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The Benthic Fauna and Water Physicochemical Characteristics in the Estuarine Ecosystem of the Mouth of Moulouya River (Morocco)

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Research Article

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Abstract

Moulouya is the most important river of Morocco flowing into the Mediterranean Sea. The present study was carried out to assess the impact of anthropogenic activities on the distribution and biodiversity of benthic fauna as well as water quality in the Moulouya River estuary area, Oriental region, Morocco. Three stations at the downstream receiving anthropogenic impacts were selected along the river estuary. Physicochemical characteristics of the river water including temperature, pH, salinity, DO, conductivity, SM, Cl^-, NH_3, PO_4^{3-}, NO_3-, NH_3-N, COD and BOD were investigated. The study of the current state of the benthic fauna stationed at the mouth of the river resulted in 22 detected species distributed in 4 classes. Crustaceans were the most frequently collected with 4 inventoried types accounting for 43.5% (236/542). Molluscs represented 38.2% (207/542) of the collected specimens and *Melanopsis costellata* was the most abundant species. The investigation of the physicochemical parameters revealed water quality degradation mainly due to discharged organic matter of industrial and municipal effluents without proper treatment. The present study findings

may allow updating data regarding the taxonomic inventory of the fauna as well as highlighting the water quality status in the estuarine ecosystem of the mouth of Moulouya River (Morocco).

Keywords: Benthic fauna; Estuarine ecosystem; Physicochemical parameters; Moulouya River; Morocco

Abbreviations: COD: Chemical Oxygen Demand; EC: Electrical Conductivity; DIN: Deutsche Institut fur Normung; BOD: Biochemical Oxygen Demand

Introduction

Estuaries act as a transitional zone between land and sea are considered as fragile ecosystem with unique physical, chemical and biological features [1]. They are complex and dynamic aquatic environment receiving considerable amounts of nutrients as well as anthropogenic wastes [2]. Moulouya River, originating in the southern part of the Middle Atlas, is the second largest fluvial system of North Africa draining into the Mediterranean Sea [3]. The mouth of the river and its marsh complex constitute a Site of Biological and Ecological Interest. It used to be a refuge for numerous birds of international and national interest, as well as the habitat of privileged and extremely diversified fauna and plant formations that are exceptional for Morocco [4,5]. In this sense, the knowledge of the benthic fauna of the rivers and Moroccan water plans have been a real concern for naturalists, scientists and organisms involved in sustainable development due to its richness and diversity [6,7]. In addition to climate change, the aquatic ecosystem of Moulouya River suffers from a severe and increasing degradation due to discharge of domestic, municipal, industrial, recreational and constructional activities in the catchment areas [8-11]. This anthropic activity, exacerbated by low and uneven rainfall has a major impact on aquatic biodiversity, such as benthic fauna. Also the water physico-chemical characteristics may be greatly affected. The current study was conducted to explore and update data on the distribution and biodiversity of the benthic fauna in the Moulouya River estuary and to assess the effects of the anthropic activity on this biodiversity and water quality through measurement and analysis of physicochemical parameters.

Material and Methods

Study Area

The current study was carried out in Oriental Region, Morocco. The Moulouya watershed is the largest river basin of Morocco with a surface area of about 54,500 km^2, and covers much of the Oriental region. With a length of 520 km, Moulouya River is the largest river in Morocco. Its sources are placed in the Atlas Mountains and flows into Mediterranean Sea near the Algerian border (Figure 1). The climate of the Moulouya Basin is of a semi-arid Mediterranean type, characterized by low and irregular precipitation with an annual pluviometric index ranging from 230 to 380 mm [12]. The study was conducted in the estuary area of Moulouya River (Morocco).

