Recovery of an Estuarine Ecosystem after the Stopping of Wastewater Discharges: Macrobenthic Community Characterization in the Estuary of Oued Souss (Southwestern Morocco)

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Abstract: The communities of benthic macroinvertebrates, living in the estuary of Oued Souss (Agadir Bay, Morocco), were studied in parallel with the changes that this ecosystem had underwent after the stopping of pollution caused by untreated wastewater discharges. The specific richness was greater in the year following the end of discharges (22 species in 2003 instead of 14 found during the pollution period (2001-2002). A similar finding was noted for the dominance of the species. Indeed, if the dominating species was *Hydrobia ulvae* during the pollution period, followed by *Hediste diversicolor* and *Scrobicularia plana* in decreasing order, the sequence: *H. diversicolor* > *H. ulvae* > *Cerastoderma edule* > *S. plana*, was noted in 2003. The longitudinal distribution of species living in this site in 2001 and 2002 had wider in 2003 and average biomass, determined by the study of the ash-free dry weight, had become clearly greater.

1. INTRODUCTION

Estuarine ecosystems are part of most productive coastal environments but remain the most vulnerable due to exposure to toxic anthropogenic effluents transported by rivers from remote and nearby conurbations, and industrial and agricultural areas. The estuary of the Oued Souss (30°21'N, 9°35'W), located in an arid zone and part of the Souss-Massa National Park in the Ramsar site, constitutes one of the rarest humid areas in South Western Morocco. It is an ecosystem of great ecological interest, particularly for many migratory birds (Dakki et *al.*, 1995; El Bekkay, 2013; Oubrou & El Bekkay, 2014). However, the estuary experienced a profound ecological change. For a long time, it has been subjected to the discharge of large amounts of sewage and industrial effluents (Moukrim et al., 2000). And since November 2002, the establishment of a sewage treatment plant marked the end of wastewater discharge in the estuary (Ait Alla et al., 2006).

If the period in which the estuary was receiving the discharges has been the subject of several studies (Snoussi, 1988; Id-Halla et *al.*, 1998; Mimouni et *al.*, 2002; El Hamidi et *al.*, 2002; Gillet et *al.*, 2003; Bergayou et *al.*, 2005; Ait Alla et *al.*, 2006a; Ait Alla et *al.*, 2006b; Anajjar et *al.*, 2008; Moukrim et *al.*, 2008; Bergayou et *al.*, 2008; Bergayou et *al.*, 2009], investigations after the establishment of the plant are of interest because they allow not only to compare the situation of the mouth of the valley before the end of the wastewater discharges, but also to follow the evolution of the restoration of the ecosystem.

It is within this framework that our laboratory has set up a multidisciplinary research program covering all the components of the ecosystem. Thus, the research focused on the physico-chemistry of water and sediment (Lefrère, 2005), heavy metals (Anajjar

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et *al.*, 2008; Moukrim et *al.*, 2008), pesticides (Agnaou et *al.*, 2014), biomarkers (Ait Alla et *al.*, 2006a; Idardare, 2005; Bergayou et *al.*, 2009), population dynamics and the biology of some species (Ait Alla et *al.*, 2006b; Lefrere, 2005; Bergayou et *al.*, 2008).

It is within the framework of this research program that our investigations are being conducted. The aim is to study the benthic invertebrate communities of the intertidal zone of the estuary during the wastewater discharge period (2001, 2002) and after their termination (2003). The analysis focused on faunal composition, longitudinal distribution of species, species richness, abundance, dominance and biomass. It also made it possible to define and compare the biocenotic units during the two periods.

2. MATERIALS AND METHODS

Three campaigns were undertaken during the summer season. Two of them were carried out while the estuary was receiving wastewater discharge in 2001 and 2002. The 2003 campaign was carried out after the cessation of the pollution. To ensure a good coverage of the ecosystem through our samples, 12 radials along the estuary and part of Oued Souss are defined. Radials were numbered from 0 to 12 from the mouth to upstream with radial 7 being the direct receptacle of wastewater during the discharge period (Figure 1).

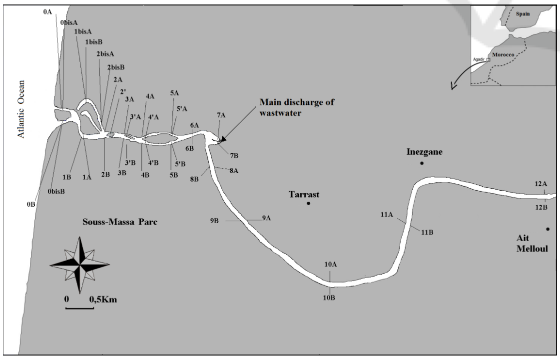

Figure 1. Location of the sampling stations of the intertidal macrobenthos in Oued Souss estuary (Agadir Bay, Morocco) during the summer campaigns in 2001, 2002, and 2003.

