula safiana*	100	*****
				Patella caerulea	100	*****
				Patella rustica	100	*****
	Polyplacophora	Chitonida	Acanthochitonidae	*Acanthochitona* sp.	33,33	**
Sipuncula	Phascolosomatidea	Phascolosomatida	Phascolosomatidae	*Phascolosoma* sp.	100	*****

Table 3. Frequency of occurrence of aquatic macroinvertebrate taxa collected from El-Kala, Annaba and Skikda sites during the 2019. F = designates the frequency of occurrence; ** = accessory taxa; *** = regular taxa; ***** = ubiquitous taxa.

Numerical structure of benthic macroinvertebrate populations - Representation of abundance

A total of 5226 macroinvertebrate individuals were collected from all 3 sampling stations surveyed in the three sites during the study period. The greatest relative abundance of this macrofauna is obtained in the site of El-Kala where 2180 individuals are counted corresponding to 41.71% of the total abundance. The Annaba site follows it with

1756 individuals collected with 33.60% relative abundance. The Skikda site is in last position with only 1290 individuals counted with 24.68% of the total abundance (Fig. 3).

Spatial and seasonal variations in the abundance of the main families

The spatial variations in the relative abundance of the main families of macroinvertebrates were inventoried across the sites (Fig. 4). In total, 16 families including 1 of Annelids (Nereididae), 5 of Arthropods (Epialtidae, Eriphiidae, Grapsidae, Majidae and Cirolanidae), 1 of Cnidarians (Actiniidae), 3 of Echinoderms (Arbaciidae, Parechinidae and Holothutiidae), Molluscs (Mytilidae, Trochidae, Muricidae, Patellidae and Acanthochitonidae) and 1 of Sipuncula (Phascolosomatidae) are retained. The families represented at the El-Kala site are absent at the other sites (Annaba and Skikda) and vice versa. At the three study sites, the Nereididae and Trochidae families dominate the macrofauna. At the El-Kala site, the Nereididae family is the majority with 35% relative abundance followed by the Trochidae with 26.88% relative abundance while at the Annaba site, the Trochidae are the majority with 37.07% relative abundance. In the Skikda site, the Trochidae family is the most represented with 40.69% of the workforce.

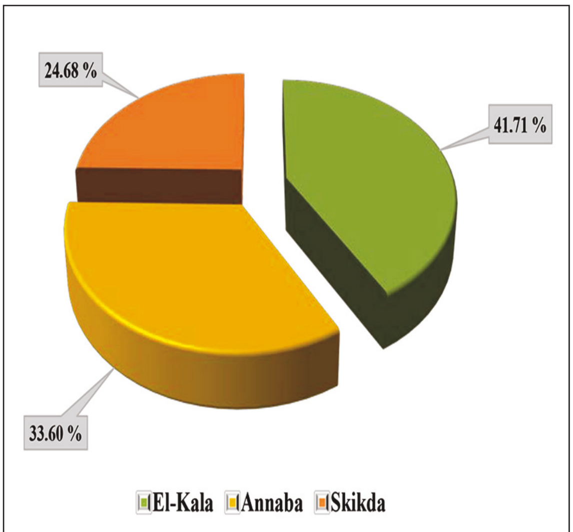

Figure 3. Relative abundance of macroinvertebrates collected in the three study sites (El-Kala, Annaba and Skikda).

Spatial and seasonal variations in the abundance of the main species

The spatial and seasonal variations in the relative abundance of the main species of aquatic macroinvertebrates are presented in Fig. 5. Only taxa identified beyond the rank of the family and

