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Assessment of the coastal and estuarine environment quality of western Algeria using the bioindicator Polychaeta; the genus Nereis.

F. Kies[1,2*], A. Kerfouf[1], I. Elegbede[3], S. Matemilola[4], P. De Los Rios Escalante[5], A. Khorchani[1], S. Savari[6]

[1]*Department of Environmental Sciences, University Djilali Liabès of Sidi Belabess, Algeria*
[2] *Department of Earth and Environmental Sciences, Università Degli Studi di Milano-Bicocca, Milan, Italy*
[3] *Department of Environmental Planning, Brandenburg University of Technology, Cottbus-Senftenberg, Germany*
[4] *Department of Public Law concerning the Law of Environment and Planning, Brandenburg University of Technology, Cottbus-Senftenberg, Germany*
[5] *Laboratorio de Ecología Aplicada y Biodiversidad, Escuela de Ciencias Ambientales, Facultad de Recursos Naturales, Universidad Católica de Temuco, Casilla 15-D, Temuco, Chile*
[6] *Khorramshahr Marine Science and Technology University, Iran*

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f.kies@campus.unimib.it ;
Phone: +393396658327

Abstract

This study was carried out in the Cheliff estuary and adjacent coastal areas to determine in particular the impact of environmental stress on the biodiversity of the Western-Algerian littoral Polychaeta, with the motive to analyze the health status of the marine ecosystem as bio-indicator species of pollution. Monitoring took place in five stations (Sokhra, Hadjaj, Salamandre, and Sonactere) during the wet and dry seasons in 2014 respectively, including Cheliff estuary as a reference site and the other four coastal sites. We detected in total, four taxa comprising 392 individuals. The taxa having the highest frequency rate were *Nereis virens* (62%), *Nereis diversicolor* (58%), *Nereis falsa* (43%), and *Nereis pelagica* (51%). We noted low Polychaeta abundances in Sokhra and Hadjaj stations, in the Eastern area of Cheliff Estuary with a high pH, OS, DO, and Chlorophyll "a". Cheliff Estuary has high nutrients, *N. diversicolor*, and *N. virens* values. The sites Salamandre and Sonactere in the Western part of the Cheliff Estuary have high BOD, COD, PO_4, suspended solids, turbidity, *N. pelagica*, and *N. falsa*. The data monitoring and analysis of the stations based on similarities of Annelida communities show the link between the components of the environment and the biodiversity abundance.

1. Introduction

Estuaries and adjacent coastal areas occupy a considerable zone along the coast of the Mediterranean countries, including Algeria [1, 2]. The physical structure and the ecological functioning of the estuarine environments are influenced by the marine environment, while the continental domain constitutes their sources of water and other resource inputs [3]. The situation encountered makes it challenging to classify estuaries and coastal ecosystems in terms of their biological diversity and ecological status, which is dependent on the "land-sea" interface [4]. In the Mediterranean Sea, estuaries, and coastal areas are essential for tourism leading to economic and ecological issues. They are increasingly subject to pollution because of escalating human population growth, accompanied by urbanization and industrialization [5, 6, 7]. Consequently, estuary and coastal water qualities, and their aquatic ecosystem structures with functions have been severely impaired. Their responses to the water, sediment quality changes, and hydrogeological structures, also act as stressors to different species such as Annelids and their biota [8]. However, these require an Integrated Coastal Zone Management approach as a basis for sustainable coastal spatial planning [9, 10, 11, 12].

The Polychaeta is one of the biological keys to detect any disturbance of the ecological system. Annelida are essential indicators of estuaries and coastal ecosystem health, and the absence or presence of some species can give information about the water quality status [13,14]. Biomonitoring potential has been recognized as suitable criteria for understanding the quality of the aquatic environment [15]. According to the Water Framework Directive WFD (Directive 2000/60/ CE 2000) [16], the surface of the estuary and coastal waters should be assessed by the usage of the biological quality under the concept of Ecological Quality Status (EQS) [17].