Downstream from radial 2, the stations 1bis and 2bis belong to an arm of the Oued. Between radial 2 and radial 6, the mudflat is wide, and the bed of the Oued shows sandbanks which, very often, are accessible. This is why we generally chose four sampling points by radial: two on the north bank (A, A') and two on the south bank (B, B'). From radial 6 going upstream, the mudflat decreases. Therefore, we selected only two points of sampling by radial: one on each bank. A total of 36 and 39 stations were respectively sampled at low tide during the period before and after the discharges were terminated. Their coordinates were recorded using a GPS (MLR brand, type SP12X). During the last campaign, three additional stations were selected (0bis A, 0bis B, and 2'). They are the result of marine hydrodynamics that have made new sandbanks appear. Finally, it should be noted that after the discharges stopped, there was a modification of the watercourse that no longer reached radial 7. Samples were taken using the quadratic sampling technique (Elliot & Descamps, 1973). For all the stations considered, each sampling point consists of 4 quadrats of 0.25m x 0.25m (over a depth of 0.20m), ie a sampling area of 0.25m² per sample.

The sorting of the different species was carried out on site or in the laboratory, with a sieve with 1 mm mesh. The animals were kept in ethanol at 70° and their determination was carried out using a binocular magnifier and, in some cases, using a microscope (to study the morphology of the parapodia of some Annelids).

As a first step, the inventory of fauna, the spatial distribution of species, and parameters such as abundance (number of individuals of a species in a sample); the dominance (percentage represented by a species, a class, or an embranchment in a sample) that make it possible to reconstruct the faunistic composition are determined. Species richness (number of species present in the settlement) as well as biomass were also evaluated. For the last parameter, we performed a prior decalcification to the molluscs in a 10% hydrochloric acid bath and a drying at 80°C of all the individuals during 48 hours (to measure the dry weight). The animals are then placed in an oven at 600°C for 2 hours to reduce them to ashes. The difference between the decalcified dry weight and the ash quantity corresponds to the dry weight of the soft masses (ashless), expressed in g/m² (Bachelet et *al.*, 1981).

In order to define biocenotic units, a hierarchical ascending classification is performed. For this, we first calculated the coenotic affinity between the station communities estimated from the Jaccard coefficient (Gillet, 1986):

$$J = Na, b / (Na + Nb - Na, b)$$

with Na: number of species in sample survey a, Nb: number of species in sample survey b, Na, b: number of species common to sample surveys: a and b. The different values are grouped in a similarity matrix from which the dendogram is built according to the algorithm (Lance & Williams, 1967):

$$dhij = 0.625\ dhi + 0.625\ dhj - 0.25\ dij$$

This method is highly recommended by various authors (Legendre & Legendre, 1998)

3. RESULTS

3. 1. Settlement Faunistic Composition

3.1.1. The Ecosystem Receiving Wastewater Discharges

The macrobenthic fauna shows a similar faunal composition for both seasons during the period when the ecosystem was receiving wastewater discharges. The number of individuals, all species combined, amounts to 11270 and 9131 for 2001 and 2002, respectively (Tables 1 and 2).

Table 1. Faunistic composition of the macrobenthos of the Oued Souss estuary by phylum during the period of wastewater discharges (in 2001).

	2001 Campaign	
	Total Abundance	%
Nemathelminthes		
Sp		
Annelids	2459	21.82
Arenicola marina		
Glycera tridactyla	12	0.106
Hediste diversicolor	2426	21.526
Pectinaria koreni	21	0.186
Molluscs	8747	77.61
Cerastoderma edule	378	3.354
Hydrobia ulvae	6500	57.675
Macoma cumana	33	0.293
Scrobicularia plana	1836	16.291
Crustaceans	64	0.57
Bathyporeia sp		
Carcinus maenas	4	0.035
Eurydice pulchra	44	0,390
Haustorius arenarius	15	0.133
Urothoe brevicornis	1	0.009

Molluscan phylum largely dominates the settlement with 77.6% (in 2001) and 84.1% (in 2002). The rest of the benthic fauna is divided between the Annelids (21.82% in 2001 and 12.42% in 2002), the Crustaceans (0.57% in 2001 and 3.18% in 2002) and the Nemathelminthes which constitute a minority and are identified only in 2002 (less than 1%).

The ecosystem is poor in terms of biodiversity (table1). Only a limited number of species (N = 14) are encountered. However, these species are abundant. Thus, the annelid *Hediste diversicolor* and the molluscs *Hydrobia ulvae* and *Scrobicularia plana*, alone represent more than 94.5%. In fact, in descending order, *H. ulvae* has an abundance of about 6500 and 6730 and densities of up to 7016 ind/m^2 and 8088 ind/m^2 respectively for 2001 and 2002; followed by *H. diversicolor* with abundances of 2426 and 1112 and densities of up to 1464 ind/m^2 and 732 ind/m^2 respectively in 2001 and 2002; then *S. plana* with abundances of the order of 1836 and 827 and densities up to 3780 ind/m^2 and 1808 ind/m^2 respectively in 2001 and 2002.

