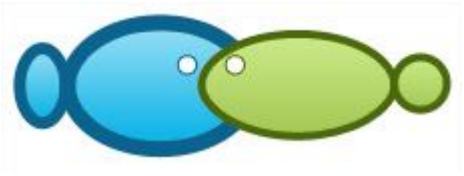

Preliminary data on the composition and spatial distribution patterns of echinoderms along Safi rocky shores (NW Morocco)

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Abstract. The distribution of echinoderm assemblages was investigated for the first time along the Safi rocky shore (Atlantic coast of NW Morocco). Five sampling locations were chosen to discriminate a large array of environmental conditions on the community distribution. The samples were collected during spring 2014 from Cape Beddouza in the north of Safi city southward to Souiria (spanning a distance of 70 km). Abundance and species richness were sampled by scraping 0.25 m^2 quadrats (4 quadrats/station). Species richness was generally low (1 to 6 taxa), with a total of 1 Ophiotrichidae, 1 Asteriidae, 2 Parechinidae and 2 Amphiuridae. Abundance and species richness were higher in Souiria Beach (S5), and Parechinidae dominated these assemblages with an average of 70 ind m^{-2}. In contrast, intertidal echinoderm assemblages collected at sites near to discharges (S2 and S3) were lower (one species or no species), where Parechinidae averaged 7 ind m^{-2}. We also analysed a set of 9 environmental variables as potential factors for echinodermal assemblages; pH and water temperature were strongly correlated with echinodermal assemblages, and anthropogenic variables such us phosphate had a similar correlation. Our results indicate that coastal echinoderm assemblages appear to be formed by different responses of various echinoderm taxa, as well as by a network of environmental and ecological processes, making it difficult to generalize patterns of echinoderm assemblages in rocky shore habitats. The correlation between species and main environmental variables was high (r = 0.9) using Principal Component Analysis. The results reveal that pH, temperature and phosphate could be the variables explaining the distribution of the echinoderm species along the Safi rocky shore.
Key Words: Echinoderms, diversity, rocky shore, anthropogenic factors, Moroccan Atlantic coasts.

Résumé. La distribution des assemblages d'échinodermes a été étudiée pour la première fois le long de la côte rocheuse de Safi (côte atlantique du nord-ouest du Maroc). Cinq stations d'échantillonnage ont été choisis pour discriminer un large éventail de conditions environnementales sur la distribution communautaire. Les échantillons ont été prélevés au printemps 2014 du cap Beddouza au nord de la ville de Safi jusqu'à Souiria Kdima au sud (sur une distance de 70 km). L'abondance et la richesse spécifique ont été échantillonnées par raclage de quadrats de 0,25 m^2 (4 quadrats/station). La richesse spécifique était généralement faible (1 à 6 taxon), avec un total de 1 Ophiotrichidae, 1 Asteriidae, 2 Parechinidae et 2 Amphiuridae. L'abondance et la richesse spécifique étaient plus élevées à la plage de Souiria Kdima (S5), et les Parechinidae dominaient ces assemblages avec une moyenne de 70 ind m^{-2}. En revanche, les assemblages d'échinodermes intertidaux collectés sur des sites proches des rejets (S2 et S3) étaient plus faibles (une espèce ou aucune espèce), où les Parechinidae représentaient en moyenne 7 ind m^{-2}. Nous avons également analysé un ensemble de 9 variables environnementales en tant que facteurs potentiels pour les assemblages échinodermiques; Le pH et la température de l'eau étaient fortement corrélés avec les assemblages échinodermiques, et les variables anthropogéniques tel phosphate présentaient une corrélation similaire. Nos résultats indiquent que les assemblages d'échinodermes côtiers semblent être formés par différentes réponses de divers taxons d'échinodermes, ainsi que par un réseau de processus environnementales et écologiques, rendant difficile la généralisation des modèles d'assemblages d'échinodermes dans les habitats côtiers rocheux. La corrélation entre les espèces et les principaux variables environnementales était élevée (r = 0,9) en utilisant l'analyse en composantes principales. Les résultats révèlent que le pH, la température et le phosphate pourraient être les variables expliquant la distribution des espèces d'échinodermes le long de la côte rocheuse de Safi.
Mots-clés: Echinodermes, diversité, substrat rocheux, facteurs anthropiques, côtes atlantiques marocaines.

