

RESEARCH ARTICLE

## Macrozoobenthic species composition and distribution in the Northern lagoon of Tunis

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### Abstract

- 1 - The macrobenthic community and abiotic parameters of a Méditerranéan lagoon (Northern lagoon of Tunis) was studied on autumnal season during 1995, 1996 and 1997.
- 2 - Analysis of abiotic parameters revealed significant differences between stations. Variations of temperature and salinity reported in this study show a gradient increasing in the direction of circulating currents. Tidally driven marine waters cause a continuous refreshment of lagoon waters, thus promoting oxygenation and nutrient loading.
- 3 - In total, 61 species were recognized, divided into seven zoogroups with Molluscs always dominant. A noticeable increase in specific richness occurred due to hydrologic and environmental improvement after sanitation in 1984-1988.
- 4 - Comparison of ecological indexes (specific richness, abundances, density, Shannon-Weaver indexes and evenness) indicate significant variations in the spatial distribution and structure of benthic community, area A subjected to marine refreshment having a more diversified benthic fauna. In contrast, stations (B and C) remote from the sea display a neat faunal disturbance.
- 5 - Multivariate analysis helps characterize heterogeneity in the benthic community structure of stations; thus, Echinodermata and Porifera phyla represent a great heterogeneity in species abundances.
- 6 - Physico-chemical properties of lagoon waters and macrobenthic faunal characters help identify three main sectors: i) a northeastern sector near the lagoon entrance, with newly introduced marine species (as *Pinctada radiata*); ii) a transitional sector which suffered pollution earlier to lagoon sanitation; iii) a sector with confinement and typically lagoonal, eurythermal and euryhaline species

**Keywords:** community, macrozoobenthos, Northern lagoon Tunis, diversity, pollution, sewage.

### Introduction

The lagoon of Tunis City is a coastal Mediterranean marine basin located in Northeastern Tunisia, on the southwestern border of the Gulf of Tunis (Fig. 1). This lagoon comprises two principal basins separated by a ship canal: the *Northern lagoon* which communicates with the Gulf of Tunis via the Keireddine channel, and the *Southern lagoon* which is linked to the open marine milieu in the Gulf throughout the Radès channel.

During the 20<sup>th</sup> century, the Northern lagoon of Tunis has reached eutrophication and as a consequence, ecological disturbances by sewage from the neighboring Tunis City. Dystrophic crises notably during the dry season, prevailed in this ecosystem with nitrophilic Algae, anoxia, fish mortality, and nauseating smells (Belkhir & Hadj Ali Salem, 1983). Since the early 1944 (Heldt, 1953), the lagoon was largely invaded by

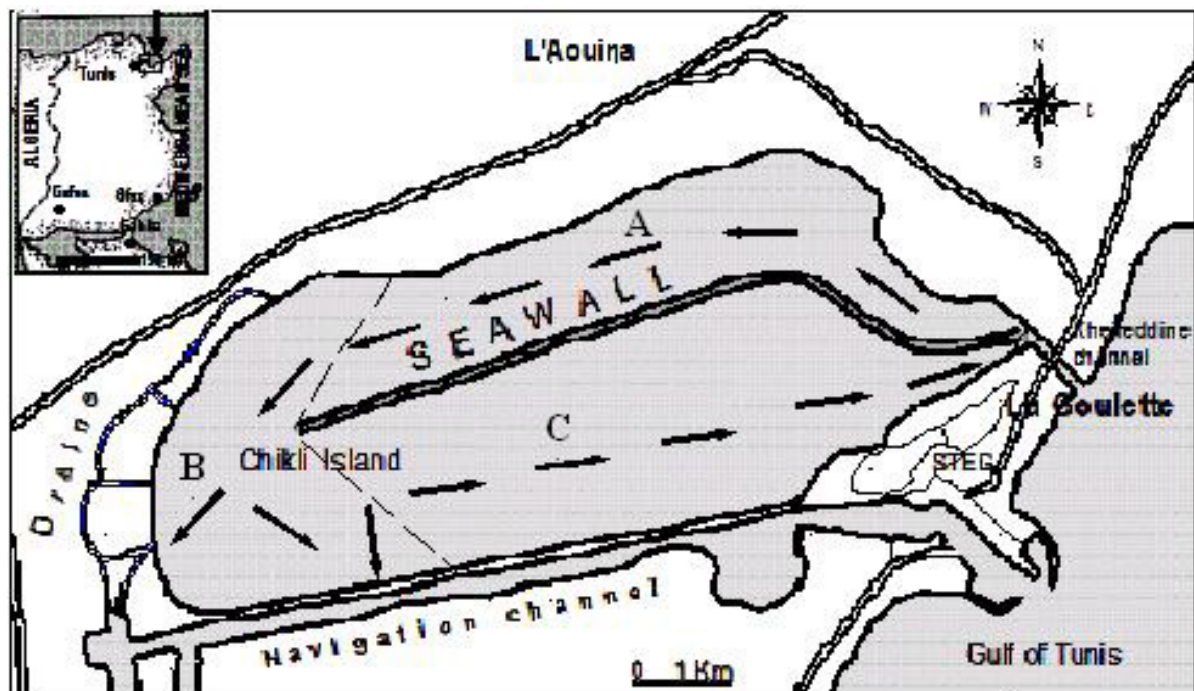


Figure 1. Location of the lagoon of Tunis, hydrologic improvement of the lagoon following sanitation in 1984-1988, and location of sampling stations (A, B and C).

*Ficopomatus enigmaticus* (detritivore Annelids) build-ups with atolls emergence during tidal drop-down. The atoll barriers have intensified eutrophication, along with phytoplankton and benthic Algae (notably *Ulva*) developments. Atolls have profoundly altered the currents hydrodynamics and hence, oxygenation of waters (Rudis, 1966; Zaouali & Baeten, 1984). Moreover, lagoon eutrophication prevailed in the 1980s, due to a neat increase in sewage (Zaouali & Baeten, 1984).

Sanitation works in the period 1984-1988 were carried out with the aims of i) sanitating the basin and land gains for enlargement of Tunis City, ii) reestablishing the lagoon communication with the sea, and iii) a regeneration of basin hydrodynamics (Ben Maiz, 1993; Ben Maiz, 1994).