These form abundant biological populations in the mud sediments and constitute essential elements of trophic chains, which are widely consumed by Crustaceans and juvenile fish. Also, they are considered as good water quality indicators controlling their dynamics [14]. The Cheliff estuary and coastal waters (figure 1) were chosen for this study due to their high anthropogenic impact, and there has been insufficient research on how the various activities affect the ecology of these areas. Previous studies have been conducted on these species in Eastern Algeria [18, 19, 20, 21, 22, 23]. Many authors have studied the impact of pollution on the biochemistry of Polychaete organisms. They used many species as bioindicators of pollution [24, 25, 26, 27, 28, 29]. The Cheliff River, which drains an urbanized and industrialized catchment in the Western Basin of Algeria [15], is no exception. An integrated environmental water quality (EWQ) approach is needed to measure the impacts of deteriorating water quality on its marine ecosystem structures and functions to sustain these vital ecosystem-attributes. In this study, we adopted an integrated EWQ approach, which includes *i*) the analysis of water physicochemical variables; *ii*) Annelida-based community behavior analysis.

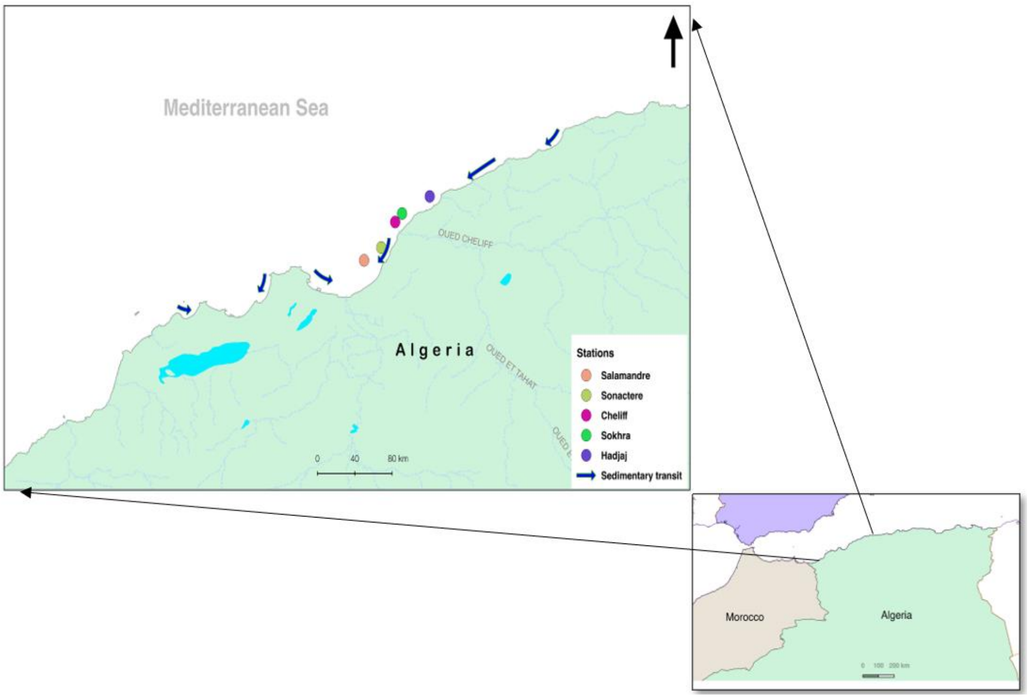

Figure 1. Polychaeta localization in the Western-Mediterranean coasts and estuaries

The study targets the evaluation of some of the Polychaeta communities including four taxa; *i*) *Nereis pelagica* (Linnaeus, 1758), *ii*) *Nereis (Hediste) diversicolor* (Müller, 1776), *iii*) *Nereis virens* (Sars, 1835), and *iv*) *Nereis falsa* (Quatrefages, 1866). The critical justification of choosing these species is to determine the critical water quality indicators along the Cheliff Estuary and coastal water in Algeria; mainly using various physical-chemical parameters and biodiversity abundance, recommending a risk-based selection of biodiversity components to assess the biodiversity state of a sensitive Algerian region including Cheliff Estuary.