Introduction. The assessment of the biodiversity in marine systems is of great interest from both an ecological and management perspective. It is important for understanding the ecological patterns of the area and for managing the use of these marine resources (Gray 1997; Worm et al 2006). An ecological interest involves the identification of biodiversity models to study potential factors related to diversity and provide context for local ecological studies.

As an important component in marine benthic communities, echinoderms are often ecologically essential in shallow and tidal waters, especially as herbivores and predators (Benedetti-Cecchi & Cinelli 1995).

Echinoderms are important for understanding the functioning of the ecosystem and ecological patterns, as well as for managing the use of marine resources (Gray 1997; Worm et al 2006). Moreover, species in the Echinothurioida Order form dense aggregations in different basins of the North Atlantic and is the dominant group in the epibenthic communities (Billett 1991; Levin & Gooday 2003).

Studies on Moroccan echinoderms began in the 20th century, when some specimens of Holothuroidea were collected by Hérouard (1929). Later, Menioui (1998) published the checklists of fauna, including echinoderms, found in Moroccan waters. Afterward, El Jouhari et al (2011) produced a cartography and spatial distribution of the sea urchin *Paracentrotus lividus* Lamarck, 1816 in the region between El Jadida and Safi. In addition, Taï et al (2015) recently identified 7 echinoderms in the spatial distribution of demersal and epibenthic communities between Cape Spartel and Sidi Ifni along the northern Atlantic waters of Morocco. However, the marine benthos of the Safi intertidal shores have not been sufficiently studied. Moreover, studies of hard-bottom benthic communities are scarce (Menioui 1992) when compared to those of soft-bottom habitats (Bayed 2003). The hard bottom fauna of Moroccan coasts, especially echinoderms, are poorly known, and significant scientific effort is needed to improve the ecological understanding of this area. This understanding is vital, as the coastal ecosystems of Morocco are regarded as highly valuable habitats on account of their striking aesthetic features and of the varied species they support.

This work was performed in the intertidal rocky area of Safi (central Atlantic coast of Morocco). The objective was to contribute to the study of the spatial distribution patterns of the echinoderm fauna along the Safi coastline and elucidate common environmental parameters that may explain patterns in echinoderm assemblages.

Material and Method

Study area. Five intertidal stations were sampled: Beddouza beach (S1), Marissa III beach (S2), Jorf Lihoudi beach (S3), Oulad Salman beach (S4), and Souiria kdima beach (S5). All are located within approximately 70 km of each other in Safi region on the Atlantic coast (32°15'23.52"N, 9°15'42.36”W) in western Morocco (Figure 1). The Mediterranean climate (‘Csa’ under the Köppen-Geiger classification) is characterized by mild, rainy winters (rainfall > 200 mm year^{-1}) and hot, dry summers. Major hydrological characteristics include upwelling caused by changing air temperatures in response to ‘Alizés’ winds from the north/northeast that blow parallel to the coastline (Bayed 2003). Study areas are usually exposed to northwest swell for approximately 7-18 s. In winter, the swell may come from the southwest. Tides are semi-diurnal, averaging 745 min (Bayed 2003), and tidal excursions range from 0.40 to 1.55 m at neap tides and 2.35 to 3.95 m at spring tides.

The choice of sampling stations was made for the purpose of comparing various degrees of pollution at five sites along the Safi coast. Beddouza beach (32°55'36.14"N, 9°27'12.88”W) (S1) is 34 km from the industrial city of Safi. Marissa III beach (S2) (2 km south of Safi city) (32°24'42.76"N, 9°26'25.08”W) receives the main effluents from the city and include domestic sewage and industrial discharge waste water. Jorf Lihoudi beach (S3) (5 km south of Safi city) (32°20'52.85"N, 9°25'25.52”W) is in front of three industrial complexes of chemistry and phosphorus discharge. Oulad Salman beach (S4), (32°13'45.57"N, 9°30'00.16”W) (16 km south of Safi city) is characterized by the

absence of industrial activity. Souiria kdima beach (S5), (32°05'09.35"N, 9°34'18.16"W) (30 km south of Safi city) is characterized by small scale fishing activities.

