SPECIFIC DIVERSITY OF THE BENTHIC MACROFAUNA WITHIN THE WESTERN COAST OF TUNIS BAY AND THE DJERBA ISLAND COAST (SOUTH-WESTERN MEDITERRANEAN)

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ملخص

التنوع البيولوجي للافقريات القاعية في الساحل الغربي لخليج تونس وساحل جزيرة جربة (جنوب غرب البحر الأبيض المتوسط): في هذه الدراسة، تم اقتناء عينات من 21 محطة، 11 في سواحل جزيرة جربة و 10 في الساحل الغربي لخليج تونس. ثم تم بعد ذلك غربلة العينات عبر فتحات مربعة الشكل طول ضلعها 1 ملم، وتم التعرف على اللافقريات وتعدادها. وفي غياب مؤشر واحد فعال ومناسب لتقييم التنوع البيولوجي، فقد تم اختيار عدة مؤشرات تقليدية. أظهرت النتائج أن مجتمعات اللافقريات القاعية تختلف في تركيبتها اختلافا تاما في المنطقتين، بالرغم من ان عديد الأنواع مشتركة لكنها تتبادل فيما بينها مراكز الزعامة من منطقة إلى أخرى. وبالنظر إلى الفارق الكبير في القيم التي سجلتها المؤشرات المستخدمة، تم اعتماد مؤشر حسابي معدل يتمثل في احتساب المتوسط الحسابي للمؤشرات الأكثر انسجاما. ويظهر هذا المؤشر المعدل بأن التنوع البيولوجي هو عموما أعلى بكثير في خليج تونس مقارنة بساحل جربة. وتبدو هذه النتائج أكثر واقعية بالنظر الى حقيقة مصادر التدهور البيئي ومدى اتساعها في المنطقتين. ففي الواقع، فان ساحل جربة يخضع في العقود الأخيرة الى أنشطة حضرية وصناعية متزايدة والى صيد بحري جائر، مما أدى إلى تراجع كبير في الموائل القاعية، والتي تؤدي بدورها إلى تدهور التنوع البيولوجي.

الكلمات المفاتيح: مؤشرات التنوع البيولوجي، اللافقاريات القاعية، مؤشرات التنوع، مؤشرات الهيمنة، السواحل التونسية، المؤشر الحسابي المعدل

RESUME

Diversité spécifique de la macrofaune benthique dans la côte ouest de la baie de Tunis et la côte de l'île de Djerba (sud-ouest de la Méditerranée) : Dans cette étude, 21 stations ont été échantillonnées, 11 dans la côte de l'île de Djerba et 10 dans la côte ouest de la baie de Tunis. Ensuite, les échantillons ont été tamisés sur une maille carrée de 1 mm de côté, et les animaux capturés ont été identifiés et comptés. Faute d'un indice unique efficace et adapté à toutes les situations, plusieurs indices traditionnels de biodiversité ont été choisis, calculés et discutés. Les résultats montrent que la composition de la communauté est totalement différente dans les deux sites étudiés, et, à chaque site, plusieurs espèces sont communes, mais ils se substituent aux places des leaders d'une station à l'autre. Pour la mesure de la biodiversité et étant donné la grande différence dans les valeurs enregistrées par les indices retenus, une moyenne arithmétique a été calculée à chaque station sur la base des indices les plus cohérents. Elle montre que, globalement, la biodiversité est nettement plus élevée dans la baie de Tunis par rapport à la côte de Djerba. Ces résultats semblent être plus fiables tenant en compte les contraintes réelles environnementales et anthropiques imposées aux deux sites. En effet, la côte de Djerba est l'objet, ces dernières décennies, à de fortes activités urbaines et de pêche industrielle, entraînant une régression significative des habitats benthiques, ce qui peut conduire à la réduction de la biodiversité.

Mots clés: Invertébrés benthiques, indices de biodiversité, indices de richesse, indices de dominance, côtes tunisiennes, indice arithmétique moyen

ABSTRACT

In this study, 21 stations were sampled, 11 in the Djerba island coast and 10 in the western coast of Tunis bay. Then, samples were sifted on a square mesh of 1 mm a side, and the animals collected were identified and counted. Lacking an efficient single index suitable for application in all situations, several traditional nonparametric indices of biodiversity were selected, calculated and discussed. Results show that the community composition is totally different in the two studied sites, and, within each site, several species are common, but

they exchange the leader ranks from one station to another. For biodiversity measurement and since results show varying values depending on indices at several stations, an arithmetic mean index was calculated at each station on the basis of the most similar indices. It shows that, overall, the biodiversity is significantly higher in Tunis bay coast than in Djerba coast. These results are more reliable considering the real environmental / anthropogenic constraints imposed on both sites. Indeed, Djerba coast is subject, these last decades, to strong industrial, urban and fishing activities, causing significant regression of benthic habitats, which can led to a reduction of the biodiversity.
Keywords : benthic invertebrates, biodiversity indices, richness indices, dominance indices, Tunisian costal areas, arithmetic mean index