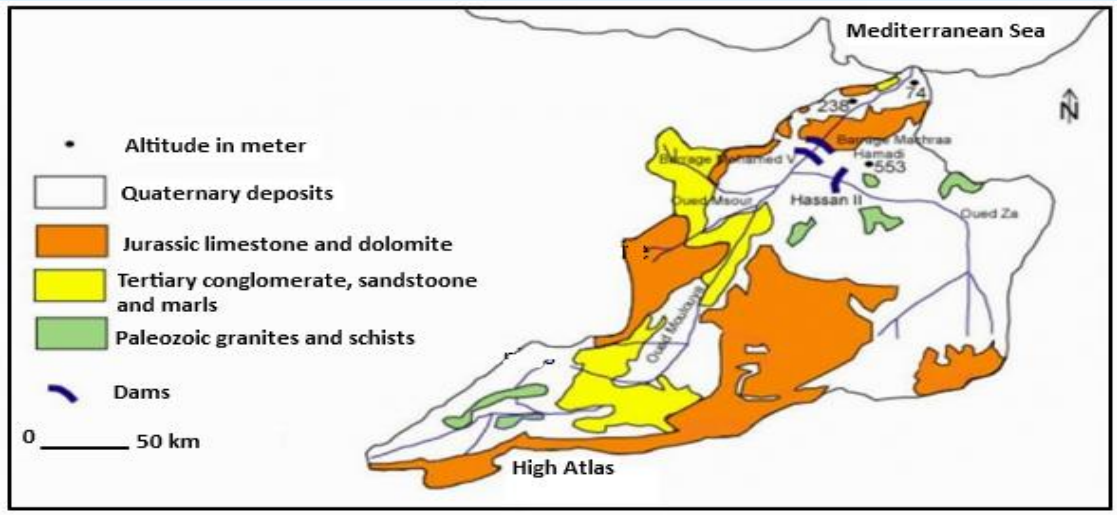

Figure 1: Geographical location of the study area (Moulouya Estuary, Morocco).

Three intertidal stations are distributed over the first 20.5 kilometers of the estuary zone and were located on the right bank (station 1 and 2) and the left bank (station 3):

- Station 1 (S1): located near a channel at 20 km upstream of the river mouth.
- Station (S2): located 10 km from the river's mouth, receiving urban and industrial liquid discharges of the city of Saïdia.
- Station (S3): located at the mouth of Moulouya River.

Sampling Materials and Methods

The sampling material used in the conducted study was a modified Juday-bogoroff's net [13,14], with a conic shape and 120 CMs length, fixed to posterior and anterior metallic rings with respective diameters of 32 and 24 cm. The net was made with a silk mesh size 150 µm. At the end, the net is closed off with a plastic cylinder (cod-end) that collects the fauna [15,16]. Hard substrate and loose substrate (bare or with vegetation) have been explored.

On the hard substratum, a surface of 900 cm^2 (30cm x30cm) was scratched; as it has been reported to be representative [17]. The sampling of the macro-fauna (macro-crowd) was undertaken at low tide.

The collected samples were fixed in 40% formalin then conserved in 10% estuary formalin water. Sorting the collected benthic fauna by size was made easy by using a column of 3 sieve meshes in a decreasing order 2 mm, 1 mm and 0.3 mm [18]. The zoological groups were separated then conserved in 70% alcohol [19]. The species of every group were identified, and then counted. The identification of species was done using Binocular Stereo Zoom Microscope.

With regards to water quality, eleven hydrological parameters were investigated to characterize the estuary water: water temperature (Te), electrical conductivity (EC), dissolved oxygen (DO), pH, suspended matter (SM), Chlorides, orthophosphate, nitrates (NO), ammonia nitrogen(NH_3-N), chemical oxygen demand (COD) and biochemical oxygen demand (BOD).

Along the estuary of Moulouya River and throughout the study area, water samples were taken during wet period (March) and in dry period (July). Samples were collected in plastic bottles, pre-rinsed with water from the sampling station. The bottles were then transported to the laboratory at 4°C. The water temperature was measured "in-situ" using a mercury thermometer graduated 1/10 from 0 to 50 °C. The hydrogen potential (pH), electrical conductivity (EC) and dissolved oxygen (DO) were determined using a CONSORT-Model 835 multi- parameter analyzer. The suspended matter (SM) was determined by filtering a volume of water through a cellulosic filter (0.45 µm pore size) according to the protocol described by Rodier [20]. The BOD_5 was evaluated by the method based on respiration measurement using a BOD-meter brand WTW, model 1020T following the technique described by the German Institute for Standardization (DIN) [21]. The COD was determined by refluxing the sample with excess of potassium dichromate in acid condition (at 148°C) and estimated by titration to find amount of dichromate consumed which is directly proportional to COD as described in the literature [22]. Chlorides were assessed in acid solution (HNO_3) by direct titration with a standard mercuric nitrate solution, using a pH indicator. Nitrates, ammonium and orthophosphates were analyzed by colorimetric methods using a Visible Type 722 S Beijing UV spectrophotometer.