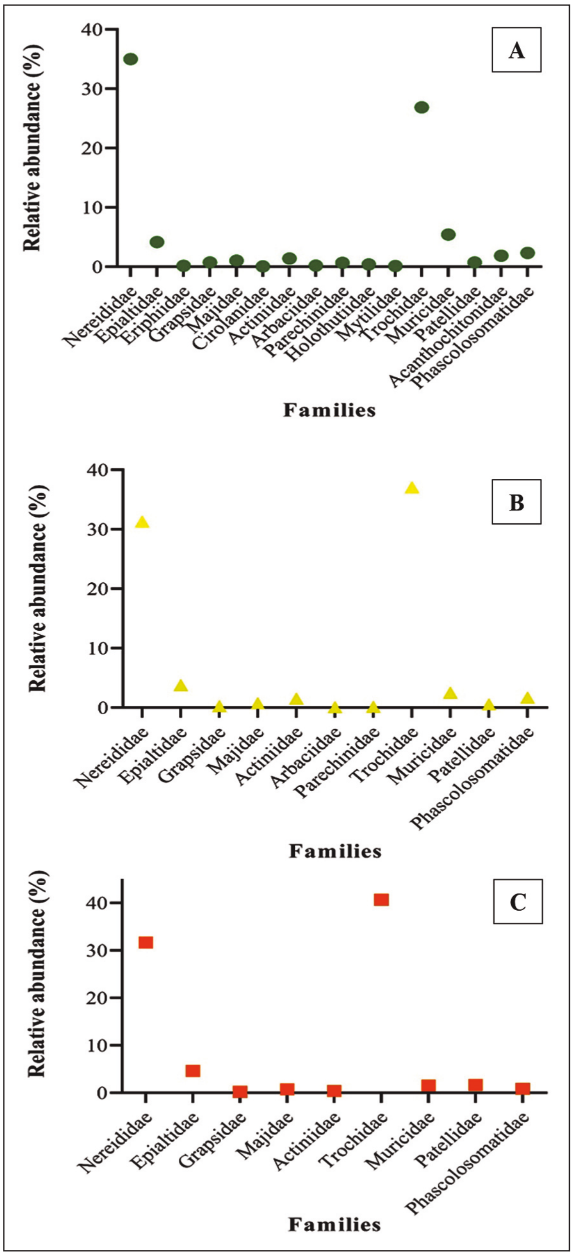

Figure 4. Spatial variations in the relative abundances of the main families of macro-invertebrates inventoried in all the sites during the study period. A: El-Kala, B: Annaba and C: Skikda.