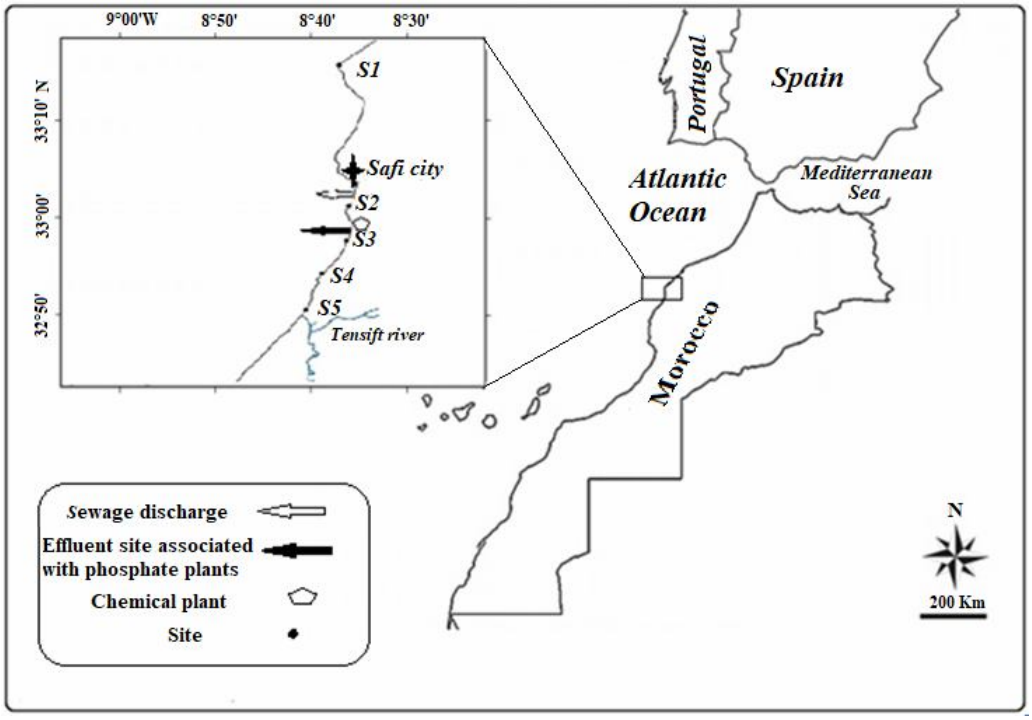

Figure 1. Geographical position of the study area and sampling site locations along the coast of Safi, NW Morocco. S1: Beddouza beach; S2: Marissa III beach; S3: Jorf Lihoudi beach; S4: Oulad Salmane beach; S5: Souiria beach.

Sample collection. Sampling was carried out during spring 2014 using a 0.25 m² quadrat. The contents of each quadrat were carefully scraped and removed with a knife and a spatula. They were placed in a plastic bowl and fixed in 10% saline formaldehyde solution. In the laboratory, the macrofauna was sieved through a 1 mm mesh size. Then were sorted and preserved in 70% alcohol solution.

The echinoderms were identified to the possible lowest taxonomic level using taxonomic identification keys of Mortensen (1927), Southward & Campbell (2006) and The World Marine Registry (WoRMS) database was used to check the validity of species names.

During low tide some variables of the water (temperature, pH, dissolved oxygen, and salinity) close to the rocky-bottom were measured in situ at each station with a multiparametric analytical device (Multi340i WTW 82362 Weilheim) (UNESCO 1985). The colorimetric method was used to analyse nutrients (nitrite, nitrate, ammonia nitrogen and phosphate) (Rodier et al 2009).

Data analysis. Echinoderm community structure was analysed using the total number of individuals (N), number of species (S), Shannon–Wiener's species diversity (H', as log2) and Pielou's evenness (J') indices for each station using the DIVERSE routine of the PRIMER software package (Clarke & Warwick 1994).

Echinoderm assemblages were determined through non-parametric multivariate techniques, as described by Field et al (1982) using the PRIMER v7.0 (Plymouth Routines in Multivariate Ecological Research) software package (Clarke & Warwick 1994). A similarity matrix was constructed using the Bray-Curtis similarity coefficient after applying the square root transformation to species abundance (Clarke & Warwick 2001). To identify the main assemblages, hierarchical clustering with group-averaged linking and non-metric multidimensional scaling (MDS) was performed using the similarity matrix. Possible differences in faunistic composition between groups of stations were tested using a one-way ANOSIM test.