Results

Investigation of the Physical-Chemical Characteristics

Samples taken at the study site were analysed to determine the physico-chemical properties of the estuary water and assess temporal and spatial variations of hydrological parameters.

With regards to temporal variations, on the basis of the analyses results, the mean values and standard deviations were calculated over time during the dry period (March) and wet period (July) for all of the investigated parameters. The obtained results are summarized in Table 2. Water temperatures ranged from 13-25°C, with minimum and maximum values in March 2014 and July 2014, respectively. A slight difference in water pH between the dry and wet periods was recorded with respective levels of 7.1 and 6.97. Significant higher levels of DO, COD, NH3-N and EC were recorded during the wet period compared to dry period. Conversely, for BOD, SM, PO_4^{3-}, NO^{3-} and Cl^-, the highest concentrations were recorded during the dry period. A significant negative correlation ($r = -0.617$; $p < 0.01$) was observed between Suspended Matter and DO, indicating that the DO is largely influenced by the SM.

Physicochemical parameters	Sampling period	
	Dry period (March)	Wet period (July)
Temperatures (°C)	25±0.5	13±1.5
Potential hydrogen pH	7.10±0.5	6.97±1.5
Electrical Conductivity EC (µs/cm)	1100±200	1250±150
Suspended Matter SM (mg/l)	750±90	500±120
Dissolved Oxygen DO (mg/l)	5.5±2.5	8.9±1.5
Biochemical Oxygen Demand BOD (mg/l)	21±10	7±5.5
Chemical Oxygen Demand COD (mg/l)	25±12.5	30±5.5
Chlorides Cl^-(mg/l)	356±135.5	347±125.5
Orthophosphate PO_4^{3-} (mg/l)	0.13±0.5	0.08±0.3
Nitrates NO_3^- (mg/l)	0.15±0.5	0.1±0.5
Ammonia nitrogen NH_3-N (mg/l)	0.001±0.003	0.0071±0.002

Table 2: Seasonal variation of water physicochemical characteristics

The spatial variation of the investigated physicochemical parameters was evaluated along the transect S1-S2-S3. The obtained results are presented in Table 3. Water temperature as well as pH, BOD, Cl^-, NO_3^- and NH3-N levels were found to be significantly higher in S1 (upstream) as compared to those recorded in S2 and S3. An increase in DO, COD and NO_3^- concentrations was detected in S2 waters in comparison to S1 and S3, while the highest values of EC, SM and PO_4^{3-} were found in S3 located at the mouth of the river.

Physicochemical parameters	Stations		
	S1	S2	S3
Temperatures (°C)	25±0.5	12±1.5	13±1.5
Potential hydrogen pH	8±1.5	6.97±1.5	7.10±0.5
Electrical Conductivity EC (µs/cm)	1100±200	1050±140	1250±150
Suspended Matter SM (mg/l)	550±90	480±120	750±90
Dissolved Oxygen DO (mg/l)	5.5±2.5	8.1±1.5	6.1±2.5
Biochemical Oxygen Demand BOD (mg/l)	21±10	4.5±0.5	7±5.5
Chemical Oxygen Demand COD (mg/l)	22±2.5	28±5.5	25±12.5
Chlorides Cl^-(mg/l)	356±135.5	222±10	347±125.5
Orthophosphate PO_4^{3-} (mg/l)	0.08±0.3	0.10±0.3	0.13±0.5
Nitrates NO_3^- (mg/l)	0.15±0.5	0.5±0.5	0.1±0.5
Ammonia nitrogen NH_3-N (mg/l)	0.011±0.003	0.0071±0.002	0.001±0.003

Table 3: Spatial variation of water physicochemical characteristics

Investigation of the Benthic Fauna

The results of the collected benthic fauna from the mouth of Moulouya River made it possible to identify the current state of species biodiversity belonging to four classes (Figure 2). A total of 542 invertebrates were collected. Molluscs were the most abundant with 38.2% (207/542) rate. They were represented by 2 orders: Gastropods and Bivalves. In contrast, insects were the minority class in term of diversity (represented only by Diptera), with abundance level similar to that recorded for the Annelids.