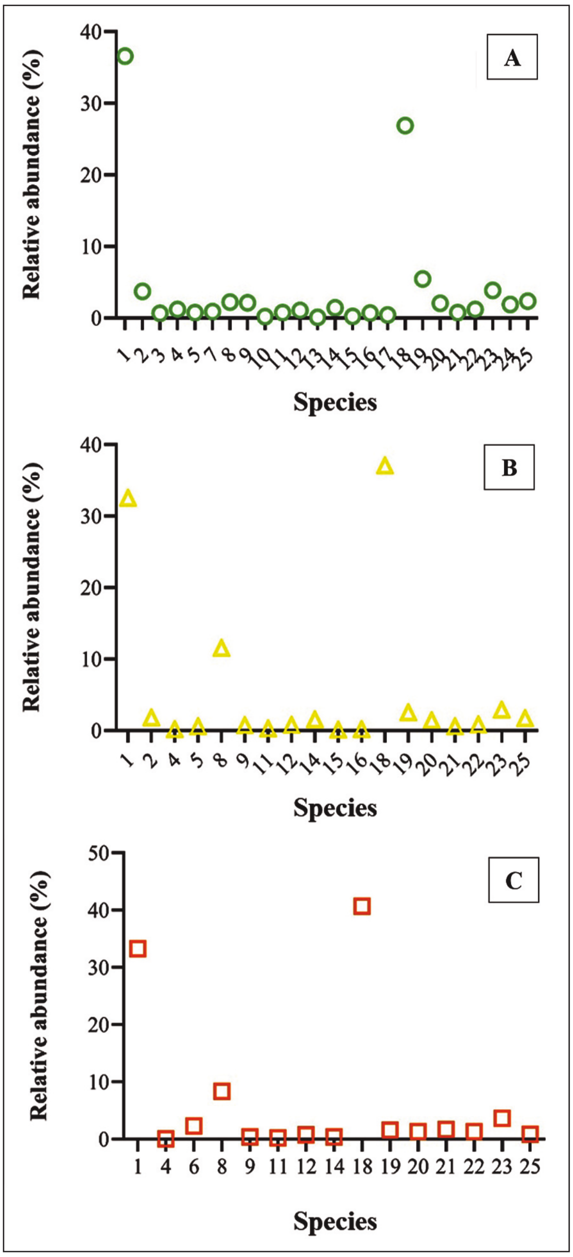

Figure 5. Spatial and seasonal variations in the relative abundance of the main macroinvertebrate species inventoried at all sites during the study period. 1: *Perinereis-cultrifera,* 2: *Perinereis floridana,* 3: *Perinereis oliveirae,* 4: *Perinereis macropus,* 5: *Perinereis marionii*, 6: *Pseudonereis anomala*, 7: *Platynereis dumerilii*, 8: *Nereis falsa, 9: Perinereis* sp., 10: *Pisa* sp., 11: *Eriphia verrucosa*, 12: *Pachygrapsus marmoratus*, 13: *Maja* sp., 14: *Eurydice pulchra*, 15: *Anemonia viridis*, 16: *Arbarica lixula*, 17: *Paracentrotus lividus*, 18: *Mytilus* sp., 19: *Gibbula* sp., 20: *Stramonita haemastoma*, 21: *Cymbula safiana*, 22: *Patella caerulea*, 23: *Patella rustica*, 24: *Acanthochitona* sp., 25: *Phascolosoma* sp. A: El-Kala, B: Annaba and C: Skikda.

representing at least 5% of the relative abundance in the considered site are taken into account in this analysis. Some species represented at the El-Kala site are not all present at the Annaba and Skikda sites throughout the study period and conversely.

At the El-Kala site, the species *Perinereis cultrifera* (36.57%), *Paracentrotus lividus* (26.88%) and *Mytilus* sp. (5.45%) dominate the stand. While at the Annaba site, it is more the *Mytilus* sp. (37.07%) and *Perinereis cultrifera* (32.56%) which are the most represented at this site. In the Skikda site, these are the *Mytilus* sp. (40.69%) and *Perinereis cultrifera* (33.25%) which are the most abundant.

Spatial and seasonal variations in the Shannon-Weaver diversity index and Piélou index

Overall, the Shannon-Weaver diversity index (H' = 3.11 bits/ind) and Piélou fairness (J' = 0.65) are higher in the El-Kala site (La Montagne) (Table 4) and weak in the other sites. The Annaba site is in second position with H' = 2.58 bits/ind. and J' = 0.54. The Skikda site is the least diverse (H' = 2.42 bits/ind and J' = 0.50) (Table 4, Fig. 6).

The Kruskal-Wallis H test ($p < 0.05$) revealed that the Shannon-Weaver diversity index and fairness were not significant ($p = 0.56$) at each site.

Similarity/dissimilarity of macrobenthic communities between the different sites

The rates of taxonomic resemblance between the macrobenthic populations collected in the different sites are presented in Table 5. The taxa listed at the Annaba and Skikda sites have a similarity rate of 85.71%. However, these taxa are dissimilar to those found at the El-Kala site, with similarity coefficients of 84.44% for El-Kala and Annaba and 71.42% for El-Kala and Skikda (Table 5).

DISCUSSION

The chemical and biological processes influence the quality of seawater. The study of marine ecosystems is based on the measurement of complementary physicochemical parameters as well as on the presence or absence of microorganisms (Rodier, 1996), the literature confirms that these parameters influence the functioning of aquatic ecosystems.

	El-Kala	**Annaba**	**Skikda**
Nt (ind.m^{-2})	2180	1756	1290
H′	**3.11**	2.58	2.42
J'	**0.65**	0.54	0.50

Table 4. Total abundance (Nt), Shannon-Weaver (H') and Piélou indices (J') of aquatic macroinvertebrates in the three study sites in 2019.