INTRODUCTION

Following the wave of extinction and rarefaction of species during last decades, the concept of "biological diversity" has widely appeared in the scientific literature from the 1970s (Stork 1996, Dubois 2004). Then, the concept of "biodiversity" appeared for the first time in 1985, but has been widely used about 3 years later (Wilson 1988). Several non-parametric indices have been conceived to measure taxonomic biodiversity, their fundamental purpose is to express the data on the number of species and their proportional abundances (Izsák & Papp 2000). Their most important advantages are the ability for direct comparisons between communities that have few or no species in common and the easiness of their application and interpretation (Magurran 2004). These traditional indices fall roughly into three categories; diversity, evenness or dominance indices, according to their mathematical formula weighting more to the species richness or evenness components of community structure (Spatharis & Tsirtsis 2010). Richness indices assume generally a relationship between the number of species and the sample size, dominance indices consider both the number of species and the distribution of the density among them, and evenness indices are simultaneously affected by the total abundance and species richness (Chadwick & Canton 1984, Lamb et al. 2009). Some recent studies have tried to conceive an index able to take into account simultaneously both categories, as weak diversity indices (Ricotta 2002) and the quadratic entropy index (Izsák & Papp 2000). Nevertheless their effectiveness and usefulness need to be confirmed.

Currently, no non-parametric index of biodiversity can be considered ideal and can measure adequately biodiversity in all situations (Clarke & Warwick 1998, 1999, 2001, Snelgrove 1998, Nielsen et al. 2007, Lamb et al. 2009). These traditional indices are yet clearly less efficient to determine the ecological status of marine costal areas subject to anthropogenic and environmental stresses, and the numerous studies which have tried this have not given real reliable results (Danilov & Ekelund 1999, Foggo et al. 2003, Labrune et al. 2006, 2008, Dauvin et al. 2007). Actually, the biodiversity status of a given community depends not only on pollution conditions, but also on several other factors (edaphic, hydrodynamic, trophic, etc.) (Afli et al. 2008a, 2009). It is certain that the new biotic indices conceived, for the most of them, in the context of the European Water Framework Directive, specially to access the ecological status are clearly more appropriate in this examination, because they are based on the sensitivity and the tolerance of species to increasing pollution (Afli et al. 2008b).

The aim of this work is to give a taxonomic knowledge of Tunisian macrofauna, and to study the taxonomic biodiversity of two different Tunisian coastal areas. Indeed, lacking an efficient single index suitable for application in all situations (Lamb et al. 2009), several biodiversity indices on the benthic macrofauna must be used and will be discussed. They can produce reliable results and be more efficient (Taft et al. 2006).

STUDY SITES

The western coast of Tunis bay

Tunis bay covers approximately 350 km² surface, not exceeding 31m depth (Afli et al. 2008a). Its western coast alternates Posidonia and Cymodocea beds and mud and fine sand substratum. It is subject to industrial and urban development of the northern suburbs of Tunis (Ayari & Afli 2008). For a few decades, significant commercial and fishing activities in ports of Goulette and Radès have been noted, as well as thermal and waste discharges of industrial estates of Radès and of Jebel Jeloud (Diawara et al. 2008). Other pollution sources are also located along the southern and eastern coastline, such as effluents of non-permanent watercourses, food-processing industry, settlements and water-treatment plants which discharge directly into the bay (Ben Charrada & Moussa 1997).

The Djerba island coast

Djerba island covers approximately 500 km² and belongs to the gulf of Gabès. Its coast is subject to the urban waste discharges of Houmet-souk and Ajim settlements and also to the touristic development of Midoun. Whereas, an important industrial, urban and maritime development along the littoral of the gulf of

Gabès (west of Djerba island) has lead to a generalized increase of pollution and impacts on marine systems, producing changes in the structure and functioning of benthic communities (Hamza et al. 2000, Louati et al. 2001, Drira et al. 2008). The gulf of Gabès has great importance for the fishing sector in Tunisia. It contributes about 65% of fishing production and concentrates about 75% of trawlers and almost two thirds of the fishing total fleet (Anonymous 2008).

MATERIAL AND METHODS

In total, 21 stations were sampled for this study, 11 in the Djerba island coast (July 2009) and 10 in the western coast of Tunis bay (May 2008) (figure 1). In the first site where stations are more deep (Table I), three samples were collected at each station by a Van Veen grab (0.12 m²). In the second site relatively less deep, five samples were collected at each station by diving and using a square metallic quadrat (0.08 m²). In the laboratory, samples were sifted out of the freshwater, on a square mesh of 1 mm a side. Then, the animals collected were preserved with diluted alcohol (70 %) before being identified, for most of them, up to species level.