Table 2. Faunistic composition of the macrobenthos of the Oued Souss estuary by phylum during the period of wastewater discharges (in 2002).

	2002 Campaign	
	Total Abundance	%
Nemathelminthes		
Sp	25	0.274
Annelids	1134	12.42
Arenicola marina	12	0.131
Glycera tridactyla	10	0.110
Hediste diversicolor	1112	12.178
Pectinaria koreni		
Molluscs	7682	84.13
Cerastoderma edule	72	0.789
Hydrobia ulvae	6730	73.70
Macoma cumana	53	0.580
Scrobicularia plana	827	9.057
Crustaceans	290	3.18
Bathyporeia sp	48	0.526
Carcinus maenas	6	0.066
Eurydice pulchra	236	2.585
Haustorius arenarius		
Urothoe brevicornis		

3.1.2. The Ecosystem after Stopping Wastewater Discharges

The number of individuals harvested is of the order of 15968 (Table 3). There are 22 species belonging to four phyla. The Molluscan phylum is dominant (69.6%), followed by that of the Annelids (28.9%), followed by the Crustacea (1.4%). Dominance by species shows that it is *Hediste diversicolor* which dominates the settlement with an abundance of 4599 individuals and a density which reaches in some stations 2328 ind/m^2, followed by *Hydrobia ulvae* with an abundance of 4495 and a density of up to 4200 ind/m^2, *Cerastoderma edule* with an abundance of 3765 and a density of 6760 ind/m^2 and *Scrobicularia plana* with an abundance of 2795 and a density of up to 2336 ind/m^2.

Table 3. Faunistic composition of the macrobenthos of the estuary of Oued Souss by phylum after cessation of wastewater discharges (2003)

	2003 Campaign	
	Total abundance	%
Nemathelminthes Sp	16	0.100
Annelids	4615	28.9
Nemerte sp	1	0.006
Arenicola marina	5	0.031
Capitella capitata	1	0.006
Glycera tridactyla	1	0.006
Heteromastus filiformis	1	0.006
Hediste diversicolor	4599	28.801
Lanice conchylega	1	0.006
Nephtys hombergii	1	0.006
Pectinaria koreni	5	0.031
Molluscs	11113	69.6
Aplysia punctata	2	0.013
Cerastoderma edule	3765	23.578
Donax trunculus	21	0.132
Hydrobia ulvae	4495	28.15
Macoma cumana	35	0.219
Scrobicularia plana	2795	17.504
Crustaceans	224	1.4
Bathyporeia sp	48	0.301
Carcinus maenas	17	0.106
Eurydice pulchra	128	0.802
Gammarus marinus	12	0.075
Haustorius arenarius	10	0.063
Urothoe brevicornis	9	0.056

These data show that the ecosystem is experiencing a significant ecological change in faunistic composition. The number of individuals harvested is significantly larger compared to the period when the ecosystem received wastewater. Although the phylum of molluscs is still dominant, followed by that of Annelids and Crustaceans, the composition of macrobenthic fauna and the abundance of these organisms change during this campaign carried out after the cessation of discards.

In fact, we notice an enrichment of the macrobenthic population in new species and if we consider the dominance of the species in decreasing order, four species dominate the population, in descending order: *H. diversicolor*, *H. ulvae*, *C. edule* and *S. plana* instead of three species during the discard period: *H. ulvae*, *H. diversicolor* and *S. plana.*

3. 2. Longitudinal Distribution of Species and Biocoenotic Units

3.2.1. The Ecosystem Receiving Wastewater Discharges

Species populating the environment were divided into four groups of species, depending on their distance from the sea (Figure 2):

- a first group linked to the mouth of the estuary (radials 0, 1, 1bis) and not sinking beyond 250 meters. It consists of the following species: *Arenicola marina*, *Glycera tridactyla*, *Bathyporeia sp*, *Eurydice pulchra*, *Haustorius arenarius* and *Urothoe brevicornis*;

- a second group that is distributed on radials 1, 1bis, 2bis and 2. It is *Cerastoderma edule* and *Macoma cumana*;

- a third group corresponding to species with very wide distribution on the estuary. It is *Scrobicularia plana* in radials: 1 to 4, *Hediste diversicolor* in radials: 1 to 6 and *Hydrobia ulvae* in radials: 0 to 8;

- a fourth group, spotted in 2002 alone, and represented by the parasitic nematode which is confined upstream of the estuary, at the level of radials 7 and 8.