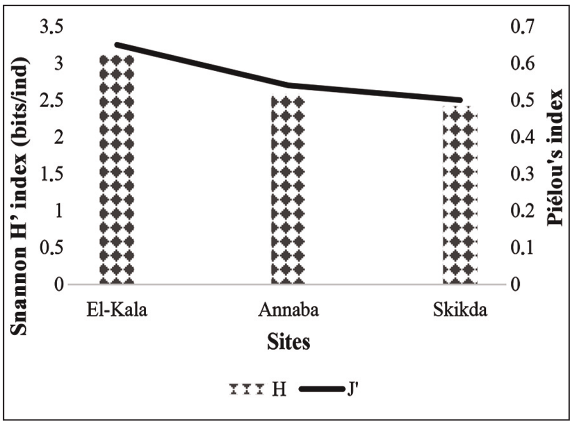

Figure 6. Spatial variations of the Shannon-Weaver diversity and Piélou's indices.

	El-Kala	Annaba
Annaba	**84.44**	
Skikda	**71.42**	**85.71**

Table 5. Values of the Sörensen coefficient of similarity (%) between the macrobenthic communities collected at the different sampling sites during the study period.

Examination of the recorded temperature values reveals that the lowest values are recorded in winter and autumn and the highest in spring and summer. However, ocean currents can supply regions with cold water masses (Agoumi & Orbi, 1992). Temperature is an important ecological factor, it plays a fundamental role in the distribution of species and the limitation of certain biological activities (Rodier, 1996). In addition, the temperature variation has effects on all the other parameters measured such as the pH and the level of dissolved salts. Temperature and its interaction with other abiotic factors, such as water speed, oxygen rate, etc. determined distribution patterns of macro-benthos and other organisms Ekau et al. (2010). The increase in temperature together with other factors favors primary productivity and therefore an increase in food for aquatic fauna (Bremond & Vuichard, 1973). In the three study sites, the results obtained show variation at the site level, and the average temperature at La Montagne is higher than that of the other stations. The results obtained correspond with the work carried out on the Algerian coast by Rouibah et al. (2005), where they recorded a temperature value in a reference station higher than that of the contaminated station.

The pH is one of the parameters physico-chemicals that conditions the aquatic environment, and influences a large number of biological and chemical processes (Pezo et al., 1985). The data collected does not show a significant variation between the three sites, and presents generally similar values, the alkalinity of the different study sites teaches a good quality of the environment for biodiversity and the production of aquatic fauna. The sightings were reported at El-Kala (Benchikh, 2009; Allouti, 2011), at the level of the Gulf of Annaba (Sifi, 2009), at the site of Skikda (Bentayeb & Mechtouf, 2007; Allouti, 2011), from the coast of Algiers (Rouibah et al., 2005; Bachari-Houma, 2011). These results have also been highlighted by other authors who have previously studied this zone (Kaimoussi et al., 2001).

Salinity refers to the amount of salts dissolved in a liquid; sodium chloride (NaCl) is just one of the many salts that make up a solution. This is the essential character of seawater, but there are, inland, bodies of water and soils totally independent of the present sea, which derive their salinity directly from the sea lithological substratum (Lamotte, 1971). The results obtained from measurements of the salinity carried out during the study period shows a decrease in salinity in the month of September and October at the El-Kala site. This variation obtained between the winter and summer period is due to the combined action of high temperatures, which generate heavy evaporations and reduced precipitation (Soucek, 2007).

Dissolved oxygen is consumed during the heterotrophic oxidation of matter organic, and respiration by fauna, and aquatic flora. The amount of dissolved oxygen in water is necessary for aquatic life and the oxidation of organic matter essential to aquatic life as food (Tran et al., 2001; Tran et al., 2002). The dissolved oxygen in seawater at La Montagne sites is relatively high compared to the other sites studied, this could be explained by the movements of the tide, which generates a continuous stirring of the body of water and therefore an enrichment of the dissolved phase. Our results are in agreement with those found in the Bay of Algiers by Bachari-Houma (2011), and in the Oran coast during the period autumn by Rouane-Hacene (2013). Low oxygen values were recorded in the Annaba and Skikda sites.