Principal Component Analysis (PCA) was constructed according to the main abiotic parameters and number of individuals of the most dominant species using a Multi-Variate Statistical Package (MVSP v.3.22). The data were statistically analysed using Spearman rank correlation and all analyses were performed within SPSS, version 17.

Results. The specific composition and distribution of echinoderms are listed in Table 1. A total of 6 echinoderm taxa were found within the Safi region: there was 1 Ophiotrichidae, 1 Asteriidae, 2 Parechinidae and 2 Amphiuridae with members of Parechinidae being the most dominant family, accounting for more than 85% of all echinoderms in the studied samples (Figure 2).

Table 1

List of identified echinoderm species in Safi coast

Family	*Species*	*Stations*				
		1	*2*	*3*	*4*	*5*
Amphiuridae	*Amphipholis* sp. 1	-	v	v	-	-
	Amphipholis sp. 2	v	v	v	v	-
Asteriidae	*Asterias* sp.	-	v	v	v	v
Ophiotrichidae	*Ophiothrix* sp.	+	v	v	-	-
Parechinidae	*Paracentrotus* sp.	++	+	v	++	mf
	Paracentrotus lividus	+	v	v	v	++

Legend: - = less than five; + = more than five; ++ = more than ten; mf = more than fifty; v = not found.

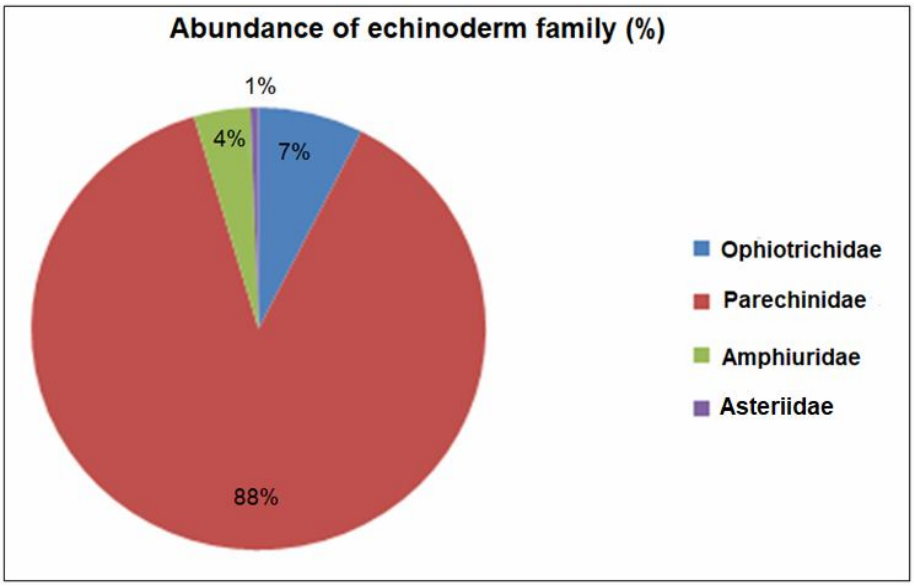

Figure 2. Species abundance of echinoderm families along the Safi coast during spring 2014.

The highest abundances were observed at S5 (70 ind m^{-2}), followed by S1 (66 ind m^{-2}) and S4 (31 ind m^{-2}) (Table 2). In station S2, abundance was less than 10 ind m^{-2}. However, no echinoderms were found in S3. Intertidal assemblages in S5 were dominated by echinoids (Figure 2), represented almost exclusively by *Paracentrotus lividus* and *Paracentrotus* sp. In S4 and S5, echinoids were once again dominated by *P. lividus* and *Paracentrotus* sp.

The Safi rocky shore's diversity indices and the number of taxa (S) are given in Table 2. A variation in taxa diversity was observed in this study. The maximum number of taxa was detected at Sites 1 and 5 (5 for each site), and the lowest number was observed at Site 2 (1 taxon); no taxa were observed at Site 3.

Table 2

The biotic variables at five sites along Safi rocky shore during Spring 2014

Site	*S*	*N*	*J'*	*H'*
S1	5	66	0.57	1.32
S2	1	7	-	-
S3	0	0	-	-
S4	3	31	0.41	0.65
S5	5	70	0.53	1.24

Note: S - species richness; N - number of individuals; J' - Pielou's evenness; H' - Shannon-Wiener's diversity.