Regarding the stations beyond radial 8, they constitute an azo-zone.

The study of the coenotic affinity between settlements of different radials allowed us to separate 2-3 groups of radials (Figure 3). Thus, in 2001, the dendrogram distinguishes (Figure 3A): a first group consisting of radials 0 and 1, 1bis, 2 and 2bis; and a second group which associates radials 3, 4, 5, 6, 7, and 8. The latter has two subgroups (3-6 and 7-8). Whereas in 2002, Figure 3B shows three groups: Group 1 (radials 0, 1, 1bis and 2bis), Group 2 (radials 2, 3, 4, 5 and 6) and Group 3 (radials 7 and 8).

3.2.2. The Ecosystem after Stopping Wastewater Discharges

The species composition and distribution, after discharges stopped, showed a change that was manifested by a species enrichment, a longitudinal widening of their distribution area and the repopulation of radials that were azo during the discharge period. Four groups are dentified:

- Group 1. (Radials, close to the sea: 0, 0bis, 1). It is composed of: *Arenicola marina*, *Capitella capitata*, *Glycera tridactyla*, *Heteromastus filiformis*, *Lanice conchylega*, *Nephthys hombergii*, *Bathyporeia sp.*, *Gammarus marinus*, *Haustorius arenarius*, *Urothe brevicornis*, and finally *Eurydice pulchra* which populated also radials 1 bis and 2 bis;
- Group 2. It is constituted by *Cerastoderma edule, Macoma Cumana* and *Donax trunculus*. This group has a widening of the distribution range of the e species that compose it, since we note a penetration of *C. edule* in the estuary (station 4), as well as *M. cumana* which populates radial 2;
- Group 3. It is composed of species that populate the most radials. This is the case of *S. plana* (0 bis to 8), *H. diversicolor* and *H. ulvae* (radial 0 or 0 bis to 12). To these species, *C. maenas* (0 bis to 6) can be included. Species in this group have all expanded their range in the estuary.
- Group 4. It consists mainly of nematodes having migrated upstream of the estuary (radials 11 and 12).

In addition, some species are found exclusively in radial 3: *Pectinaria koreni* and *Aplysia punctata*.

In terms of affinity between settlements (Fig. 3C), we can classify radials into three groups, after stopping discharges in the estuary:

- Group 1, consisting of settlements from radials: 0, 0bis, 1, 1bis, 2bis;
- Group 2, counting of settlements from radials: 2, 2 ', 3, 4, and 5;
- Group 3, associating the settlements of radials 6, 8 and those of radials which were azo during discharges: 9, 10, 11, 12.

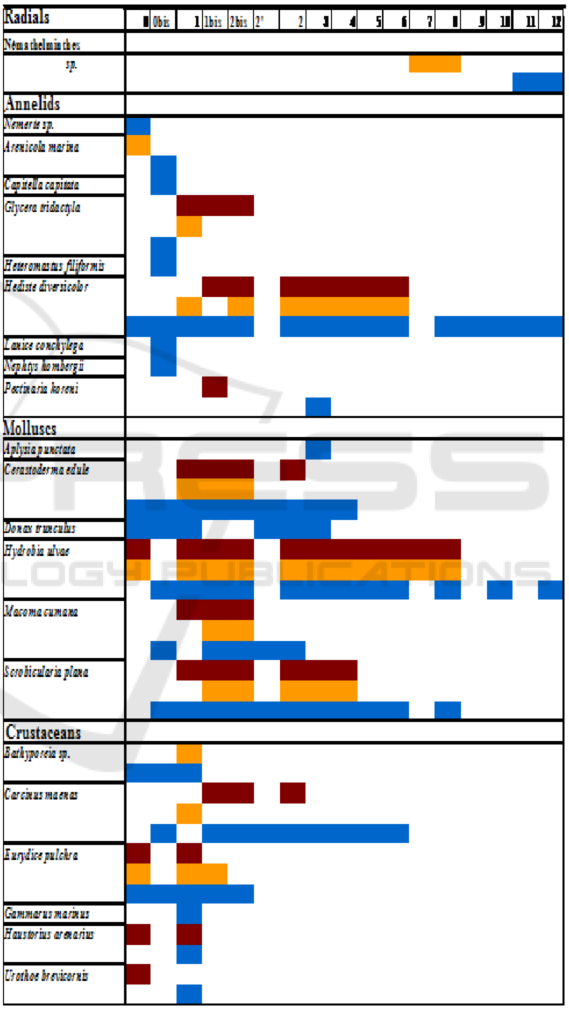

Figure 2. Longitudinal distribution of intertidal benthic macrofauna in the mouth of Oued Souss, Agadir Bay: during the discharge period (2001 and 2002) and after that period (2003).