The Kheireddine Channel equipped with one-way locks driven by tidal movements, was dredged to facilitate tidal water exchanges between the lagoon and the gulf of Tunis (Fig. 1), A sea-wall, 5-8 m large

and 8,2 km long, subdivides the Northern lagoon and favors sinistral movements of marine waters. Dredging and backfilling and coastline modifications help prevent local eutrophication; the lagoon total area was reduced from 3000 to 2600 ha (Trabelsi *et al.*, 2001).

Many studies have dealt with the hydrodynamic, physical and chemical aspects of waters from the northern lagoon of Tunis (Rudis, 1966; Cruzet, 1973; Zaouali, 1977, Belkhir and Hadj Ali, 1983; Ben Charrada, 1992); in contrast the distribution of macrozoobenthic community has not been taken into adequate consideration. Previous studies by Letourneaux and Bourguiniat (1887), Dautzenberg (1895) and Pallary (1904 - 1914) which have reported on the malacologic fauna in the basin, were followed by the contributions of Heldt (1929) and Bruun (1940) and later, by a paper of Vuillemin (1952) who described the ecological aspects of *Ficopomatus enigmaticus* built-ups in the Northern lagoon. In 1966, the Rudis Team

study (1966) undertakes the quantitative aspects of the Mollusc community. Zaouali (1971) published results on the distribution of the malacological community, and later, the eutrophic effects in the Northern lagoon of Tunis (Zaouali and Baeten, 1984) prior to sanitation in the period 1984-1988.

This study reports on the results of two Research Programs from 1992 to 1998 carried out with the aim of understanding the environmental changes of the Northern lagoon of Tunis (Tlig-Zouari *et al.*, 1999), and to characterise the overall reconstruction of benthic invertebrates community in response to sanitation in the period 1984-1988.

## Materials and methods

### Field sampling and processing

The sampling plan was simple; during each session, samples were taken by day-time, randomly in three stations A, B and C of the lagoon, in the direction of water renewal in the basin (Fig. 1).

- **Station A** is located to the North-East in the lagoon (Fig. 1), in the vicinity of the keireddine locks with a continuous income and renewal of marine waters throughout the channel by tide driven water currents. Bathymetry approximates 2.5m in this part of basin deeply dredged for restoration in 1984-1988. Bottom sediments therein, with a few organic matter, include oozes with a sandy fraction prevailing relative to fine-sized clays.

In the area, vegetation bears phanerogame prairies, dominantly *Ruppia cirrhosa*, but in association to *Zostera noltii*. There also arise a few clumps made up with either *Caulerpa prolifera*, *Dasya sp.*, *Cymodocea nodosa* or *Chetomorpha linum* (Trabelsi, 1995 and Shili, 1995).

- **Station B** (2-4 depth) is located westerly (Fig. 1) and covers a zone with a transitional change in direction of circulating water currents. This sector subjected to pollution by sewage from Tunis city. Despite restoration

efforts and removing of anoxic mud layers, a one meter thick deposits still exhibit a black coloured slimy mud with high amounts of organic matter.

The area consists of prairies with *Ruppia cirrhosa* and *Chetomorpha linum*; the latter gains more and more ground towards the South and South-East, and a neat prosperity and preference to those protected shallow areas of the lagoon (Trabelsi *et al.*, 2001).

- **Station C** extends to South and South-East with 1 to 2.5m bathymetries, and marks the end of marine circulating currents inside the lagoon; this area was not dredged (Fig. 1).

The sector is invaded by a community of *Chetomorpha linum*. To the East, the species accompany local clumps bearing more or less thick *Gracilariaria verrucosa*. To the West, around the small Chekli island, *Chetomorpha linum* associates with *Gracilariaria verrucosa*, *Hypnia musciformis* and *Ceramium sp* (Trabelsi, 1995).

Triplicate samples of benthic macroinvertebrate were collected in three stations (A, B, and C) of the Northern lagoon of Tunis in each campaign, by diving aboard a boat, in a bottom fixed quadrat 0.5x0.5m wide (0.25 m<sup>2</sup>), designed to collect infauna and epifauna. Sampling sessions took place in autumn, during three successive years (three campaigns: first at November 1995, second at November 1996 and third at November 1997).

Were measured *in situ*, by station, the main physical and chemical parameters of surface waters (temperature, salinity, pH and dissolved oxygen). The sediments collected in a bottom fixed sled were immediately passed through a 1mm-sized sieve, and the screened macroinvertebrates species were fixed in a 10% formaline solution. In the laboratory, the specimen in samples were sorted, classified for taxonomy and counted under the microscope in respect to appropriate guides.

Table 1. Physical and chemical data for waters in the Northern lagoon of Tunis. T: temperature (°C), S: Salinity (%); Dissolved Oxygen (mg l<sup>-1</sup>); Saturation (%) and pH.

Station	A	B	C
Temperature (°C)	17.2 ± 3.75	18 ± 3.70	18.73 ± 3.85
Salinity (%)	38 ± 0.91	39.06 ± 0.57	39.60 ± 0.87
Dissolved oxygen (mg l <sup>-1</sup> )	7.53 ± 0.93	7.26 ± 1.02	7.23 ± 1.26
Saturation (%)	100.7	100.5	94.36
pH	7.73 ± 0.40	8.20 ± 0.10	7.93 ± 0.46

Table 2: Kruskal Wallis test applied to physical and chemical parameters.

Kruskal Wallis test (Clustering criteria station)				
	T	S	O	PH
Khi-deux	200	1.681	7.61	3.919
ddl	2	2	2	2
Asymptotic signification	.027*	.0432*	.027*	.141

\* p<0.05

## Data analysis

Determinations include: the species abundances and diversity, as well as their densities expressed as the number of individuals per square meter bottom lagoon space. The diversity of species is measured by the Shannon & Weaver (1963) diversity index and the evenness is calculated as defined by Pielou (1966).