The highest diversity (H' = 1.328, J' = 0.572) was observed at Site 1. The lowest value (H' = 0, J' = 0) was detected at Site 2. The Shannon index shows a positive correlation with Parechinidae ($r = 0.200$, $p < 0.05$), phosphate ($r = 0.975$, $p < 0.01$) and number of species ($r = 0.312$, $p < 0.05$).

The results of cluster and NMDS analyses revealed that echinoderm community structure changed between sites (with an acceptable stress value of 0.13; Figure 3), forming three main groups: E1, E2, and E3 (Figure 3A, 3B). Average similarities within each group were > 50% (SIMPER global R = 0.982, p = 0.05; Table 3). E1 comprised three stations (S1, S4, and S5) that exhibited 82.42% similarity. Representative species at these three stations were *P. lividus*, *Ophiothrix* sp. and *Paracentrotus* sp. (maximum abundance: 47 ind m^{-2} at S1). In particular, S5 had a relatively high *P. lividus* population (maximum 51 ind m^{-2}). In contrast, E2 and E3 only exhibited 70.17% and 41.43% similarity with E1, respectively. Furthermore, E1 and E2 exhibited 74.23% dissimilarity, while E1 and E3 exhibited 87.39% dissimilarity. The difference between the first two groups was primarily driven by *P. lividus* (13.83%) and *Paracentrotus* sp. (11.69%), while the difference between the latter two groups was driven by all species.

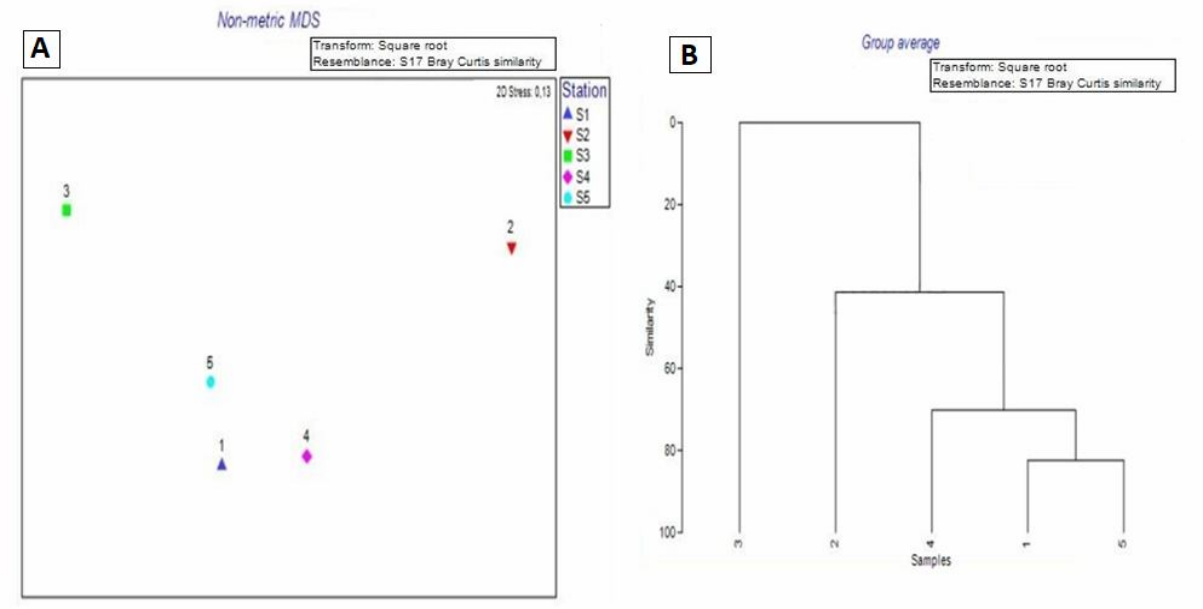

Figure 3. (A) Bray-Curtis NMDS ordination analysis based on species abundance at sampled stations. 1 - Site 1; 2 - Site 2; 3 - Site 3; 4 - Site 4; 5 - Site 5. (B) Cluster analysis of Bray-Curtis similarity between spatial samples.