2001 2002 2003

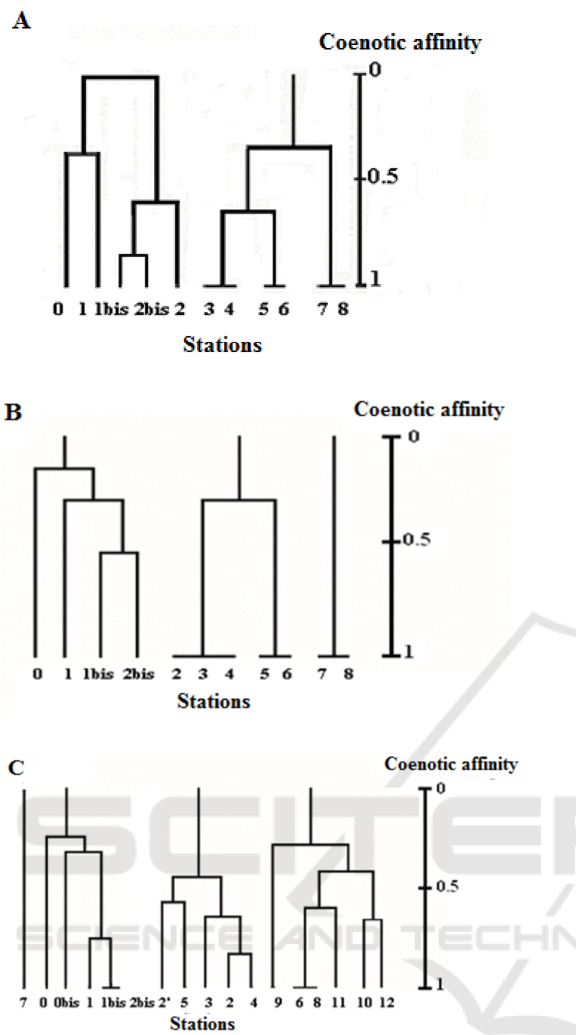

Figure 3. Hierarchical ascending classification of intertidal invertebrate settlements living during the period of wastewater discharges (A: 2001, B: 2002), and after (C: 2003) at the Oued estuary Souss (Bay of Agadir)

3. 3. Species Richness and Biomass, before and after the End of Wastewater Discharge

3. 3.1. Species Richness

During the period when the estuary received wastewater discharge, the number of species recorded during the harvest was 14. Figure 4 shows the specific richness for each radial. There is a negative correlation between this parameter and the distance of the radial with respect to the sea. After the cessation of rejections, the number of species harvested is 22.

Thus, one records an enrichment on almost all the radials of the estuary with the exception of radial 7, which has become azoic, after the cessation of discharges. This last observation is surely in relation with the change of the river at this level of the estuary.

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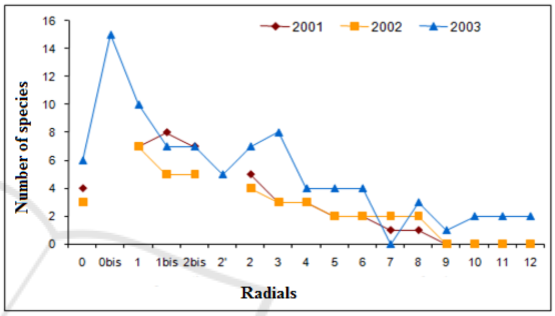

Figure 4: Variation of the species richness of the macrobenthos in the Oued Souss estuary by radial, before (2001 and 2002) and after (2003) the end of wastewater discharge

3. 3.2. Biomass

Figure 5 shows differences between the results obtained for the biomass of fauna recorded by radial during campaigns carried out before and after the cessation of discharges.

The results show an increase in the biomass at radials 0 to 2 of the mouth after the cessation of the pollution, whereas for radials 3 to 6, there is a decrease in the biomass.

However, the average biomass calculated after cessation of discharges has increased significantly. It is 20.46 g / m^2 (in 2003) compared to 15.54 g / m^2 or 15.84 g / m^2 (in 2001 or 2002 respectively) in the presence of wastewater discharges

Biomass results by species (all radials combined) also make it possible to distinguish differences between the two periods (Table 4).