In order to separate the stations in homogenous groups, the Ascending Hierarchical Clustering was applied on contingency table according to Ward's method (Ward, 1963). The Factorial Correspondence Analysis (FCA and FDA) taking into account the eight phyla identified as variables of classification in better distinguish any tiny heterogeneity among samples, were also used. Before statistical treatment species abundances were transformed log (x+1). Multidimensional analysis were carried out with R2.2.0 ADE4 Software.

## Results

### Abiotic factors

Significant differences were calculated for

physical and chemical parameters from one station to another (Tab. 2). Mean values of temperature measured in the selected stations of the three successive autumn sessions (Tab. 1) vary from a low 17.16°C value due to influence of open marine waters in station A, to a higher 18.73°C temperature measured in stations C. The temperature gradient increases in direction of circulating waters. The lower average salinities (38) (Tab. 1) may be explained (Tab. 1) by influential open marine currents near the Kheireddine channel (station A). In contrast, higher average salinities in area C (39.60) characterize waters evaporated in the Southeastern lagoon areas. Salinity may yearly vary, in a gradient always increasing in direction of circulating currents. The dissolved oxygen amounts in waters (Tab. 1) lie in the range: 7.23 – 7.53 mg l<sup>-1</sup> (saturation 94.4 % - 100.7 %). Area A is oxygenated enough in response to fresh marine waters from the Kheireddine channel; whereas the lowermost mean amounts in oxygen occur in area C, and correlate with high temperatures. The pH values fall in a narrow range: 7.73 –



8.20 (Tab. 1); the lower values were those in sector A, and the higher, in area B..

*Benthic Community*

A total of 27 samples totalling 37086 individual macroinvertebrates were collected and sixty one species were identified (Tab.

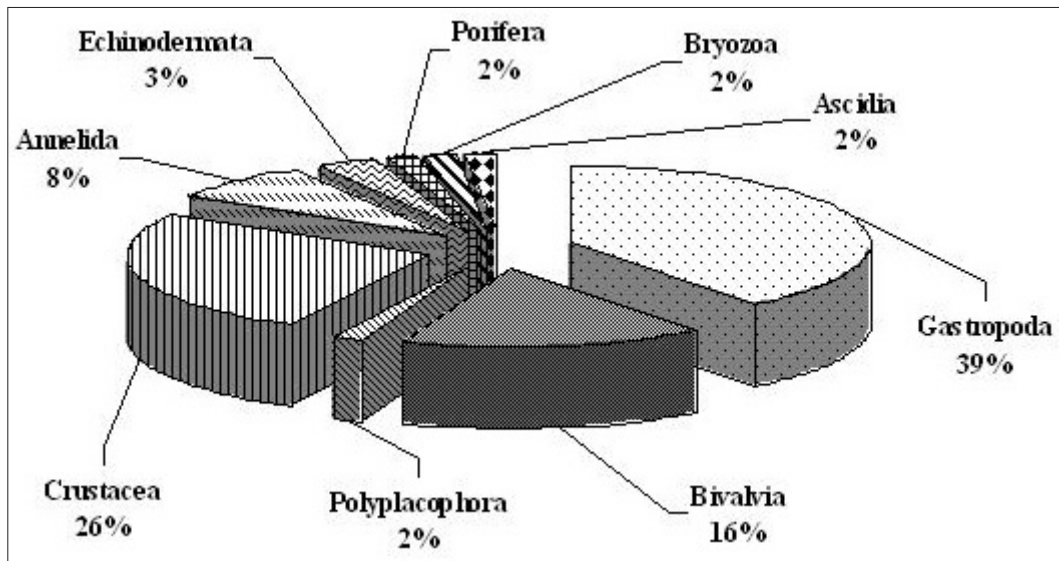


Figure 2. Percentages of taxonomic groups collected in the Northern lagoon of Tunis.