Our results are in the same direction as other studies carried out at the level of different localities on the East Algerian coast, where the monitoring of the physico-chemical parameters of seawater shows the existence of the following seasonal variations. Concerning the temperature two major thermal periods have been reported: one hot thermal period corresponding in Spring and Summer, and the other cold thermal period in Autumn and Winter. The salinity values were minimum in Winter, and maximum in Summer with regard to dissolved oxygen, the high levels were recorded in the cold period while low levels were observed in hot weather; pH values revealed a neutral to slightly alkaline medium; these observations were reported on the coast of Skikda, Annaba, and El-Kala (Snani, 2016).

Biodiversity is essential in environmental assessment through the use of bioindicator species. The study of marine biodiversity within species and between species, as well as that of ecosystems will be of great use for species of commercial or ecological interest or for the protection of nature (Rouabah & Rouabah, 2007). Several authors have noted a remarkable diversity of coastal marine ecosystems in the Mediterranean (Ballesteros, 2003). This diversity as well as the richness of these ecosystems allow the proliferation of wildlife. Polychaetes are often important components of any benthic community (Papageorgiou et al., 2006). The examination of the inventories carried out on the different populations of fauna at the level of the three sites during the study period allowed us, on one hand, to determine the qualitative composition represented by a taxonomic list detailing the different taxa and their presence, while on the other hand, all the samples are analyzed to the quantitative structure using the various ecological indices. The biotope analysis allowed us to identify several species of aquatic fauna characteristic of each site. The animal species are divided into 6 phylum (Annelida, Arthropoda, Cnidaria, Echinodermata, Mollusca and Sipincula) at the level of the three study sites (El-Kala, Annaba and Skikda. In terms of distribution and abundance of the species concerning these 6 phylym , the polychaete Annelids dominate there, but the Molluscs and the Arthropods are also very common, the association between these three branches is rather traditional (Ayari & Afli, 2003).

The goal of calculating the most widely used ecological indices of diversity, namely the index of Shannon-Weaver (H’) and Piélou index J’ is the state’s estimate of the numerical balance of the stands. Our results show a higher H’ at the El-Kala site compared to those of Annaba and Skikda, correlated with the dominance of different species present at each site. In general it is accepted that the values of H’ are zero when the sample contains only one species, while the values of H’ are high when the individuals are distributed among different species, that correspond to a sample balanced and diverse, however, it should be noted that the values of H’ also vary in function of the logarithm chosen; to interpret such results. Grimes (2010) considered a scale of 4 following classes: H ’<1.5 => very unbalanced; H ’varies between [1.5-2.5] => unbalanced; between [2.5-4] => balanced; H ’> 4 => very balanced, thus underlining a (H’) balanced at the level of El-Kala and Annaba, versus one unbalanced at the level of Skikdar. As for the data relating to the Piélou index, Grimes (2010) also proposed a scale relating to this index of 4 following classes: J ’<0.4 => very unbalanced; I vary from [0.4-0.6] => unbalanced; from [0.6-0.8] => subnormal; of [0,8-1] => normal, which therefore leads us to propose that the stands of the El-Kala site present an unbalanced distribution, compared to those of the two sites Annaba and Skikda which are subnormal.

CONCLUSIONS

The diversity, structure and determinism of populations of benthic macroinvertebrates were studied in three sites on the East-Algerian coast.

Analysis of abiotic variables showed that the El-Kala site has water of very good ecological quality with high temperatures and good oxygenation comparing it to the two other sites (Annaba and El-Kala).

The El-Kala site is the most diverse with 26 taxa divided into 6 branches, 9 classes, 14 orders and 17 families. The Polychaete class is the most diverse with 8 taxa. The high values of the Shannon-Weaver diversity index and Piélou equitability in the El-Kala site confirm that the La Montagne macroinvertebrate community is well diversified and well structured compared to the other two stations (Rezgui-Rachid and Bikini).

REFERENCES

Agoumi A. & Orbi A., 1992. Evolution météorologique et Upwelling le long de la côte atlantique marocaine. Hydroécology Application, 4: 149–158.