Table 3

Species percentage contribution to similarity/dissimilarity according to SIMPER analysis and average index values

	Similarity			*Dissimilarity*		
	*E1**	*E2*	*E3*	*E1-E3*	*E1-E2*	*E2-E3*
Average similarity/dissimilarity	58.84	69.36	61.38	87.39	74.23	77.24
Paracentrotus lividus	22.66	-	-	13.83	47.39	-
Paracentrotus sp.	13.12	8.45	-	11.69	22.99	7.97
Ophiothrix sp.	7.56	-	-	8.28	-	-
Amphipholis sp. 1	-	-		-	-	-
Amphipholis sp. 2	3.32	-	-	7.74	-	-
Asterias sp.	1.86	-	-	-	-	-

* E1: Group 1, comprising sites S1, S4, and S5; E2: Group 2, comprising S2; and E3: comprising S3.

E2 consisted exclusively of S2 and exhibited an average of 69.36% similarity. This station was distinguished by the presence of *Paracentrotus* sp., which occurred at a relatively low population density (maximum 7 ind m^{-2}). Likewise, E3 included only S3 with an average 61.38% similarity. This group was characterized by a complete absence of echinoderms.

Correlation of echinoderm assemblages with environmental parameters. The highest correlation (r = 0.927) found between environmental variables and echinoderm assemblages from the five sites was water temperature and nutrient concentration. Water temperature and phosphate each produced a correlation of r = 0.900. Phosphate correlated strongly (r = 0.975) with echinoderm assemblage for the five sites (Table 4).

Table 4

Relationships between abiotic and biotic variables using Spearman's rank correlation coefficient

		T°	*pH*	*DO*	*Sal*	*P*	*S*	*N*	*J'*	*H'*
Abiotic data	T°	1								
	pH	-**0.900***	1							
	DO	-0.212	0.133	1						
	Sal	-0.023	0.318	0.115	1					
	P	0.023	0.418	-0.167	0.028	1				
Biotic data	S					**0.975****	1			
	N	0.090	0.311	-0.212	-0.109	**0.900****	0.813	1		
	J'	0.132	0.328	-0.221	-0.005	**0.975****	0.832	0.707	1	
	H'	0.288	0.077	-0.188	-0.050	**0.975****	0.312	**0.329***	0.775	1

T° - temperature; DO - dissolved oxygen; Sal - salinity; P - phosphate; S - species richness; N - number of individuals; H' - Shannon-Wiener's diversity index; J' - Pielou's evenness. **Bold** values represent correlation with significance: ** correlation is significant at 0.01 probability level; * correlation is significant at p > 0.05.

In the PCA, the first two axes explained 42.18% of total variance (Figure 4). The factor loading of each component is shown in Table 5. First axis (32.01% of total inertia) was positively and significantly related to *P. lividus*, *Paracentrotus* sp., *Ophiothrix* sp., while *Asterias* sp. was negatively correlated. On axis 2, pH is positively and significant related, and the most important species in the Safi region were positive to this axis. Temperature is negative and significant to axis 2. Dissolved oxygen and salinity is negative to axis 1 and positive to axis 2 with a low factor of loading. On the other hand, nitrate and orthophosphate are positive to axis 2 and negative to axis 1.