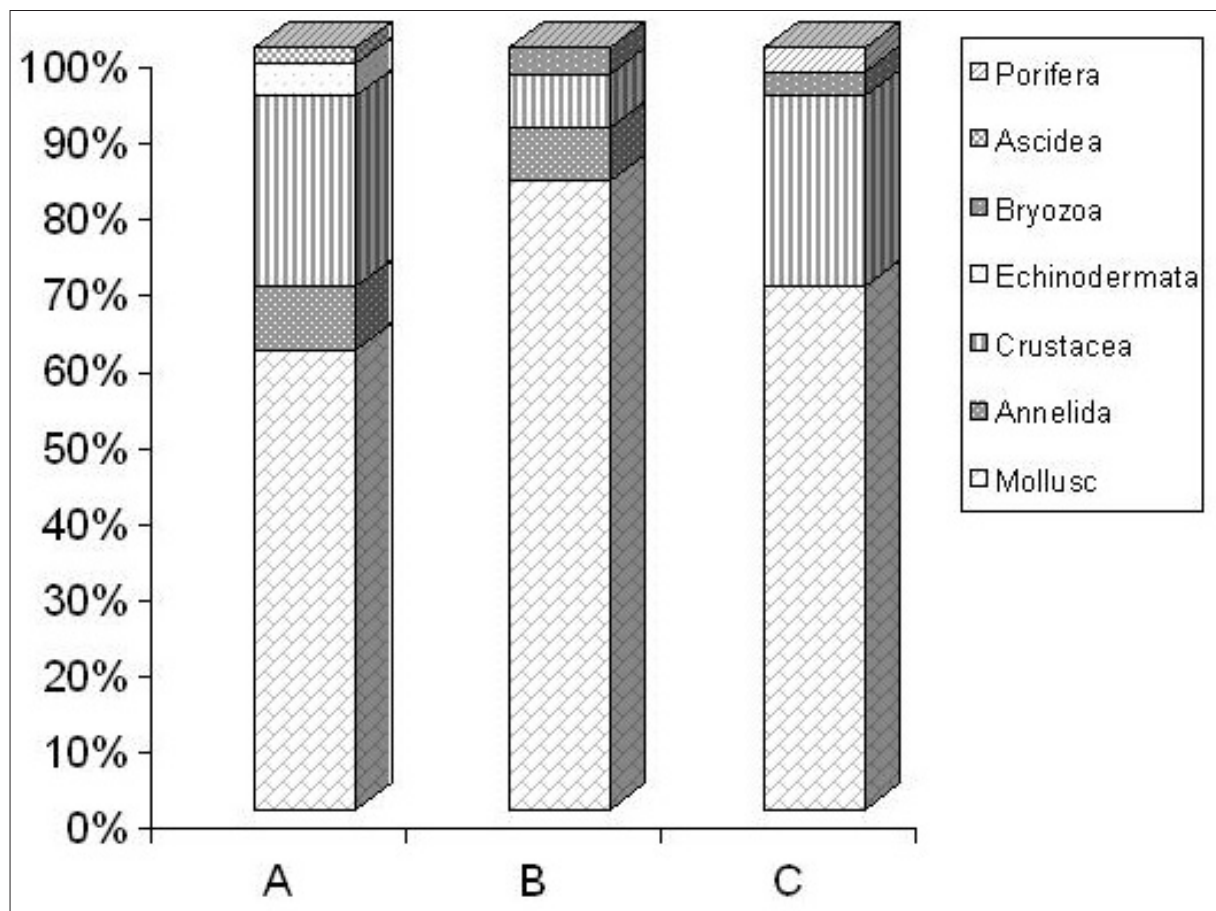


Figure 3: Percent composition of each taxonomic group collected in three stations (A, B and C) of the Northern lagoon of Tunis.

Table 3. Values of ecological and diversity indexes collected in each station. A, B and C: stations; S: species number; D: density; Mean Abundance; H: Shannon-Weaver’s diversity index; J: evenness.

Station	A	B	C
<b>Total number of species S</b>	48	29	31
<b>Variations in number of species S</b>	21 - 30	11 - 26	14 - 23
<b>Mean abundance</b>	994.66 ± 656.68	8903.00 ± 8761.06	2131.09 ± 2124.78
<b>D (ind.m<sup>-2</sup>)</b>	1526.66 ± 1220,03	2058.66 ± 973,94319	2221.33 ± 1319,8201
<b>H’(bits)</b>	3.00 - 3.77	2.31 - 2.99	2.48 - 3.21
<b>J</b>	0.70 - 0.82	0.64 - 0.83	0.60 -0.78

3); the species (Fig. 2) subdivide unequally into seven zoo-groups. Abundant Mollusc species (60..6%) always prevail with respect to Crustacea (26%); whereas remaining groups exhibit lower percentages: Annelida (8.2%), Echinodermata (3.3%), either Bryozoa, Porifera or Ascidiacea (1.6%). The Gastropoda species (39.3%) together with Bivalvia (16.4%) dominate the community, in contrast with accessory Polyplacophora (1.6%).

The composition of taxonomic groups vary from one station to another (Fig. 3) with five phyla in area A (Mollusc 60.4%, Crustacea 25%, Annelida 8.33%, Echinodermata 4.16% and Ascidea 2.08%), but only four phyla in area B (Mollusc 28.75%, Crustacea 7%, Annelida 7% and Bryozoa 3.45%) and area C (Mollusc 71%, Crustacea 25.8%, Bryozoa 3.22% and Porifera 3.22%). Moreover, Molluscs were the most dominant phylum in the three stations.

The species richness is comprised of 29 to 48 species (Tab. 3). A maximum species (48) live in area A proximal to the Kheireddine channel; whereas, a minimum of species (29) live in sector B. A less diversified fauna (31 species) were collected in area C..

Comparison between stations revealed as many as (23) benthic species (Tab. 4) collected in area A only, with a marine affinity, among which were recognized Bivalvia *Leda pella*, *Angulus tenuis*, *Mytilus galloprovincialis*,

*Anomia ephippium*, *Tellina planata*, invasive specie *Pinctada radiata* and Crustacean *Penaeus kerathurus* and *Palaemon adspersus*. Three species (*Hinia costulata*, *Bolinus brundaris* and *Neanthes caudata*) were found in westernmost area B only. In area C, six species were observed (Porifera *Suberites domunculus* and associated Crustacean *Corophium acherusicum*, *Melita palmata*, *Cymadusa hirsuta*, *Palaemon serratus* and *Palaemon xiphias*).

In contrast, eight species only were abundant and ubiquitous, including : *Hydrobia ulvae*, *Cerithium vulgatum*, *Tricolia pullus*, *Gibbula imbilicaris*, *Bittium reticulatum*, *Abra tenuis*, *Loripes lacteus*, and *Cerastoderma glaucum* (Tab. 4). The species *Pinctada radiata*, and the Crustacean *Sphaeroma serratum*, *Gammarus aequicauda* and *Pagurites oculatus* were dominant in station A; whereas the Bryozoa

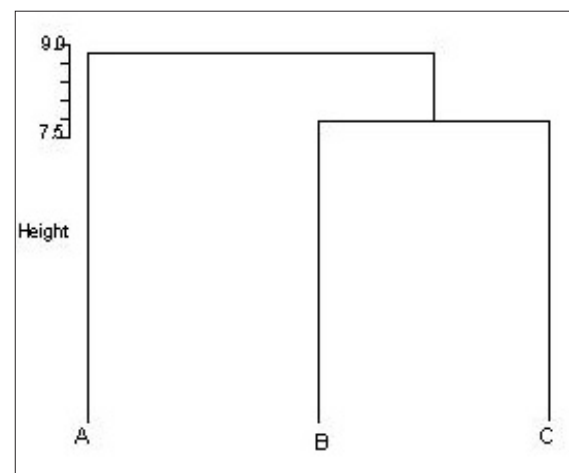


Figure 4. Ascending hierarchical clustering.

Table 4. Macrobenthic species identified in stations A, B and C during autumnal periods 1995 to 1997.