Thus, during the release period, *H. diversicolor* has the largest biomass (43.64 to 55.84%), followed by *S. plana* (38 to 35.75%), *C. edule* (13.32% to 2.53%), and finally *Hydrobia ulvae* (1.67 to 2.25%). The values quoted correspond respectively to the results of the 2001 and 2002 surveys. Whereas after the rejection of the discharges, the dominant species in biomass are in descending order: *C. edule* which represents 31.55% of the total biomass, followed by *H. diversicolor* (23.35%), *S. plana* (22.6%), *Aplysia punctata* (10.55%) and then *C. maenas* (10.23%)

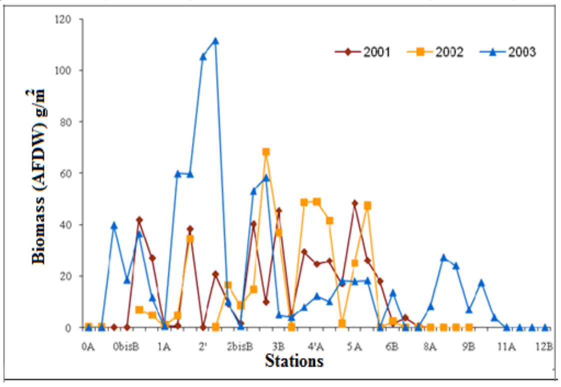

Figure 5. Variation of the total biomass of macrobenthos in the Oued Souss estuary by station [AFDW in (g/m2)] during wastewater discharges (2001, 2002) and after (2003).

Table 4. Cumulative biomass by species [AFDW in (g)] of the intertidal macrobenthos of the Oued Souss estuary, during the period of wastewater discharges (2001-2002) and after (2003), all stations being considered.

	2001 Campaign		2002 Campaign		2003 Campaign	
	Cumulative biomass (g)	**%**	**Cumulative biomass (g)**	**%**	**Cumulative biomass (g)**	**%**
Némathelminthes						
sp.			0.011	0.003	0.011	0.001
Annelids						
Nemerte sp.					0.018	0.002
Arenicola. marina			0.042	0.010	0.041	0.005
Capitella capitata					0.000	0.000
Glycera tridactyla	0.044	0.010	0.004	0.001	0.002	0.000
Heteromastus filiformis					0.000	0.000
Hediste diversicolor	189.940	43.640	230.084	55.846	176.733	23.349
Lanice conchylega					0.009	0.001
Nephtys hombergii					0.033	0.004
Pectinaria koreni	1.210	0.278			0.034	0.005
Molluscs						
Aplysia punctata					79.898	10.556
Cerastoderma edule	57.960	13.317	10.418	2.529	238.824	31.552
Donax trunculus					1.117	0.148
Hydrobia ulvae	7.279	1.672	9.277	2.252	9.651	1.275
Macoma cumana	1.120	0.257	3.514	0.853	0.927	0.122
Scrobicularia plana	165.480	38.020	147.324	35.758	171.232	22.623
Crustaceans						
Bathyporeia sp.					0.654	0.086
Carcinus maenas	12.050	2.769	10.881	2.641	77.423	10.229
Eurydice pulchra	0.160	0.037	0.435	0.106	0.293	0.039
Gammarus marinus			0.010	0.002	0.001	0.000
Haustorius arenarius	0.002	0.000			0.011	0.002
Urothoe brevicornis	0.000	0.000			0.004	0.000

4. DISCUSSION

The campaigns that took place while the Oued Souss estuary was receiving wastewater (2001-2002) made it possible to draw up the first inventory of the intertidal zoobenthic fauna in this ecosystem and to know the structure of this settlement. Regarding faunal composition, we observe a year-to-year variation in the total abundance of the individuals surveyed, without affecting the order in which species are ranked in relation to their abundance dominance. In descending order *Hydrobia ulvae*, followed by *Hediste diversicolor* then *Scrobicularia plana*.

The horizontal distribution shows a succession of three communities with regards to the coenotic affinity between the settlements. The first community occupies radials 0-2 bis (2001), or 0-2 (2002) while the second includes radials which constitute the central part of the estuary: 3, 4, 5, 6, then the last community consists of the species from radials 7 and 8, which are close to the discharges. This latter community has sometimes a certain affinity with the community of previous radials (2001) and sometimes it dissociates completely (2002). In a parallel, study in which the granulometry and physico-chemistry of water in the estuary were treated (Gillet et *al.*, 2003). It has been argued that in the absence of a true hyaline gradient at the level of the estuary of the Oued Souss, grain size and the proximity of wastewater discharges seem to be the factors that most influence the distribution of species. We have, indeed, distinguished a first group composed by the radials of the mouth where the substrate is sandy (coarse sand to fine for radial 0 to 1a, or sands silted for 2a and 2); a second group corresponding to the radials where the sediment becomes much muddier and clayey (radial: 2 or 3 to 6). Finally, a third group of radials 7 and 8, which corresponds to the zone where the influence of wastewater discharges is important and where the surface of the mud flat is very small.

After the cessation of discharges, the total abundance of the fauna is much greater, the abundance dominance has undergone modifications since it is *H. diversicolor* which becomes the most abundant, followed by *H. ulvae*, *Cerastoderma edule* then *S. plana*.