Obtained data allowed us to calculate at each station the most common biodiversity indices (Table II). A multidimensional analysis was also performed with the Primer software. Specific abundances were transformed using Bray-Curtis similarity of square-root transformed abundance data. Then, a hierarchical cluster analysis (group average mod) was performed. Lacking an ideal biodiversity index, the joint use of several indices to access the taxonomic diversity can give better results, especially if they are of different

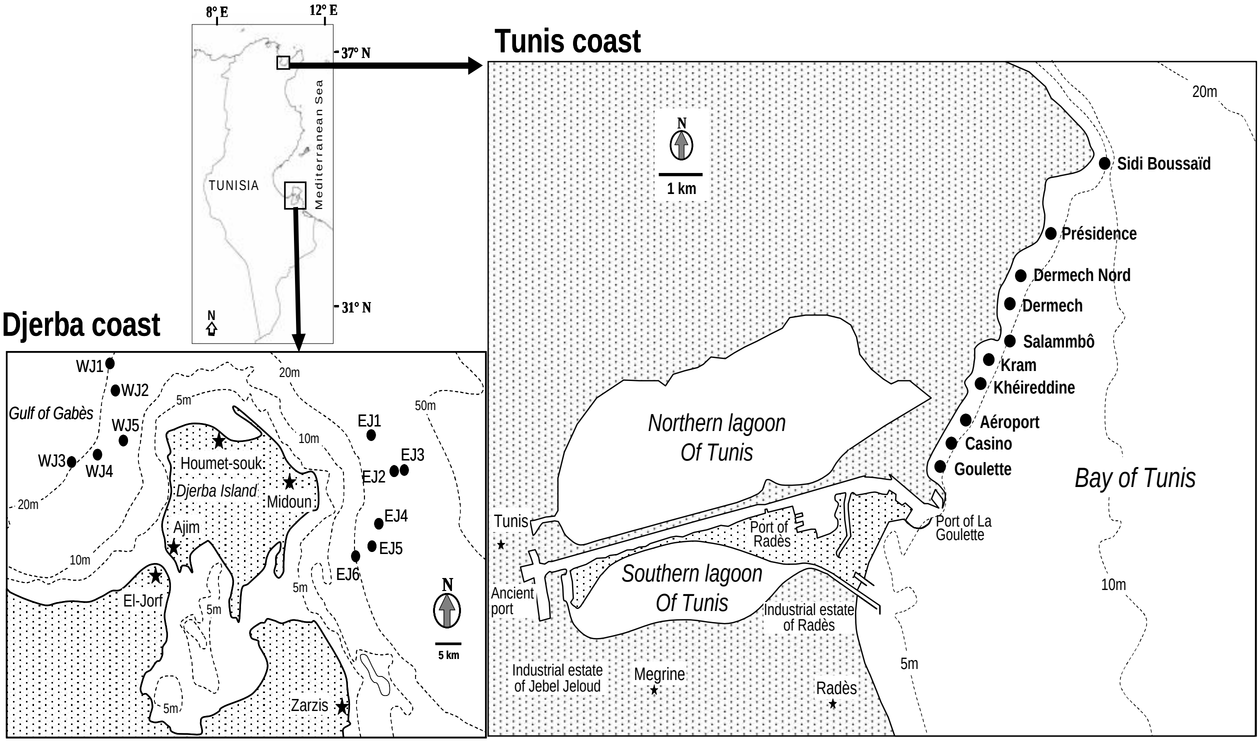

Figure 1 : Maps of the study sites showing the location of the sampling stations

Table I : Characteristics of the sampled stations

Sites	Stations	Coordinates (N / E)	Depths (m)	Substrata
	WJ1	33º 59,018' / 10º 36,929'	20	Sandy muds
	WJ2	33º 56,860' / 10º 38,189'	15,6	Sandy muds
	WJ3	33º 51,018' / 10º 32,737'	22,7	Sandy muds
	WJ4	33º 51,606' / 10º 35,313'	15,6	Sandy muds
	WJ5	33º 52,695' / 10º 38,782'	10,6	Sandy muds
Djerba	EJ1	33º 52,501' / 11º 10,219'	32,1	Mud, maerl
	EJ2	33º 49,688' / 11º 13,227'	34,8	Coarse sands
	EJ3	33º 49,802' / 11º 14,406'	39,4	Heterogenous sediments
	EJ4	33º 45,372' / 11º 11,263'	30	Heterogenous sediments
	EJ5	33º 43,762' / 11º 10,469'	25,8	Sandy muds
	EJ6	33º 42,726' / 11º 08,272'	20,6	Sandy muds
	Goulette	36° 48,833’ / 10° 18,641’	< 5	Sandy muds
	Casino	36° 49,041’ / 10° 18,871’	< 5	Sandy muds
	Aéroport	36° 49,372’ / 10° 19,127’	< 5	Sandy muds
	Khéireddine	36° 49,703’ / 10° 19,359’	< 5	Sandy muds
Tunis	Kram	36° 50,035’ / 10° 19,555’	< 5	Sandy muds
	Salammbô	36° 50,280’ / 10° 19,869’	< 5	Sandy muds
	Dermech	36° 50,690’ / 10° 19,924’	< 5	Sandy muds
	Dermech Nord	36° 50,964’ / 10° 20,203’	< 5	Sandy muds
	Présidence	36° 51,303’ / 10° 20,626’	< 5	Sandy muds
	Sidi Boussaïd	36° 52,047’ / 10° 21,497’	< 5	Sandy muds

types (richness, abundance, evenness) (Taft et al. 2006, Nielsen et al. 2007, Lamb et al. 2009). Thus, only the indices that show between them a minimum of similarity (grouped together by multidimensional analyses) were used to calculate a single arithmetic mean index (Buckland et al. 2005). Each index has been reduced, divided by the sum of its values at all stations. Then, an average has been established at each station on the basis of these weighted indices. This arithmetic mean index has been, thereafter, calibrated, and three equal intervals were designed corresponding respectively to Low Biodiversity, Moderate Biodiversity and High Biodiversity. This subdivision of the biodiversity into 3 levels may appear subjective, this is because until now there is no ideal reference to which we can refer (Buckland et al. 2005).