2. Material and Methods

2.1. Sampling and selection of stations

Different Annelida species including *Nereis pelagica* (Linnaeus, 1758), *Nereis (Hediste) diversicolor* (Müller, 1776), *Nereis virens* (Sars, 1835), and *Nereis falsa* (Quatrefages, 1866) have been located in the Mediterranean coasts and estuaries [30, 31]. The *Nereis Polychaeta* of the coastal region were collected in five stations (figure 2) during the wet (from January to April and from November to December) and dry (from Mai to October) seasons in 2014, respectively. These areas were differently influenced by hydrological and terrigenous inputs of the Cheliff river's watershed. The stations are placed (figure 2) according to a reasoned sampling plan. The sampling areas were selected based on the coastal current direction, which controls the water quality status level and the biodiversity abundance status (Polychaetes in our case). The Cheliff station represents the Cheliff inlet, while the Sonactere and Salamandre stations are located west of the Cheliff inlet, and the Sokhra and Hadjadj stations are located east of the mouth of Cheliff river. The positioning, the depth, and the nature of the bottom of all these stations are shown in figure 2.

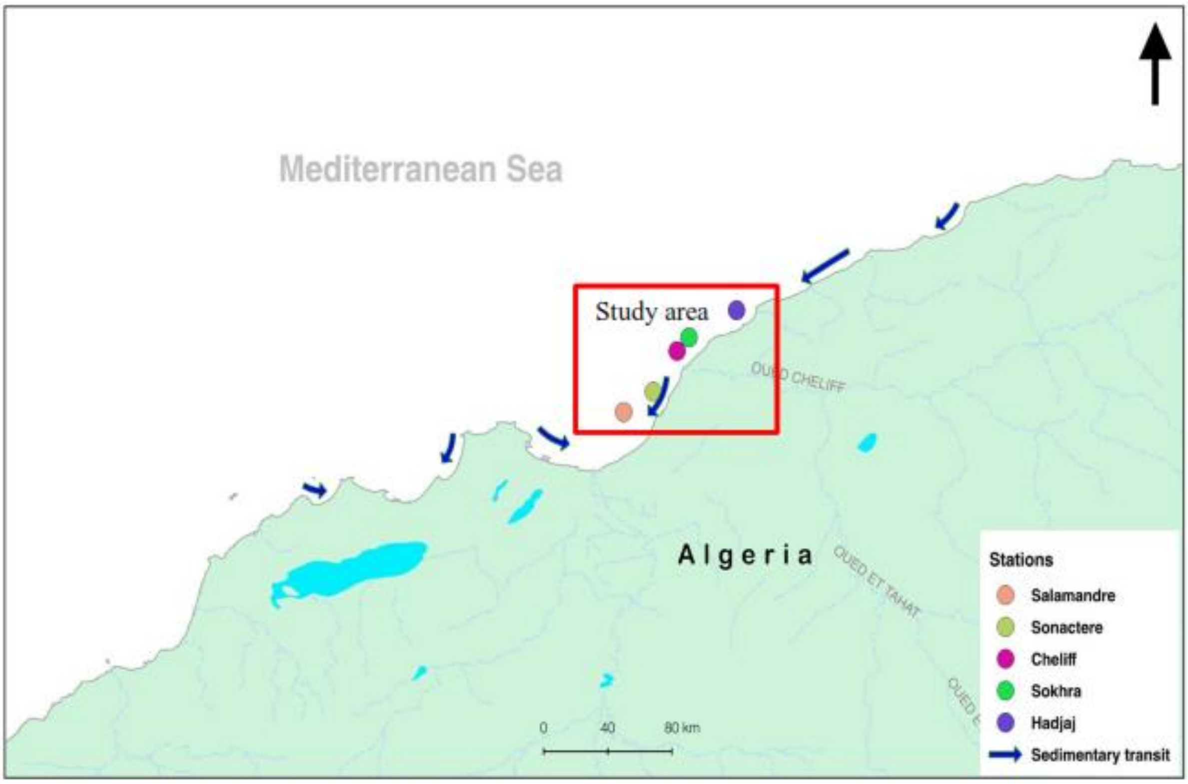

Figure 2. Map of the studied sites on Western Algeria with the Geographical characteristics of the stations surveyed.