Differences are also observed at the level of the settlement structure if we continue referring to the coenotic affinity. Indeed, this parameter allows us to distinguish three communities: a group at the mouth (radial: 0 to 2bis), a second group in the central part of the estuary (radial: 2 'to 5) and a third group which associates radials upstream (6 and 8) to those which were azo during discharges (radial: 9 to 12). Radial 7 is discarded because at high tide, the seawater does not reach it any more. This change in the course of water is surely due to the cessation of discharges.

The preexisting species have seen their range extend at the level of the estuary. This enlargement is due either to a colonization of these stations by young specimens of *H. diversicolor*, from *H. ulvae*, *S. plana*, or *C. edule*, or to a migration of these species to these new territories from nearby habitats. Indeed, several authors (Mettam, 1981; Lewis et *al.*, 2001; Meziane & Retière; 2001) report that the populations of *H. diversicolor* have a great ability to migrate at any point in their life cycle. With the exception of Macoma balthica, which is known for its frequent migrations (Perkins, 1974), molluscs are not very mobile. Three species call for particular comments:

- *H. ulvae* is famous not only for the high densities it reaches, but also for its controversial behavior. Authors indicate for this species a tidal cycle of burial, feeding in a pelagic medium (by flotation) then after falling on the ground, crawling (Newell, 1962; Anderson, 1971). On the other hand, other authors think that buoyancy is accidental, and that burial is a reaction against dehydration or predators (Barnes, 1981). The dispersion of this small gastropod would then be due only to the planktonic larval stage or passive transports, by the movements of the water (rotation of the adults on the substrate). One can thus think, after the cessation of the discharges, about a tidal (floating), exploring the upstream stations. Be that as it may, the life span of this species is rarely more than a year and a half. It is reported in the literature that eggs encapsulated by 3 to 5 are observable from March to December and larval arrival occurs three weeks later (Muus, 1986). The expansion of the range of the species could also be explained by a new recruitment.

- *S. plana*, meanwhile, can make rare displacements in the horizontal direction (Hugues, 1970). Six months after the cessation of the discharges, the longitudinal widening of the range of the scrobiculars upstream is surely due to the installation of juveniles especially as this species presents, at the level of Oued Souss, two recruitment periods, from February to March and from late spring to early autumn (Bergayou & Moukrim, 2005).

- *C. edule* also has a longitudinal widening of its distribution on the longitudinal plane. As this species is living and growing in the sand, the cessation of the flow of wastewater in the estuary and the absence of another flow of fresh water in the estuary make the estuary more susceptible to marine hydrodynamics, hence the deposit of a thin layer of sand and the installation of hulls a little further upstream (station 4). This hypothesis is based on the findings of a study at the level of the Canche estuary (northern France) (Dobroniak, 2000). The author explains that the settlements have a certain stability over time, but migrations could be caused by the morpho-sedimentary upheavals caused, among other things, by the hydro dynamism and the geographical modifications of the bed of the Canche, the distribution of the biocenoses being essentially due to these physical factors (Dobroniak, 2000). Another argument is that the hull is fairly sensitive to pollution, whatever its nature, according to a study in the Kinneil mudflats at the Forth estuary in Scotland (Mac Lusky, 1981). In these mud flats, which receive domestic, chemical or oil effluents, *C. edule* does not live in the sediment near the source of pollution, but is found 1.5 km from the effluents; and its maximum abundance is between 1.5 and 2.2 km. In the present study on Oued Souss, this bivalve was found about two kilometers from the source of pollution during discharges and its presence in 2003 in stations 3 and 4 is surely a consequence of the cessation of pollution.

In marine habitats, the phenomenon of restocking may depend on the free surfaces in question. For small areas, restocking is rapid and is done through a large variety of pioneer opportunistic species (Frid, 1989). For large areas, this repopulation can take months or years (Beukema et *al.*, 1999). However, in a more recent study of the Cochin estuary of the tropical monsoon (India) (Rehitha et *al.*, 2017) where sites that were or were not subject to dredging were compared, the authors highlighted the dominance of a single opportunistic benthic taxon that has settled in sites that have been dredged.

In this study, only the most downstream, marine-influenced stations experienced enrichment of new species. Upstream, preexisting species have expanded their range. Similar results have been reported on mudflats at Dutch Wadden Sea (Holland) (Beukema et al., 1999) and at Clonakily Bay, West Cork, Ireland (Lewis et al., 2001).