RESULTS

The counting of the samples showed that no organism has been found at stations WJ2, WJ4, EJ2 and EJ4. Obviously, these stations were not considered in the analysis. The list of species collected from the sites (Table III) shows that the western coast of Tunis bay is relatively more rich in species (74 species). Gastropods, as *Cerithium scabridum*, *Chrysallida juliae*, *Rissoa spp.*, *Bittium reticulatum* and *Euspira pulchella* represent around 58% of the total number of collected species, followed by polychaetes (30%) as *Phylo foetida*, *Melinna palmata*, *Paraone sp*. and *Glycera spp*. In Djerba island coast, only 13 species were collected. They are distributed into five taxonomic groups (6 polychaetes, 2 bivalves, 2 echnoderms and 2 Crustaceans)., Figure 2 shows that the abundance is relatively

Table II : Summary of characteristics of the indices used to qualify the biodiversity status using benthic communities. S: total number of species; N: total number of individuals; n_i: number of individuals of the species i.

Indices of biodiversity	Algorithms	References
Specific richness	S : number of species	
Margalef's index	$D_{Mg} = \frac{S-1}{Ln(N)}$	Margalef (1958)
Menhinick's index	$D_{Mn} = \frac{S}{\sqrt{N}}$	Menhinick (1964)
Simpson's index	$a' = \sum_{i=1}^{S} \frac{n_i \times (n_i - 1)}{N \times (N-1)}$	Simpson (1949)
Shannon-Wiener's index	$H' = -\sum_{i=1}^{S} \left(\frac{n_i}{N} \times \log_2 \left(\frac{n_i}{N} \right) \right)$	Shannon and Weaver (1963)
Brillouin's index	$HB = \frac{Ln(N!) - \sum_{i=1}^{S} Ln(n_i!)}{N}$	Brillouin (1962)
McIntosh's index	$U = \sqrt{\sum_{i=1}^{S} n_i^2}$	McIntosh (1967)
McIntosh's index	$D = \frac{N-U}{N-\sqrt{N}}$	McIntosh (1967)
McIntosh's evenness	$E = \frac{N-U}{N - \frac{N}{\sqrt{S}}}$	McIntosh (1967)
Berger-Parker's index	$d = \frac{n_{max}}{N}$	Berger and Parker (1970)
Pielou's evenness	$J' = \frac{H'}{\log_2(S)}$	Pielou (1966)
Fisher's alpha (α)	$S = \sim \times Ln\left(1 + \frac{N}{\sim}\right)$	Fisher et al. (1943)