(+ : present one period ; ++ : present two periods; +++ : present three periods)

Species	Stations			Zaouali and Baeten, 1984
	A	B	C	
<b>PORIFERA</b>				
<i>Suberites domuncula</i> , (Olivi, 1792)			+	
<b>MOLLUSCA</b>				
<b>Gastropoda</b>				
<i>Hexaplex trunculus</i> (Linné, 1758)	++	++		
<i>Cerithium vulgatum</i> (Bruguière, 1792)	+++	+++	+++	*
<i>Rissoa ventricosa</i> Desmarset, 1814	++	+++	+	*
<i>Rissoa parva</i> (Da Costa, 1778)	+	+	+	
<i>Nassarius corniculum</i> (Olivi, 1792)	++	+	+	*
<i>Nassa incrassata</i> (Ström, 1768)		+	+	
<i>Nassa costulata</i> (Renier, 1804)		+		
<i>Nassarius reticulatus</i> (Linné, 1758)	+			
<i>Gibbula imbilicaris</i> (Linné, 1758)	++	++	++	
<i>Gibbula varia</i> (Linné, 1758)	+	+	+	*
<i>Gibbula richardi</i> (Payraudeau, 1826)		+	+	
<i>Nucella lapillus</i> (Linné, 1758)	+			
<i>Littorina neritoides</i> (Linné, 1758)	++		+	
<i>Turritella communis</i> Risso, 1726	+			
<i>Tricolia pulla</i> (Linné, 1758)	+++	+++	+++	*
<i>Pyrene scripta</i> (Linné, 1758)	+	++	++	
<i>Hydrobia ulvae</i> (Pennant, 1777)	+++	+++	+++	
<i>Scaphander lignarius</i> (Linné, 1758)	+	+	++	
<i>Bulla striata</i> (Bruguière, 1789)	+	+	+	
<i>Monodonta turbinata</i> (Born, 1780)	++	++	+	
<i>Cantharidus striatus</i> (Linné, 1758)		+	+	
<i>Bolinus brandaris</i> (Linné, 1758)		+		
<i>Conus mediterraneus</i> (Bruguière, 1789)		+	+	
<i>Bittium reticulatum</i> Costa, 1778	++	++	++	*
<i>Cyclope (Cyclonassa) neritea</i> (Linné, 1758)				*
<i>Haminoea hydatis</i> (Linné, 1758)				*
<b>Bivalvia</b>				
<i>Leda (Nuculana) pella</i> Linné, 1758	+			
<i>Abra tenuis</i> (Montagu, 1803)	+++	+++	+++	*
<i>Cerastoderma glaucum</i> (Poiret, 1789)	++	++	++	*
<i>Loripes lacteus</i> Linné, 1758	+++	++	+++	
<i>Ruditapes decussatus</i> (Linné, 1758)	+++	+	+	*
<i>Angulus tenuis</i> Da costa, 1778	+			
<i>Tellina planata</i> Linné, 1758	+			
<i>Mytilus galloprovincialis</i> Lamark, 1819	+			
<i>Pinctada radiata</i> Leach, 1814	+++			
<i>Anomia ephippium</i> Linné, 1758	+			
<b>Placophora</b>				
<i>Lepidopleurus cinerea</i> (1767)	++	++		
<b>ANNELIDA</b>				
<i>Hydroides norvegica</i> Cunnerus, 1768	+			*
<i>Serpula vermicularis</i> Linné, 1767	+			
<i>Perinereis cultrifera</i> Grube, 1840	++	++		
<i>Portula tubularia</i> (Montagu, 1803)	+			
<i>Neanthes caudata</i> (Delle Chiage, 1828)		+		
<i>Hydroides elegans</i> (Haswell, 1883)				*
<i>Ficopomatus enigmaticus</i> (Fauvel, 1923)				*
<i>Polydora caeca</i> (Oersted, 1843)				*
<i>Amphitrite rubra</i> (Risso, 1826)				*
<i>Capitella capitata</i> (Fabricius, 1780)				*
<i>Polyphthalamus pictus</i> (Dujardin, 1839)				*
<i>Harmothoe sp</i>				*

<b>ARTHROPODA</b>				
<b>Crustacea</b>				
<b>Isopoda</b>				
<i>Idotea chelipes</i> (Pallas, 1766)	+	+	+	
<i>Paracerceis sculpta</i> (Holmes, 1904)	+		+	*
<i>Sphaeroma serratum</i> (Fabricius, 1787)	+++	+	+	
<i>Idotea viridis</i> (Pallas, 1772)				*
<b>Amphipoda</b>				
<i>Gammarus aequicauda</i> (Martynov, 1931)	+++			*
<i>Cymadusa hirsuta</i> Chevreux, 1900			+	
<i>Orchestia gammarella</i> (Pallas, 1766)	+			
<i>Lysianassa longicornis</i> Lucas, (Della Valle, 1893)	+			
<i>Corophium volutator</i> (Pallas, 1766)	+			*
<i>Corophium acherusicum</i> Costa, 1851			+	
<i>Melita palmata</i> (Montagu, 1804)	+		+	*
<i>Gammarus insensibilis</i> Stock, 1966				*
<i>Lysianassa plumosa</i> (Sars, 1890)				*
<i>Leptocheirus pilosus</i> Zaddach, 1814				*
<i>Cymadusa hirsuta</i> Chevreux, 1902				*
<b>Cirripoda</b>				
<i>Balanus amphitrite</i> Darwin, 1854	+			*
<b>Decapoda</b>				
<i>Pagurustes oculatus</i> (Fabricius, 1775)	+++			
<i>Brachynotus sexdentatus</i> (Risso, 1827)				*
<i>Palaeomon adspersus</i> , Rathke, 1837	+			
<i>Palaemon serratus</i> (Pennant, 1777)			+	
<i>Palaemon xiphias</i> Risso, 1816			+	
<i>Penaeus (Melicertus) kerathurus</i> (Forska <sup>o</sup> l, 1775)	+			
<b>Insecta</b>				
Chironomes				*
<b>BRYOZOAIRES</b>				
<i>Zoobothryon verticillatum</i> (Delle Chiaje, 1822)		+++	+++	
<i>Conopeum seurati</i> (Canu, 1928)				*
<i>Bowerbankia gracilis</i> (Leidy, 1855)				*
<i>Cryptosula pallasiana</i> (Moll, 1803)				*
<b>ECHINODERMATA</b>				
<i>Amphipholus squamata</i> (Delle Chiaje, 1828)	+			
<i>Asterina gibbosa</i> (Pennant, 1777)	+			
<b>CHORDATA</b>				
<b>Ascidacea</b>				
<i>Ciona intestinalis</i> (Linné, 1767)	+			*

*Zoobothryon verticillatum* dominated in areas B and C.