The location of the sampling area is between 35°55' N-36°11' N Latitude and 00°02' W-00°17' W Longitude. The sediment nature of the different sampling sites varies between Silty (2<d<63 µm) and gravel (d<200 µm). In general, our results are close to those of Kerfouf et al., 2007 [32], which indicated that the Gulf of Oran is majority sandy (table 1).

Table 1. Sampling sites descriptions

Name	Latitude	Longitude	Nature	Diameters (µm)	Fraction %
Salamandre	35°55'N	00°02'W	Sand (fine and coarse)	63<d<200	74
Sonactere	35°59'N	00°03'W	Silt	2<d<63	87
Cheliff	36°05'N	00°07'W	Clay-mud	d<63	89
Sokhra	36°07'N	00°09'W	Gravel	d<200	57
Hadjaj	36°11'N	00°17'W	Sand (fine and coarse)	63<d<200	68

2.2. Sampling and analysis of physicochemical parameters

Sampling was done for the wet and dry season in 2014, respectively. The sampling point selection was based on periods of River-Sea connectivity depending on the flow system, to capture distinct changes in land use. Cheliff estuary area is very sensitive. It is influenced by the coastal current which transports and distributes the sediment, biodiversity, and water mass.

Water samples were about 30 cm to 50 m deep from the surface and were collected following AFNOR (Association Française de Normalisation) guidelines to obtain a representative sample [33]. Sample transport, preservation, and maximum holding periods proposed by the AFNOR guidelines were adapted for this research. Five sampling stations were selected and described in figure 2 and table 1. The laboratory analyses of the different chemical elements were undertaken according to AFNOR guidelines.

2.*3. Data analysis*

All the statistical analyses considered in this research, including correlation analysis, were applied using Microsoft Office Excel and the software R [34]. To further determine the main grouping variables, a Principal Component Analysis (PCA) data matrix was applied using the HSAUR R package [35]. Niche sharing analysis for Polychaeta data was applied, using EcosimR [36].

3. Results and discussion

The sample size of each species has been indicated for every station by season in table 2. The highest values were noted within the wet season with the utmost species in December. Site Cheliff estuary features a high *N. diversicolor* and *N. virens* values (max: 9, 11 species). Sonactere features a high abundance of *N. pelagica* not exceeding 8 species. Salamandre features a high *N. falsa* value (max: 7 species). The species collected within the sites Sokhra and Hadjaj have not any Polychaeta abundances (max: 4 species).

Results of the PCA performed for the physicochemical and biological parameters of the studied sites. Sites Sokhra and Hadjaj have low polychaete abundances, but high pH, OS, DO chlorophyll "a" and latitude. Site Cheliff estuary has high SiO_2, NH_4, NO_2, and NO_3 *N. diversicolor* and *N. virens values*. Salamandre and Sonactere have high BOD, COD, PO_4, suspended solids, turbidity, and abundance of *N. pelagica* and *N. falsa* (figure 3, table 3).

Table 2. sample size for each specie/station/season during the year 2014. Sal: Salamandre; Son: Sonactere; Ch: Cheliff estuary; Sok: Sokhra; and Had: Hadjaj.

Species	Seasons	Stations				
		Sal	Son	Ch	Sok	Had
N. diversicolor	Wet	3.33 ± 1.63	3.67 ± 1.63	4.67 ± 2.88	2.17 ± 1.17	2.00 ± 1.41
	Dry	0.17 ± 0.41	0.50 ± 0.55	0.50 ± 0.55	0.17 ± 0.41	0.17± 0.41
N. virens	Wet	3.00 ± 1.41	4.33 ± 2.34	5.00 ± 3.63	3.33 ± 1.75	1.17 ± 0.75
	Dry	0.17 ± 0.41	0.33 ± 0.52	0.50 ± 0.84	0.33 ± 0.52	0.17 ± 0.41
N. falsa	Wet	3.50 ± 1.41	3.17 ± 2.48	2.83 ± 1.72	2.67 ± 0.82	2.67 ± 0.75
	Dry	0.33 ± 0.52	0.17 ± 0.41	0.33 ± 0.52	0.17 ± 0.41	0.17 ± 0.41
N. pelagica	Wet	2.33 ± 1.75	4.33 ± 3.01	2.50 ± 0.84	1.50 ± 1.22	2.00 ± 1.41
	Dry	0.17 ± 0.41	0.17 ± 0.41	0.17 ± 0.41	0.17 ± 0.41	0.33 ± 0.52

Table 3. Results of PCA, % contribution of variables. (* corresponding to main contributor variables for respective axis).