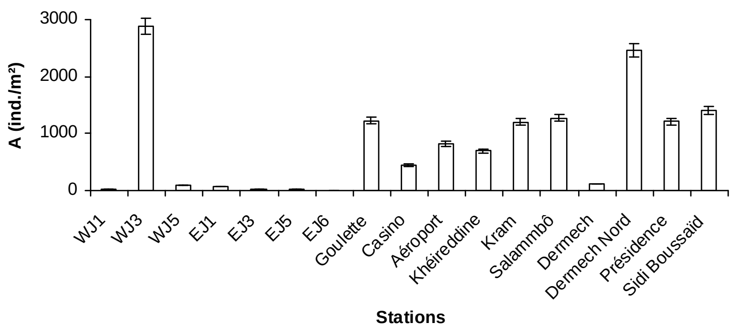

Figure 2 : Spatial variability of the macrofauna abundance

Table III : List of collected species

Espèces	Djerba	Tunis	Espèces	Djerba	Tunis
Abra alba (W. Wood, 1802)	+		*Lyonsia norwegica* (Gmelin, 1791)		+
Alvania lineata Risso, 1826		+	*Maldane glebifex* Grube, 1860		+
Ampelisca sp.	+		*Marphysa* sp.	+	
Amyclina sp.		+	*Melanella* sp.		+
Antalis vulgaris (da Costa, 1778)		+	*Melarhaphe neritoides* (Linnaeus, 1758)		+
Aricia foetida imitans Eisig, 1914		+	*Melinna palmata* Grube, 1870		+
Aricidea (Acmira) cerrutii Laubier, 1966		+	*Mitrella minor* (Scacchi, 1836)		+
Astropecten sp.	+		*Nassarius corniculum* (Olivi, 1792)		+
Balanus sp.	+		*Nassarius cuvierii* (Payraudeau, 1826)		+
Barleeia sp.		+	*Nassarius mutabilis* (Linnaeus, 1758)		+
Bittium reticulatum (da Costa, 1778)		+	*Naticarius* sp.		+
Bittium sp.		+	*Nephtys* sp.	+	
Bolinus brandaris (Linnaeus, 1758)		+	*Nereis falsa* Quatrefages, 1866		+
Bulimulidae		+	*Nereis* sp.		+
Calliostoma zizyphinum (Linnaeus, 1758)		+	*Notomastus latericeus* Sars, 1851		+
Cerithium scabridum Philippi, 1848		+	*Nucula nucleus* (Linnaeus, 1758)		+
Cerithium sp.		+	*Nucula sulcata* Bronn, 1831		+
Cerithium vulgatum Bruguiere, 1792		+	*Nucula turgida* Gould, 1846		+
Chaetozone setoza Malmgren, 1867		+	*Nuculana commutata* (Philippi, 1844)		+
Chrysallida juliae (de Folin, 1872)		+	*Ocinebrina aciculata* (Lamarck, 1822)		+
Cirratulus cirratus (O. F. Müller, 1776)		+	*Ophiura* sp.	+	
Cirriformia tentaculata (Montagu, 1808)		+	*Orbinia bioreti* (Fauvel, 1919)		+
Columbella rustica (Linnaeus, 1758)		+	Oweniidae	+	
Conus mediterraneus Hwass in Bruguière, 1792		+	*Paraonis* sp.		+
Corbula gibba (Olivi, 1792)	+		*Phyllodoce* sp.		+

Ctenocardia sp.		+
Cucumaria sp.	+	
Cyclope neritea (Linnaeus, 1758)		+
Diaphana minuta T. Brown, 1827		+
Euclymene oerstedi (Claparède, 1863)		+
Eulima sp.		+
Euspira pulchella (Risso, 1826)		+
Gastrana fragilis (Linnaeus, 1758)		+
Gibberula sp.		+
Gibbula varia (Linnaeus, 1758)		+
Glycera convoluta Keferstein, 1862		+
Glycera sp.		+
Glycera unicornis Savigny in Lamarck, 1818		+
Gyroscala De Boury, 1887		+
Hexaplex (Trunculariopsis) trunculus (Linnaeus, 1758)		+
Homalopoma sanguineum (Linnaeus, 1758)		+
Kurtiella bidentata (Montagu, 1803)		+
Lumbrineriopsis paradoxa (Saint-Joseph, 1888)		+
Lumbrineris latreilli Audouin & Milne Edwards, 1834		+
Phylo norvegicus (M. Sars in G.O. Sars, 1872)		+
Pisania striata (Gmelin, 1791)		+
Prionospio steenstrupi Malmgren, 1867		+
Pygospio sp.		+
Rissoa paradoxa (Monterosato, 1884)		+
Rissoa sp.		+
Rissoa ventricosa Desmarest, 1814		+
Ruditapes philippinarum (Adams & Reeve, 1850)		+
Sabella pavonina Savigny, 1822		+
Sabella sp.		+
Serpulidae	+	
Smaragdia viridis (Linnaeus, 1758)		+
Tellina compressa Brocchi, 1814	+	+
Terebellidae	+	
Tricolia sp.		+
Trophonopsis muricata (Montagu, 1803)		+
Typhloscolex muelleri Busch, 1851		+
Venerupis aurea (Gmelin, 1791)		+