4.1 Species Richness

Specific wealth was very low during the discharge period (14 species). Indeed, the number of species usually encountered in an estuary varies between 30 and 300 species. By way of comparison, authors have identified 32 species in the Loire estuary (Marchand, 1972; Robineau, 1986), 66 species in the Gironde estuary (Bachelet et *al.*, 1981), 86 species in the Tagus estuary (Portugal) (Calvario, 1984), 264 species in the Bou Regreg estuary (Morocco)

(Elkaim, 1974; Elkaim, 1976); or 52 species in the same estuary (Cheggour, 1988) after the Sidi Mohamed Ben Abdellah dam was commissioned in 1974 in the Bou Regreg basin and, in more recent studies, 37 species for the macrobenthos furniture in the Smir lagoon in northern Morocco (Chaouti & Bayed, 2005) and 57 taxa at the Khnifiss lagoon in southern Morocco (Lefrere et *al.*, 2015). In the case of the estuary of Oued Souss, the factors explaining this faunistic poverty are numerous: the freshwater inputs are very low because of the rare rainfall; this phenomenon is further accentuated by the installation of dams on the bed of the Oued, the most important of which is that of Aoulouz, 150 km upstream; in addition, the pollutant load is important because of urban discharges. Moreover, the lesser diversity of habitats (lack of rocky substrates, absence of sea grass beds) at the level of the estuary and its geographical position with a certain number of species which are at the southern limit of their distribution area explain to some extent this low specific wealth.

After the discharges, we counted 22 taxa. This observation puts the index on the negative effect of wastewater. However, this is a punctual result and should be taken with caution. Indeed, the specific wealth, which reflects stability, depends first and foremost on breaks in the climax of the ecosystem: maximum in average conditions, it decreases when disturbances are important and / or frequent (Connell, 1978). Secondly, the biological regulation of communities can only take place when the resources of the environment are fully utilized. Thus, when the environment remains stable for a very long time, resources become restricted and competition sets the limits of the number of species. The dynamic equilibrium is then reached (Huston, 1994; Pickett & Cadenasso, 1995): the composition of the settlement varies according to the colonization and results in a stable global structure determined by the physical environment and the predation.

4.2 Biomass

The average biomass of the harvested fauna has varied. Thus, during the discharge period, it was 15.54 g/m² then 15.84 g/m² (in 2001 and 2002 respectively), with three species (*H. ulvae*, *H. diversicolor* and *S. plana*) which constitute the majority: 83.33 to 93.85% respectively for the first two campaigns. These species are typical of Atlantic estuaries and are known for their tolerance (Gonzales Oreja & Sais Salinas, 2003).

On the other hand, after the cessation of discharges, the average biomass was 20.56 g / m², of which 78.79% is represented by the four dominant species in abundance: *H. diversicolor*, *S. plana*, *C. edule* and *H. ulvae*. In order of dominance in biomass, the cockles come first with 31.52% of the total biomass. This is important and can be explained by the spectacular expansion in terms of numbers marked by the species.

The other three species represent only 47.25% of the total biomass. If we consider the two species *S. plana* or *H. diversicolor*, their total abundance marks, respectively for the two species, an increase of 1.5 to 3.4 times and 1.89 to 4.13 compared to the period of discharges. This increase is not accompanied by an increase in the biomass of these two species. Knowing their diets: mixed for *S. plana* (detritivore at low tide and suspensivore at high tide) and detitivore for *H. diversicolor*, we can think of a slimming of individuals in relation to the decline in the rate of organic matter noted in the sediment after the cessation of discharges (Ait Alla et al., 2006b).

In a comparative study of *H. diversicolor,* populations of the Bou Regreg estuary (Morocco) (Gillet, 1986) with populations of this species from the Ythan (Scotland) estuary (Chambers & Milne, 1975), the author (Gillet, 1986) reaches the same findings by emphasizing that for neighboring densities. The highest biomasses corresponded to the populations of the stations close to the sewage outlets, and thus whose sediment contained a high level of organic matter.

Still regarding the biomass, our results are comparable to those obtained in the Gironde estuary (France) where 90% of the average biomass (estimated at 10.4 g / m²) consists of the biomasses of three dominant species (Bachelet et *al.,* 1981). In comparison, in a study on mud flats at Duch Wadden Sea (Holland), an average biomass of 26.6 g/m² (Beukema, 1976) and a biomass of 13.2 g/m² in the Lynher estuary (England) are reported (Warwick & Price, 1975). However, it should be noted that this type of comparison is difficult because the methods used are not always homogeneous and the environmental conditions are rarely taken into account.

5 CONCLUSIONS

This study proposes an inventory of the intertidal benthic system of the Oued Souss estuary from a structural point of view. First of all, it allowed us to acquire a qualitative (species list, specific wealth) and quantitative (abundance, biomass, species density) database of intertidal benthic macrofauna. It represents a reference state. This tool was used to respond to requests for information about the quality of the environment immediately after the cessation of wastewater discharges and could serve as a basis for conducting impact studies later.

However, while the spatial dimension is relatively well documented, the temporal dimension was not taken into account in this study. Finally, we suggest a continuation of the investigations along the estuary according to a monthly or seasonal monitoring in order to be able to establish the structure of the benthic population over time (seasonal and interannual variations) and to see the new state of equilibrium, which must be currently reached by the different zoobenthic populations of the estuary.

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