A low density was measured in area A ( $1526.66 \text{ ind.m}^{-2} \pm 1220,03$ ) (Tab. 3), thus contrasting with a higher value ( $2221.33 \text{ ind.m}^{-2} \pm 1319,8201$ ) in area C; an elevated density ( $2058.66 \text{ ind.m}^{-2} \pm 973,94319$ ) was also measured in transitional area B.

The Shannon indexes (Tab. 3) fall in

the range: 2.31 – 3.77; the higher index corresponds to station A (3.77), and lower to station B (2.31). The evenness values (Tab. 2) vary from 0.60 to 0.83 is elevated and points to an environmental stability of fauna living in station A. Rather low evenness (<0.72) in areas B and C may be accounted for by local disturbance.

Ascending hierarchical methods (Fig. 4)



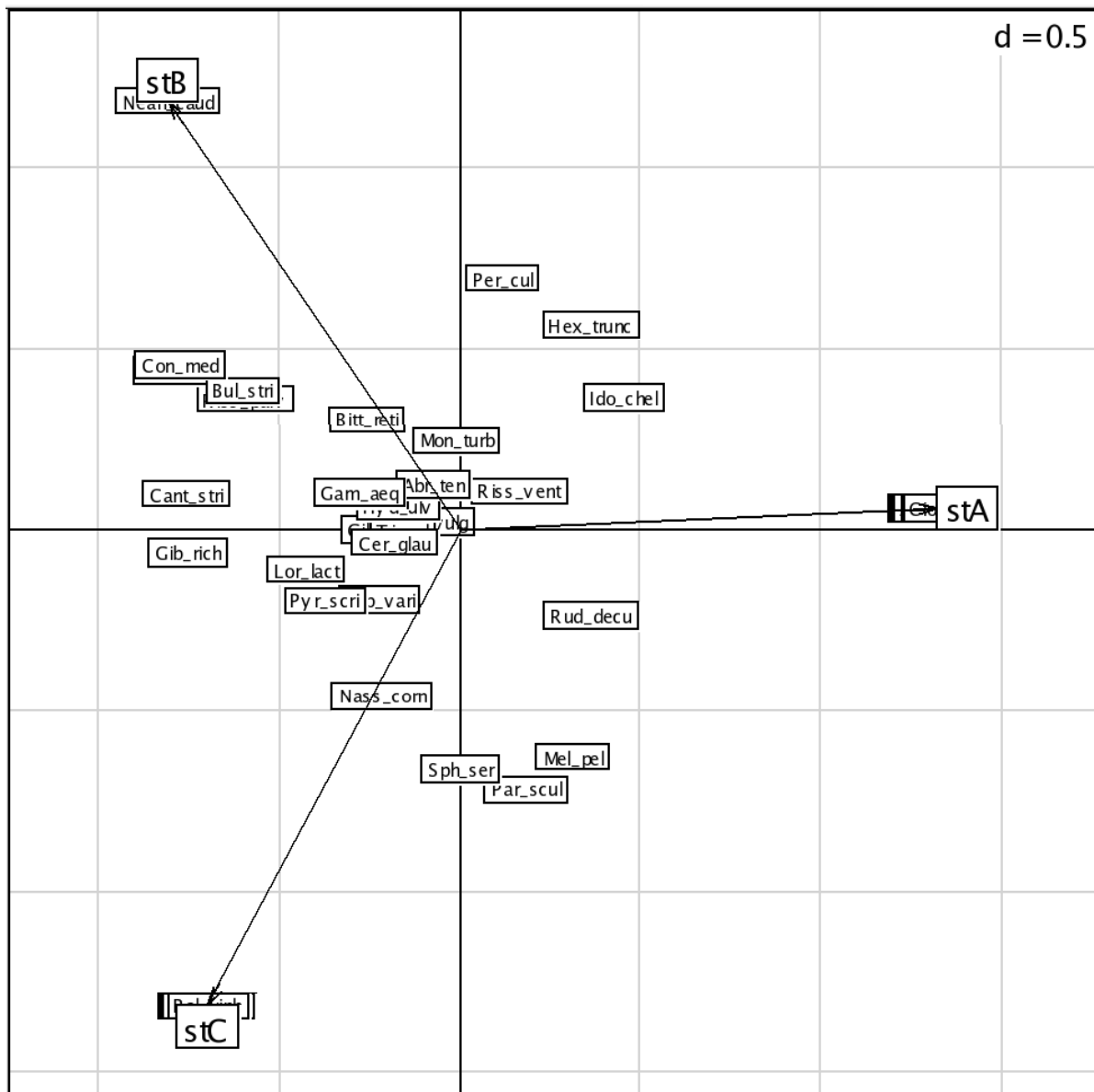


Figure 5. FCA: simultaneous projections of both stations and species according to their mean abundances, on the axis 1 and 2.

enabled distinction between stations (A B and C), and correspondence analysis, simultaneous projection of both species and stations (Fig. 5), with the first two axes (F1/F2) explaining 99.97% of total variance. Axis 1 contrains 68.22% of initial information and distinguished a first group (stations B and C) on the negative side, and station A on its positive side. The overwhelming species that present

the strongest contribution in this axis are *Ciona intestinalis*, *Pinctada radiata*, etc. The second axis (31.75% total inertia) segregated station B with *Neanthes caudata* on the positive side, and station C on the negative side. Species with a strong loading are *Corophium acherusicum* *Palaemon adspersus*, etc. In FDA graph (Fig. 6) Echinodermata and Porifera phyla only present a great