high at WJ3 (2883 ind./m²) and Dermech Nord (2463 ind./m²), and very low at WJ1, WJ5, EJ1, EJ3, EJ5, EJ6 and Dermech. For the other stations, it varies from 438 ind./m² (Casino) to 1413 ind./m² (Sidi Boussaïd). At first glance, registered values of the biodiversity indices (figure 3) show approximately the same spatial trend, except McIntosh's index U which seems to be very different. Overall, they show low values at stations WJ1, WJ3, EJ5, EJ6, Salammbô and Dermech Nord, high values at stations WJ5, EJ1, EJ3, Aéroport, Khéireddine and Présidence and varying values depending on indices at the other stations. The hierarchical cluster analysis (figure 4) separates, at 57% of similarity, the index U from all the other indices, which are themselves divided at 73% of similarity into 3 groups. The first group includes H', D_{Mg}, HB, D_{Mn} and 1/d, the second includes J', E, 1-λ' and D and the third group includes α and S. The calculated values of the arithmetic mean index (AMI) allowed to define 3 equal intervals corresponding to different statuses of biodiversity (figure 5). Thus, 5 stations (WJ1, WJ3, EJ5, EJ6 and Salammbô) were classified in "Low Biodiversity" (0.000<AMI<0.040), 7 stations (WJ5, EJ1, EJ3, Casino, Kram, Dermech Nord and Sidi Boussaïd) in "Moderate Biodiversity" (0.040<AMI<0.080) and 5 stations (Goulette