	Axis 1	Axis 2
Latitude	-0.13134337	-0.32285417*
Temperature	-0.09632254	0.35198510*
pH	-0.29063767*	0.11695414
Turbidity	0.28640544*	0.09483034
Suspended solids	0.27546571*	0.09483034
DO	-0.28778310*	0.02860306
OS	-0.27641592*	0.05577088
BOD	0.12987322	0.40140900
COD	0.12342219	0.40448400*
NO_3	0.29548560*	-0.08731403
NO_2	0.23049280*	-0.28339433*
NH_4	0.21470742	-0.30916874*
SiO_2	0.22935553	-0.28914028*
PO_4	0.20500567	0.18072309
Chl.*a*	-0.20892112	-0.05833627
Nereis diversicolor	**0.29443755***	**-0.08678460**
Nereis falsa	**0.13405576**	**0.21131256**
Nereis virens	**0.27850797***	**0.09526788**
Nereis pelagica	**0.18088077**	**0.21739028**

Sites Sokhra and Hadjaj have low polychaete abundances, but high pH, OS, DO chlorophyll "a" and latitude. Site Cheliff estuary has high SiO_2, NH_4, NO_2, and NO_3 *N. diversicolor* and *N. virens* values. Salamandre and Sonactere have high BOD, COD, PO_4, suspended solids, turbidity, and abundance of *N. pelagica* and *N. falsa* (figure 3, table 3). The results revealed that reported species do not have niche overlap, and in consequence, would have not interspecific competence. ($P < 0.05$).

The sites -located at East of the Cheliff Estuary with high oxygen and chlorophyll levels have no Polychaeta abundances (figure. 3). The reported species would be at different environmental parameters (table 3) probably owing to *i*) the spring bloom in May and autumn bloom in November [37] *ii*) the weak sedimentary transit depending to the wave attacks in these zones, forming different nature of sediment which was Gravel in Sokhra site (57%) and Sand fine and coarse (68%) in Hadjaj site (table 1), *iii*) to the high depths in the Eastern coast comparing to the center and western part, and finally, *iv*) to the vigorous artisanal fishing activities in these areas which mainly use Annelida for this coastal activities according to our interview with the fishermen.

In the Cheliff Estuary, *N. diversicolor* and *N. virens* are associated with high SiO_2, NH_4, NO_2, and NO_3 values (figure 3), probably owing to *i*) the increases in nutrient concentrations (N, P, and Si) depending on the flow of water resources in the Cheliff Basin and soil leaching [38] which are high in wet periods (winter mixing in December) and are low in dry periods (May), *ii*) the strong sedimentary transit depending to the healthy coastal circulation (winter mixing in December and summer upwelling-stratification in August) in this zone, forming the nature of muddy sediment (89%) in the Cheliff Estuary site (table 1), *iii*) to the low depths in the estuary area comparing to the Eastern and western part, and finally, *iii*) to the richness of this area with Annelida predators species such as shrimps (red, white, and grey), lobsters and langoustines.