Allouti N., 2011. Etude biologique de deux néreidés: *Pernereis cultrifera* et *Nereis falsa* (Annélides, Polychètes) dans l'est algérien (El-Kala): cycle de reproduction, activité biochimique et enzymatique. Mémoire de magister. Option: Ecotoxicologie. Université d'Annaba, 87 pp.

Ayari R. & Afli A., 2003. Bionomie benthique de petit golfe de Tunis. Bulletin INSTM de Salammbô, 30: 79–90.

Bachari-Houma F., 2011. Monitoring et étude de la pollution dans les eaux marines et lessédiments superficiels de la côte algéroise: modélisation et impact sur l'environnement. Ecole Nationale Supérieure des Sciences de la Mer et de l'Aménagement du Littoral, 23 pp.

Bachari-Houma F., 2011. Monitoring et étude de la pollution dans les eaux marines et les sédiments superficiels de la côte algéroise: modélisation et impact sur l'environnement. Ecole Nationale Supérieure des Sciences de la Mer et de l'Aménagement du Littoral, 23 pp.

Ballesteros E., 2003. The coralligenous in the Mediterranean. RAC-SPA editor, Tunisia. 104 p. (under press).

Benchikh N., 2009. Etude de la croissance et cycle de reproduction de la moule *Perna perna* dans le golf d'Annaba et le littoral d'El Kala. Thèse de Magister, Université BadjiMokhtar-Annaba, 99 pp.

Bentayeb I. & Mechtouf M., 2007. Evaluation du niveau de pollution des effluents ducomplexe de raffinage de Skikda (RA1K). Mémoire d'ingénieur d'état en Ecologie et Environnement. Université de Constantine, 125 pp.

Bremond R. & Vuichard R., 1973. Paramètres de la qualité des eaux, Ministère de la protection de la nature et de l'environnement, SPEPE, Paris, 179 pp.

Coll M. Piroddi C., Albouy C., Ben Rais Lasram F., Cheung W.W.L. & Christensen V., 2012. The Mediterranean Sea undersiege: spatial overlap between marine biodiversity, cumulative threats and marine reserves. Global Ecology and Biogeography, 21: 465–480.

Ekau W., Auel H., Portner H.O. & Gilbert D., 2010. Impacts of hypoxia on the structure and processes in pelagic communities (zooplankton, macro-invertebrates and fish). Biogeosciences, 7: 1669–1699.

Froglia C., Galil B.S., Gasol J.M., Gertwagen R., Gil J., Guilhaumon F., Kesner-Reyes K., Kitsos M., Koukouras A., Lampadariou N., Laxamana E., de la Cuadra C.M., Lotze H.K., Martin D., Mouillot D., Oro D., Raicevich S., Rius-Barile J., Saiz-Salinas J., San Vicente C., Somot S., Templado J., Turon X., Vafidis D., Villanueva R. & Voultsiadou E., 2010. The Biodiversity of the Mediterranean Sea: Estimates, patterns, and threats. PLoS ONE, 5(8) 11842: 1–334.

Gerovasileiou V. & Voultsiadou E., 2012. Marine caves of the Mediterranean Sea: a sponge biodiversity reservoir within a biodiversity hot spot. PLoS ONE,7 (7): 39873: 1–17.

Grimes S., 2010. Peuplements benthiques des substrats meubles de la cote algérienne: Taxonomie, structure et statut écologique. Thèse de Doctorat en Sciences de l'Environnement, option: Biologie et Pollution Marines. Université d'Oran, 362 pp.

Kaimoussi A., Chafik A., Mouzdahir A. & Bakkas S., 2001. The impact of industrial pollution on the Jorf Lasfar coastal zone (Morocco, Atlantic Ocean): the mussel as an indicator of metal contamination. Les Comptes Rendus de l'Académie des sciences de Paris, 333: 337–341.

Lamotte M., 1971. Ecologie animale organismes et milieu. Doin Editeurs, sixième édition française.

Liquete C., Piroddi C., Macías D., Druon J.N. & Zulian G., 2016. Ecosystem services sustainability in the Mediterranean Sea: assessment of status and trends using multiple modelling approaches. Scientific Reports, 6 (34162): 1–14.