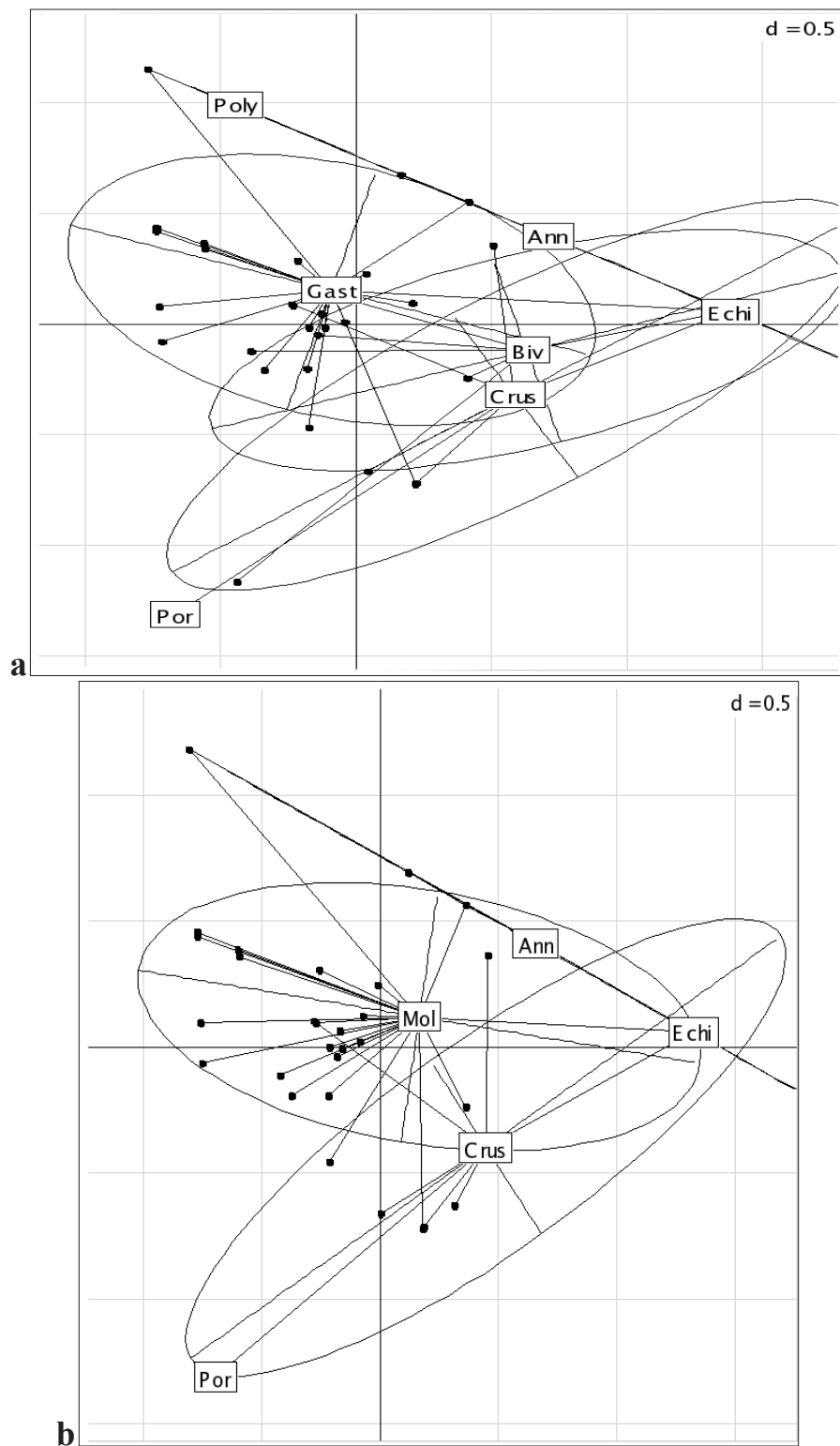


Figure 6. FDA discriminating the phyla according to the species mean abundances. (a: Ann: Annelida; Mol: Mollusca; Crus: Crustacea; Echi: Echinodermata; Por: Porifera; Bry: Bryozoa), (b: Ann: Annelida; Gas: Gasteropoda; Biv: Bivalvia; Poly: Polyplacophora; Crus: Crustacea; Echi: Echinodermata; Por: Porifera; Bry: Bryozoa).

heterogeneity in abundances of species.

## Discussion

### *Abiotic factors*

The sanitating programme and management of the lagoon in the period 1984-1988, has profoundly modified hydrology. A wide range in temperature is due to waters renewal, particularly in area A; waters from the gulf of Tunis with a low temperature mix with warmer waters inside the basin, thus causing refreshment in autumn.

Salinities vary spatially; lagoon areas with a lower bathymetry (station C) being exposed at ambient temperature, to sunstroke and intense evaporation; thus, the greater the salinity of waters, the greater the temperature of surface waters, and as a consequence evaporation.

Variations in dissolved oxygen amounts and pH may be accounted for by waters continuously exchanged with open marine milieu (Ben Maiz, 1992; Ben Charrada, 1992).

### *Benthic community*

Sixty one autumnal species were counted; Molluscs, particularly Gastropoda, dominate in number of species. The benthic community in the lagoon of Tunis, is similar to the one mentioned by Zaouali (1982) in the El Bibane lagoon. Taxa identified are mostly lagoonal, both eurythermal and euryhaline, but with additional common marine species which have invaded the lagoon.

In the vicinity of the Kheireddine channel entry (station A), species exhibit lagoonal affinities (intralagoons) (*Hydrobia ulvae*, *Gibbula imbilicaris*, *Bittium reticulatum*, *Cerithium vulgatum*, *Rissoa ventricosa*, *Tricolia pullus*, *Cerastoderma glaucum*, *Abra tenuis*, *Loripes lacteus*, *Ruditapes decussatus*, *Sphaeroma serratum*, *Corophium acherusicum*, *Gammarus aequicauda*., etc...), with additional typically marine taxa (*Mytilus galloprovincialis*, *Tellina planata*, *Angulus tenuis*, *Pinctada radiata*, *Asterina*

*gibbosa*, *Amphipholus squamata* and *Palaemon adspersus*). Marine species are spatially limited, living near the Keireddine channel (station A); moreover, *Mytilus galloprovincialis* and *Pinctada radiata* were confined nearby the channel gates.