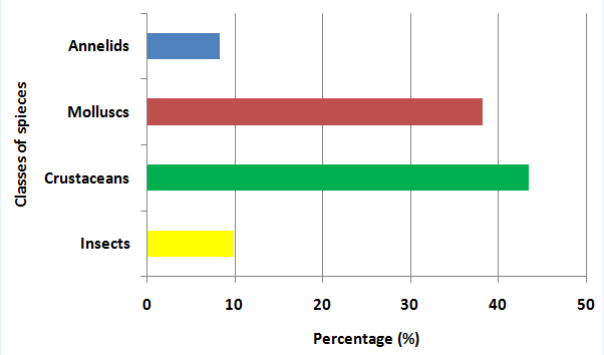

Figure 2: Distribution of the benthic fauna collected species by classes.

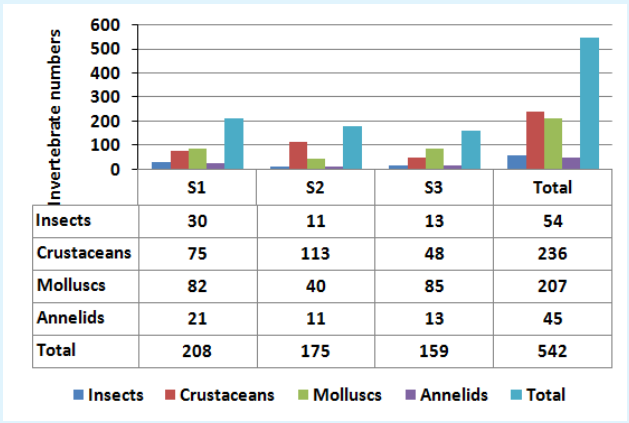

Figure 3: Spatial evolution of the benthic fauna of the Moulouya River estuary from upstream (S1) to downstream (S3).

The benthic species encountered during the various field sampling missions are listed in Table 3. Four systematic groups, 22 species were inventoried during the two sampling campaigns carried out on the benthic macrofauna of the infra-littoral floor within the estuary of Moulouya (Morocco). For the distribution of species by systematic groups, 12 species were molluscs with 54.5% of total species number (36.4% of Gasteropods vs. 18.2% of Bivalvia); 4 species of Crustacea (18.2%); 3 species of Insects (13.6%) and 3 species of Annelids, Oligochaetes (13.6%).

Class	Order	Species	Station 1	Station 2	Station 3
Insects	Diptera	*Prodiamesa olivacea*	+	-	+
		Chironomus sp.	+	+	+
		Glyptotendipes sp.	+	+	+
Crustaceans	Decapods	*Atyaephyra desmarestii*	-	+	+
	Thoracic	*Balanus montagui*	-	+	+
	Isopods	*Asellus sp.*	+	-	+
	Amphipods	*Gammarus gauthieri*	+	+	-
Molluscs	Gastropods	*Melanopsis cariosus*	+	-	+
		Melanopsis costellata	+	+	+
		Margaritifera margaritifera	+	+	+
		Cerithium rupestre	-	+	+
		Murex brandaris	+	+	+
		Philbertia leurfroyi	+	-	+
		Nassa pfeifferi	+	+	+
		Pyrene broderipi	-	+	+
	Bivalves	*Donax venustus*	+	+	-
		Cardium edule	+	-	+
		Gafrarium minimum	+	-	+
		Glycymeris glycymeris	-	+	+
Annelids	Oligochaetes	*Lumbriculidae sp.*	+	+	-
		Eiseniella tetraedra	-	-	+
		Himantopus himantopus	+	+	+

(+) Presence; (−) absence.