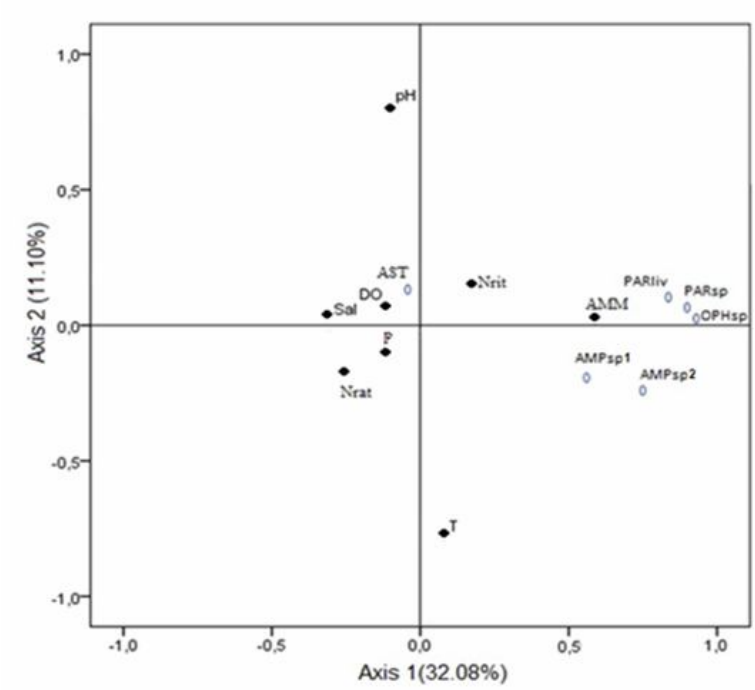

Figure 4. Factorial plan (43.18% of total inertia) of the principal component analysis. The physicochemical parameters in full black circles: T - temperature; DO - dissolved oxygen; Sal - salinity; P - phosphate; Nrit - Nitrite; Nrat - Nitrate; AMM - Ammonia nitrogen. AST - *Asterias* sp.; PARliv - *Paracentrotus lividus*; PARsp - *Paracentrotus* sp.; OPHsp - *Ophiothrix* sp.; AMPsp1 - *Amphipholis* sp. 1; AMPsp2 - *Amphipholis* sp. 2.

Discussion. The present study provides the first data on the hard bottom echinoderms distributed along the region of Safi on the Atlantic coast of Morocco in relation to environmental variables such as pH, water temperature, dissolved oxygen, salinity and nutrient contamination.

During this survey, echinoids were found to dominate the Safi rocky shore. The species richness along the Safi rocky shore was low (6 species) compared to many other studies (Rowe & Richmond 2004; Iken et al 2010). S3 contained no echinoderms, identifying environmental factors likely to influence these assemblages such as the increasing level of the phosphate (Cheggour et al 1999) and also, Ouchah et al (2014) demonstrated that average concentrations of 34.15 mg L^{-1}, 228-1025 mg L^{-1}, 2.16±0.094 mg L^{-1} for suspended matter, phosphorus, and fluoride, respectively in this site.

We have also observed a relatively high diversity of echinoderm assemblages at Station 5, 4 and 1, a region known for its wide diversity of many macrozoobenthic taxa (Cheggour et al 1999). In contrast, the low abundance and species richness we found at a station near the effluent outflow is consistent with other observations of a sharp decline in diversity due to low food abundance around discharges at station 2 and S3 (Ouchah et al 2014; Goumri et al 2017).

Environmental variables are known to stress assemblage structure between study sites, resulting in different spatial distribution of fauna (Cheggour et al 1999). We found that water temperature and pH, as well as anthropogenic factors such as phosphate, emerged as the strongest correlates in our analyses of echinoderm assemblages along the Safi rocky shore; pH and temperature could have physiological effects on assemblages of echinoderms, as they are largely stenohaline, lack specific osmoregulatory organs and are sensitive to fluctuations in pH (Stickle 1987). However, Dafni (2008) explained that salinity affects echinoderms with both hyposaline and hypersaline conditions, reducing larval dispersal and recruitment and leading to morphological deformities with reduced viability in adults.

The nutrient contamination could be the most influencing echinoderm assemblages. However, research in the Gulf of Aqaba demonstrated that pollution can be

used to explain the deterioration of echinoderm diversity (Dafni 2008). Coteur et al (2001) showed that the effects of pollution on *P. lividus* can lead to immunological deficiencies.

The stations revealed a significant spatial distribution according to the multivariate and NMDS analyses. In particular, the echinoderm communities near pollution sources (S3 and S2) differed significantly from those of the more distant stations (S1, S4 and S5). At the same time, the water variables were also significantly correlated with echinoderm structure. In particular, high levels of phosphate, nitrate and suspended solids were associated with low faunal abundance at S3 throughout the study. Although variation in the hydrodynamics of the littoral zone may increase nutrients in seawater and partly explain the differences in echinoderm structure and diversity, anthropogenic activity probably plays a major role. In particular, industrial effluents could have the greatest influence on echinoderm assemblages. Indeed, some authors have suggested that the nature of the substrate, sediment texture, presence of algae, absence of cracks, and wave action may influence the presence and distribution of echinoderms in the marine environment (Prabhu et al 2015; Calero et al 2017).

Conclusions. This study provides new data that defines spatial echinoderm community structure along the intertidal rocky shores of Safi with the support of physicochemical analyses. The Spearman correlation revealed a significant relationship between physicochemical parameters and different echinoderm groups. Six taxa were identified; pH and temperature seem to impact echinoderm regeneration. Our results could serve as the basis for further research and monitoring of the area.

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