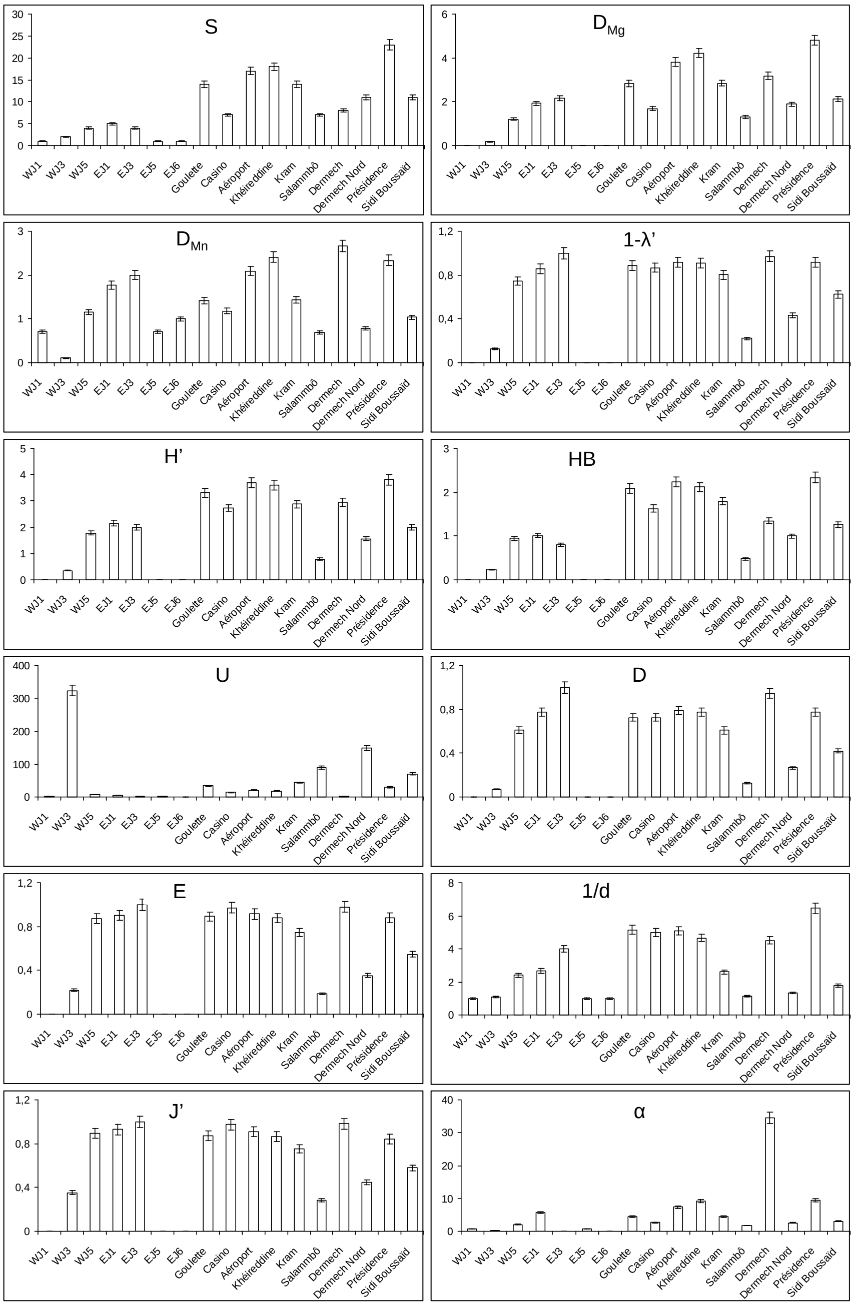

Figure 3 : Calculated values of the biodiversity indices at sampled stations

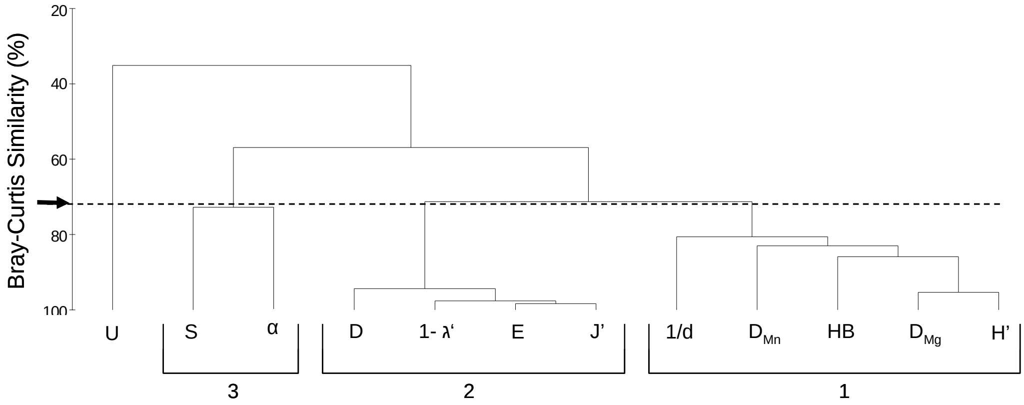

Figure 4 : Hierarchical clustering (Bray-Curtis similarity) established on calculated values of the biodiversity indices at sampled stations

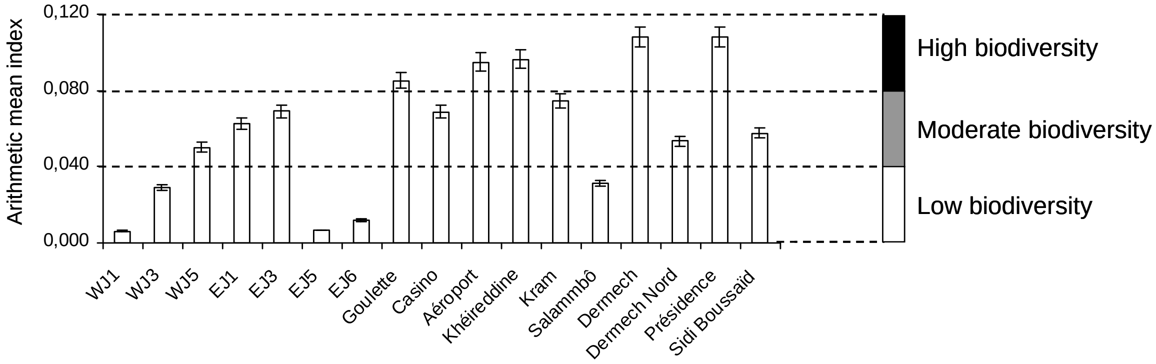

Figure 5 : The arithmetic mean index calculated on the basis of several biodiversity indices

Aéroport, Khéireddine, Dermerch and Présidence) in "High Biodiversity" ($0.080<AMI<0.120$). The test of Student applied to the values of AMI in the 2 studied sites shows a significant difference (at $p<0.005$) in favour of the western coast of Tunis bay. The same test applied separately to each index shows that only the specific richness, Margalef, Shannon-Wiener, Brillouin and Berger-Parker indices indicate significant difference (at $p<0.005$) between the two studied sites.

DISCUSSION

Although the two study sites are different on a set of characteristics (bathymetry, exposure to anthropogenic activities, hydrological parameters, etc.), used indices show a certain similarity in measuring biodiversity (57% of the Bray-Curtis Similarity). This confirms the robustness of these indices, which should theoretically be applicable to all situations. But in practice, the selection of an index depends on several criteria, such as its discrimination capacity and sensitivity to sample size, the richness or regularity of the distribution of individuals among different species. In this study for which the difference in sampling effort between the two areas is negligible, the indices used are unanimous in classifying certain stations at biodiversity levels, clearly higher than the average, and some other stations at clearly lower levels. But the problem encountered here concerns stations classified differently, and which represent a good test of robustness for these indices (Afli et al. 2008b). Also, since the interpretation of the absolute value of nonparametric biodiversity indices is subjective, these indices are generally used to compare different communities or the same community over time. Thus, and referring to indices used, the biodiversity seems to be significantly ($p<0.005$) higher in the eastern coast of Tunis bay than in Djerba coast. On average, in the first site (Tunis bay) an abundance of about 1084 ind./m² are distributed among 74 species, however in the second site (Djerba coast) only about 284 ind./m² are distributed among 13 species.