Moisan J. & Pelletier L., 2008. Guide de surveillance biologique basé sur les macroinvertébrés benthiques d'eau douce du Québec - Cours d'eau peu profonds à substrat grossier. Direction du suivi de l'état de l'environnement, Ministère du Développement Durable, de l'Environnement et des Parcs, 86 pp.

Papageorgiou N., Arvanitidis C. & Eleftheriou A., 2006. Multicausal environmental severity: a flexible framework for microtidal sandy beaches and the role of polychaetes as an indicator taxon. Estuarine Coastal and Shelf Science, 70: 643–653. https://doi.org/10.1016/j.ecss.2005.11.033

Pezo R., Maco J. & Canepa J., 1985. Ambiental por actividades petroleras en lors ri' ospastaza, Tigre, Corrientes, Samiria y Amazonas. Instituto de investigaciones de la Amazonia peruana (IIAP), Iquitos, Peru, 59 pp. In: Loayza-Muro R. and Elías-Letts R., 2007. Responses of the mussel *Anodontites trapesialis* (Unioniae) to environmental stressors: Effects of pH, temperature and metals on filtration rate. Environmental Pollution, 149: 209–215.

Ramade F., 2003. Eléments d'écologie: Ecologie fondamentale. Edit. Dunod, Paris, 308–320 pp.

Rodier J., Bazin C., Broutin J.P., Chambon P., Champsaur H. & Rodier L., 1996. L'Analyse de l'Eau (8ème Ed). Paris, Dunod, 1384 pp.

Rouabah A. & Rouabah L., 2007. Biodiversité et complexe d'espèces *Perinereis cultrifera*: un exemple de spéciation. Sciences et Technologies, 25: 79–87.

Rouane-Hacene O., 2013. Biosurveillance de la qualité des eaux côtières du littoral occidental algérien, par le suivi des indices biologiques, de la biodisponibilité et la bioaccumulation des métaux lourds (Zn, Cu, Pb et Cd) chez la moule *Mytilus galloprovincialis* et l'oursin *Paracentrotus lividus.* Thèse présentée pour l'obtention du diplôme de Doctorat en Biologie, Université d'Oran, 295 pp.

Rouibah M., Boulahdid M., Boudjellal B., Eddalia N. & Ounadi F., 2005. Etude de la pollution du littoral Algérois et du lac de Reghaia. Par l'APPL, ISMAL, 73 pp.

Sifi K., 2009. Biosurveillance de la qualité des eaux du golfe d'Annaba: croissance, composition biochimique et dosage de biomarqueurs du stress environnemental chez *Donax trunculus* (Mollusque, Bivalve). Thèse de Doctorat en Ecotoxicologie, Université d'Annaba, 140 pp.

Snani M., 2016. Etude comparative de la reproduction d'un bioindicateur de pollution, *Perinereis cultrifera* (Annelide, Polychète) du littoral nord-est algérien et des côtes de la manche française "aspects morpho-anatomiques, génétiques, immunologiques et activités enzymatiques". Thèse de Doctorat en Biologie Animale Environnementale, option: Reproduction & Développement. Université d'Annaba, 218 pp.

Soucek D.J., 2007. Sodium sulfate impacts feeding specific dynamic action, and growth rate in the fresh water bivalve *Corbicula fluminea.* Aquatique Toxicology, 83: 315–322.

Tachet H., Richoux P., Bournaud M. & Usseglio-Polatera P., 2010. Invertébrés d'eau douce: systématique, biologie et écologie. CNRS édition, Paris, France, 588 pp.

Tran D., Boudou A. & Massabuau J., 2001. How water oxygenation level influences cadmium accumulation pattern in the asiatic clam *Corbicula fluminea*: a laboratory and field study. Environmental Toxicology and Chemistery, 20: 2073–2080.

Tran D., Boudou A. & Massabuau J., 2002. Relationship between feeding-inducedventilatory activity and bioaccumulation of dissolved and algal-bound cadmium in the asiatic clam *Corbicula fluminea*. Environmental Toxicology and Chemistery, 21: 327–333.