Table 3: Checklist of benthic fauna collected at stations S1–S3 at the Moulouya River estuary.

Class	Order	Species	S1	S2	S3	Total
Insects	Diptera	*Prodiamesa olivacea*	16	-	8	**24**
		Chironomus sp.	2	1	2	**5**
		Glyptotendipes sp.	12	10	3	**25**
Crustaceans	Decapods	*Atyaephyra desmarestii*	-	90	21	**111**
	Thoracic	*Balanus montagui*	-	10	12	**22**
	Isopods	*Asellus sp.*	55	-	15	**70**
	Amphipods	*Gammarus gauthieri*	20	13	-	**33**
Molluscs	Gastropods	*Melanopsis cariosus*	11	-	22	**33**
		Melanopsis costellata	30	20	25	**75**
		Margaritifera margaritifera	10	2	8	**20**
		Cerithium rupestre	-	11	5	**16**
		Murex brandaris	2	2	4	**8**
		Philbertia leurfroyi	20	-	5	**25**
		Nassa pfeifferi	6	1	3	**10**
		Pyrene broderipi	-	1	10	**11**
	Bivalves	*Donax venastus*	1	1	-	**2**
		Cardium edule	1	-	1	**2**
		Gafrarium minimum	1	-	1	**2**
		Glycymeris glycymeris	-	1	2	**3**
Annelids	Oligochaetes	*Lumbriculidae sp.*	1	1	-	**2**
		Eiseniella tetraedra	-	-	1	**1**
		Himantopus himantopus	20	10	12	**42**
Total			**208**	**175**	**159**	**542**

Table 4: The number of species found in the estuary of Moulouya River (Morocco)

As shown in Table 3 and Table 4 a spatial variation was recorded in the occurrence of benthic fauna species along the Moulouya River estuary. The distribution of species by sampling station revealed that the station S1 contained 16 of 22 of the identified species, versus 15 species for S2 and 19 species for S3. In term of abundance, the upstream located station S1 had the highest abundance accounting for 38.4% (208/542) of the collected specimens, versus 32.3% for S2 while the lowest abundance was recorded in the downstream located station S3 with 29.3% of specimens. The Crustacean *Atyaephyra desmarestii* was the most abundant species (20.5%) while the less frequently collected was the Annelid *Eiseniella tetraedra* (0.2%) and occurred only in station 3.

Discussion

Through the analyses of the physicochemical parameters of the water in the Moulouya River estuary, the current state of water quality, reflects the presence of a moderate to permanent pollution and localized near the city of Saïdia with significant spatiotemporal variations.

The recorded mean temperature around 20°C may be related to the local conditions. The recorded temperatures are similar to those reported by several studies in Morocco and other countries [23-25]. Comparative findings were reported by Ech-chafay and coll. indicating that such temperature levels (20 to 30°C) are favorable for bacterial growth (assimilative phenomenon), parasites, mosquito larvae and other microbial germs [26]. Conversely, the found temperature was lower than that recorded by El Morhit and coll. in the Loukous River estuary ranging from 15 to 35°C [27]. In the current study, the amplitude of temperature variation between the sampling points did not exceed 25°C suggesting that the Moulouya estuary was relatively homogeneous. Similarly, a higher amplitude variation was

reported in BouRegreg River with a range of 15 to 35°Cwhich might be due to natural factors and anthropogenic activities [28,29].