The Indopacific *Pinctada radiata* has undergone a long lesseptian migration, and has invaded the entire Eastern coast of Tunisia (Tlig-Zouari, 1993); but to our knowledge, this species has not been identified or described in the lagoon of Tunis, and is reported here for the first time; we noticed specimen mostly of small-sized individuals fixed onto channel locks and onto nearby rockys; it is thought that the pinctadine driven by tide, has recently transited toward the basin and has began to invade the inner parts of Northern lagoon of Tunis..

In contrast, in intralagoon zones (B and C) no species with dominant marine affinities were recognized; the community is a less diversified taxa with a few number (3-4) of specifically Mediterranean lagoonal species living in restricted waters. This observation lends support to a rather polluted and confined sites B and C, thus causing faunal disturbance (Guelorget & Perthuisot, 1983; 1992).

Thus, our results indicate that the distribution of fauna respond to various environmental constraints: high pollution levels due to sewage to the west and south, marine refreshment near the channel, evapotranspiration and confinement to the southeast.

The sanitation programme (1984-1988) improved hydrology, and has caused a remarkable modification in community structure with a neat diversification and newly introduced marine taxa. The number of sixty one species recognized in this study (Tab. 4) is higher than the total 35 species described by Zaouali and Baeten (1984). Thus, a clear enrichment in taxa likely interrelates with improved lagoon hydrology and marine refreshment. The benthic structure has also

been modified; in fact, Zaouali and Baeten (1984) identified a benthic community regrouped as follows : i) species in stations with marine influence; ii) species living in the center of lagoon, comprise lagoon taxa; iii) species adapted to pollution, inhabit the western lagoon zones subjected to earlier eutrophication, such as: *Ficopomatus enigmatica* and *Capitella capitata* (Pearson & Rosenberg, 1978).

Among specimen of to the latter Annelida installed on soft and muddy biotopes enriched in organic matter, none were found alive in our samples. It is likely therefore that the group inhabiting polluted sectors (Zaouali and Baeten, 1984) has undergone extinction, but has been replaced by typical lagoonal taxa after restoration efforts. The forming community includes a limited number of species, but with a prominent grazing Gastropods browsers, and sometimes detritivore Crustacea often recorded in similar lagoonal environments; the faunal composition analysis showed the omnipresence of species which characterize euryhaline and eurytherm biocenosis; thus, despite restoration efforts, the lagoon of Tunis is still disturbed. and represented a stressed environment.

The community structure described in the lagoon of Tunis closely resemble those reported for the Ghar el Melh lagoon (Northeastern Tunisia) by Ben Romdhane & Ktari-Chakroun (1986). These authors stressed the idea that in their lagoon, environments under mostly seawater control, exhibit marine inhabitants ; in contrast, taxa adapted to brakich waters populate the lagoon zones subjected to major continental runoff (Moussa *et al.*, 2005); they also noticed that the great majority of benthos in the Ghar el Meleh lagoon includes eurythermal and euryhaline species.

In contrast, the Bizerte (Northern Tunisia; Zaouali, 1981; 2004 ) and Monastir (Sahel region; Mortier, 1979) lagoons present clearly diversified benthic communities of

predominantly marine species. Furthermore, in the hyperhaline El Bibane lagoon (Southeastern Tunisia), Zaouali (1982) described a diversified Mollusc community with an heterogeneous biocenotic composition where the specific distribution of taxa interrelates with local hydrologic factors and bathymetry. Surprisingly, she noticed that the specific richness index decreases considerably in those Mollusc assemblages inhabiting lagoon areas proximal to the sea, with substrates continuously destabilized by an erosive bottom currents.

The specific richness in the lagoon of Tunis corroborates those results commonly reported in Mediterranean lagoons (Guelorjet *et al.*, 1994; Tagliapictra *et al.*, 1998; Koutsoubas *et al.*, 2000; Blanchet *et al.*, 2005). Similar transistional water lagoons neighbouring cities, are shallow, relatively enclosed water bodies, with stressed environments and spatial/seasonal fluctuations of environmental parameters. The lagoon disturbances discourage species settlements, and thus result in a low number of species and low diversity (Reizopoulou *et al.*, 1996). In fact, the value in specific richness during autumn is clearly diversified in station A with marine influence, but decreases considerably in stations B and C characterized by warmer waters evaporated and enriched in elemental nutrients.

During the periods of study, values in specific density in stations A to C, somehow increase with respect to a neat decrease specific richness; it is likely that a moderate specific richness might be compensated by a proliferation of species with the larger ecological repartition. The diversity index of Shannon and evenness values calculated for stations A to C testify to a slight disturbance except in station A where faunal equilibrium has been reached under open marine influence and as a consequence, input of current-transported species.

Multidimensional analysis confirmed the same result and revealed heterogeneity between

lagoon stations B, C and A; the differences may be probably related to hydrodynamics, salinity variation, substrate type, vegetation expansion, organic matter contents, ect.

### **Conclusions**

This study of macroinvertebrate community structure during autumnal periods (1995-1997) help characterize great modifications in macrobenthic community in the Northern lagoon of Tunis after sanitation in 1984-1988; these changes are mainly due to improved hydrology physico-chemical speciation of lagoon waters. The macrobenthic community is higher in specific richness and appeared diversified with respect to the situation preceding sanitation works. In fact, the Shannon-Weaver diversity index and evenness values indicate a slightly disturbed environment and unbalanced community in the majority of stations.. The transitional zone B to the West, with the lower specific richness is due to pollution due to past sewage from the neighbouring city, which acts against the stability of benthos communities.

The highest specific richness and diversity were recorded in zone A proximal to the lagoon entry, subjected to marine refreshment and with high specific richness. The diversity

of species is likely by input of marine species by a current-transportation throughout the Kheireddine channel; nevertheless, the newly introduced marine species in zone A, seem to be continuously destroyed when attaining the transitional barrier zone B located to the West with remarkable pollution.

The Southern zone C represents a typical lagoonal environment with a moderate hydrodynamic regime of warm waters enriched in nutrients. There appears a community of benthos with a reduced and varying specific richness; the taxa include species adapted to brackish water environments. These species include euryhaline and eurythermal biocenosis. The lack of opportunist Polychaetes *F. Enigmatica* and *C. capitata* points to a moderate organic matters input and a continuous renewal and oxygenation of waters in the Southern lagoon zone.

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