Nevertheless, among the 12 indices used, only 5 indices (specific richness, Margalef, Shannon-Wiener, Brillouin and Berger-Parker) approve this result. This confirms, once more, that the joint use of a set of indices is usually more efficient than a single index, because generally, the indices have originally been developed to express either the specific richness or proportional abundances of species (Lamb et al. 2009). However, with only data currently available in the literature, we can not give reasonable explanations for these observations. Indeed, the current status of biodiversity is the result of several factors (edaphic, trophic, environmental, human, hydrodynamic, etc.). To estimate the real contribution of each factor, more targeted studies must be undertaken. Nevertheless and referring to works already carried out in the study sites, it seems that Tunis bay despite its exposure to the nuisance of the Tunis city (2250000 inhabitants in 2004), is clearly less subject to environmental / anthropogenic constraints than Djerba coast. Indeed, since a few decades, the gulf of Gabès in general is subject to deep changes, and the 4 azoic stations (WJ2, WJ4, EJ2 and EJ4) confirm these observations. It has been put under anthropogenic pressure due to industrial, urban and fishing activities, causing significant overfishing of demersal resources, the degradation of Seagrass meadows, Posidonia oceanica, and the regression of benthic habitats (Zairi & Rouis 1999, Turki et al. 2006). For example, according to Drira et al. (2008), toxic dinoflagellates, mainly Karenia cf. selliformis, reach high densities in Djerba coast waters because of the excess reactive nitrogen derived from fertilizer applications, animal wastes and fuel combustion. Moreover, the situation becomes more complicated due to the interaction of various other factors (hydrodynamism, interference in urban areas, shipping, etc.). Actually, all these factors and, certainly others, have induced an important loss of biodiversity in the gulf of Gabès. Chey et al. (1997) and Intachat & Holloway (2000) consider that, besides specific richness, Fisher's alpha is the more efficient biodiversity index to study several communities. In this study, this index is clearly higher only at the station of Dermech where only 8 species and an abundance of 113 ind./m² were registered. Thus, it appears to be not consistent with the arithmetic mean index. Landau et al. (1999) consider that Fisher's alpha and indices of Shannon-Wiener and Simpson, which are the most used measures of diversity in community ecology, are more efficient than the other indices. Nevertheless, the comparison of these indices at, for example, stations of Casino (438 ind./m²) and Salammbô (1275 ind./m²) where 7 species were identified at each of them, show that Fisher's alpha is not consistent with the other indices. Indeed, unlike most used indices, it shows no clear difference between these stations. Thus, the index alpha can not allow to distinguish between sites that have the same numbers of individuals and of species. It reaches high values for sites dominated by a few species, such as the case of Dermech. This problem is reduced for Shannon-Wiener and Simpson indices, although the Simpson index is sensitive to the abundance of species most dense. As for the dominance index of Berger-Parker, it is considered by May (1975) as the most satisfactory measure of diversity. Nevertheless, this index seems to be different from the other indices, since it expresses the proportional importance of the dominant species. For example, it is the only index that indicates a clear difference between stations of Goulette (14 species and 1225 ind./m²) and Kram (14 species and 1200 ind./m²). According to Magurran (2004), indices of Margalef, McIntosh (U) and specific richness (S) are, in terms of discrimination capacity, the more efficient. However, McIntosh's index (U) seems to be very different from the most other indices, since it takes into account exclusively the abundance. Thus, high values were registered at stations with high abundance, especially at WJ3 and Dermech nord. In general, indices whose the weighting of the specific richness is more important are more useful for detecting differences between sites than indices giving more importance to the dominance / evenness of diversity.

However, Robinson & Tuck (1993) have found that the increase of diversity index with progressive sampling deserves further study to determine after what period diversity stabilizes. In general and according to Magurran (2004), specific richness, Margalef and Menhinick indices are the more sensitive to the sample size, and Simpson and Berger-Parker indices are the less sensitive ones.

In conclusion, the indices of biodiversity used in this study showed different results, among either the two sites or the sampled stations. However, the joint use of these indices gave more reliable results considering the real constraints imposed on both sites. Thus, the arithmetic mean index shows that, overall, the biodiversity is significantly higher in Tunis bay than in Djerba coast.

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