The conductivity measurement is a good assessment of the degree of mineralization of water in which each ion acts by its concentration and its specific conductivity. The increase of the electrical conductivity of water between the upstream (S1) and downstream (S3) of the Moulouya River estuary may be explained by the influence of marine waters and industrial discharges that penetrate inside the estuary, favored by the low slope of the main water course, leading to a significant increase in chloride ions. The recorded conductivity level did not exceed the Moroccan standards of surface water (2700 µs/cm) indicating low mineralization [30]. The mean values of conductivity observed in the ecosystem were lower than those reported in Sebou River estuary varying between 1200 and 1400µs/cm [31]. However, they are much lower than those found in BouRegreg River fluctuating between 3430 and 8590 µS/cm [23]. The mean value of dissolved oxygen in this study was similar to that reported by Fekhaoui ranging from 6 to 9 mg/L [32]. However, it was lower than those reported by El Morhit and coll. in Loukouss River estuary and by El Blidi and Fekhaoui in Sebou river estuary [27,33]. The spatial evolution of the content of dissolved oxygen in the Moulouya River estuary revealed that the load of biodegradable organic matter originating from domestic, industrial and agricultural activities discharged into the river waters resulted in a significant decrease in the level of dissolved oxygen especially in S1 and S3. The excessive contributions of the organic fermentable matter rejected by sewers of Oujda city may explain the increase in dissolved oxygen consumption.

The analyses showed that average water pH in the Moulouya River estuary presented a slight, but no significant, variation remaining almost neutral. Other studies reported that pH may vary probably as a result of fluctuations in salinity following the tidal cycle and/or fluctuations in organic load [23,27]. The values of BOD and COD parameters found in the Moulouya river estuary are similar to those found by other authors [27]. Sarkar and coll. attributed the low concentration of chemical oxygen demand to the presence of organic matter [29]. The recorded spatial variation in BOD, COD, chlorides, orthophosphate, nitrates and ammonia nitrogen between stations may be due to the presence of pollution sources originating from the surrounding agglomerations.

In the Moulouya River, even with the low erosive potential of the watershed, waters are heavily charged in suspended matter, especially in S3 located at the downstream of the estuary (S3). These variations may be affected by the tidal regime as well as wide variations in hydrological parameters.

With regards to the benthic fauna, the collected species are divided into 8 orders belonging to 4 classes. Molluscs are the most numerous with 12 species. Insects, Annelids and Crustaceans come next with 3, 3 and 4 species, respectively. The species *Atyaephyra desmarestii* was the most frequently collected with a relative abundance of 20.5%. *Eiseniella tetraedra* was collected from the class of oligochaetes with a relative abundance of 0.2%.

The faunistic inventory resulted in four zoological groups of predominant invertebrates (Molluscs, Crustaceae and Oligochaetes) totaling 90.4%, considered as the characteristic groups of the estuarine areas; in agreement with the findings of Benzakour and Mergaoui and al. in the estuaries of BouRegreg River and Sebou River, respectively [25,34].

The current study results showed that the constant and common forms belong to the Crustacean group. Thus, the carcinological fauna probably may be able to develop resistance to face different environmental aggressions as reported by Boussalwa in the same estuarine environment [35]. The silting up of the river mouth impedes access of fishing boats to the port. This leads to the reshaping of the substrate and its deposition in one place, hence the high number of mollusc species (12 species). Most of the malacological specimens were collected during the summer period between March and July 2014.

From a biogeographic point of view, the benthic fauna belongs to the Palearcticozone with the endemic Moroccan species from different groups [4,36]. This approach of the benthic population, through the classical descriptors (abundance, diversity ...) has shown that the benthic fauna collected at the mouth of Moulouya River is represented by a very large number of specialized taxa as compared to other researches by Fekhaoui and Dakki in upper Sebou, El Agbani in BouRegreg River and Badri in Tensift River [32,37-39]. This benthic community is also marked by the abundance of Gastropods (36.5%) of the overall population collected in the mouth of Moulouya River.

Conclusion

The various physicochemical constituents in the Moulouya estuarine water showed spatial and temporal fluctuations. The level of measured parameters (i.e. DO, DBO, organic load…) revealed deterioration in water quality in the studied stations, especially in downstream stations, mainly due to domestic anthropogenic wastes.

The investigation of the benthic macrofauna provided a state of the art data on biodiversity of the estuarine invertebrate fauna of Moulouya River. However, the impact of physicochemical parameters may have on distribution and abundance of the benthic fauna was not investigated in this study.

Due to increasing pollution sources in the Moulouya River catchments, there is a fear of a serious deterioration in the water quality and biological diversity in the river estuary. Therefore, proper measures should be taken such as the treatment of sewage before discharge and restrictions of various anthropogenic activities affecting the health of the estuary ecosystem.

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