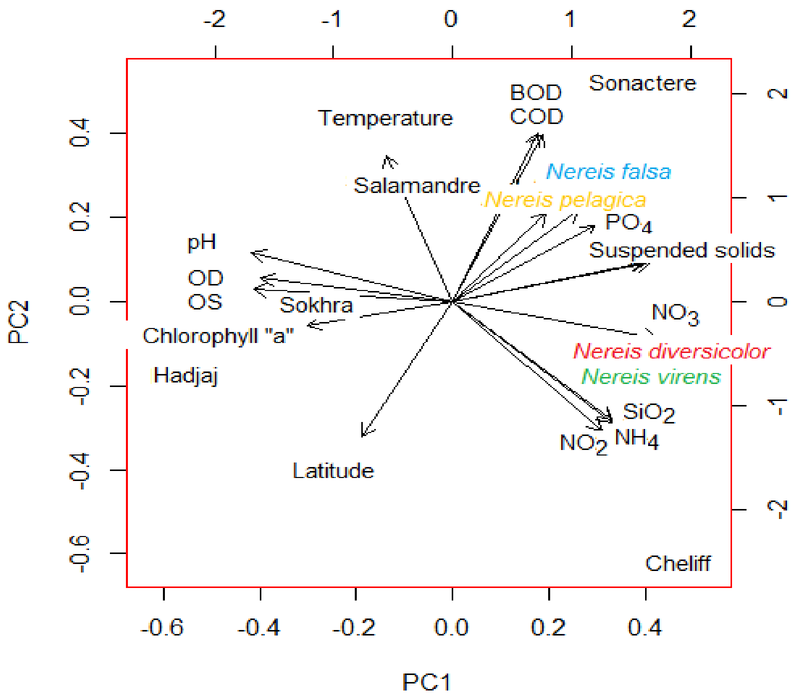

Figure 3. Results of the PCA performed for the physicochemical and biological parameters of the studied sites.

Table 4. Results of null model niche sharing for studied sites.

Mean Index	Observed index	The variance of the simulated index	P
0.55514	0.38959	0.002187	0.00600*

In the sites located at West of the Cheliff Estuary, *N. pelagica* and *N. falsa* are associated with high BOD, COD, PO4, turbidity, suspended solids, and turbidity values (figure 3). probably owing to *i*) the robust sedimentary transit depending to the wave attacks in these zones (figure 2), forming Silty sediment in the Sonactere site (78%) and Sandy (fine and coarse) sediment (74%) in Salamandre site (figure 2, table 1), *ii*) the increases in suspender and organic matter concentrations (BOD, COD, PO_4, turbidity, suspended solids, and turbidity) linked to the flow of water resources in the Cheliff Basin and soil leaching, and which are high in wet periods and are low in dry periods [15], because the two sites are close to Cheliff Estuary zone (less than 15 km), *iii*) combined with the very high anthropic impacts due to the socioeconomic activities implemented in the coastal region -especially in the last decades-, such as tourism [39-40], agri-food industry, marine transport, and finally, *iv*) to the richness of this area with Annelida predators species such as red mullet, whiting, sole, and ray.

The results suggest in this scenario. The reported Polychaeta species have a different ecological niche (table 4), with the Polychaeta community behavior depending on the fluxes and regulating factors [41]. This condition includes the physical-chemical impact of water quality of the Cheliff River on the coastal ecosystem [12, 15], the coastal water circulation (currents), and the intensity of fishery and industry activities in the Estuary water and Western Coast waters. Moreover, alterations to the habitat caused by the cumulation of sediment and deposition were also expected, affecting nutrient concentrations and Annelida assemblage [42, 43]. High turbidity is often a sign of pollution but can also be natural like silt, planktonic developments, and sand [15, 44, 45].

Conclusion

This article focused on the importance of Annelida for nutrient dynamics in the surface coastal waters of the Mediterranean Sea with relation to eutrophication. The degree of faunal impact on such processes varies depending on faunal assemblage and density, especially with a higher abundance of *Nereis virens* compared to other species. This study inferred that coastal marine annelids in these regions are reduced in quantities probably due to high Physico-chemical parameters and biotic factors of chlorophyll a. This situation is perhaps caused by human stressors such as domestic and agricultural activities around these coastal water bodies as eutrophication. However, it is surprising to observe some exceptions of some Annelids such as *N. pelagica*, and *N. falsa* thriving very well in regions with extreme physiological conditions. Although, the bioturbated muddy sediment increased the NH released compared to the sandy sediment that agrees with our results. The effect of aquatic macrofaunal activities on sediment-water nutrient dynamics results showed a higher N:P ratio of the sediment-water flux. Especially when the sediment-water were compared without the macro-organisms and through bioturbation loss from the aquatic organism. Ultimately, there is this study to confirm the interactions between biodiversity health and abundance with environmental factors influenced by anthropogenic stressors.

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