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BIODIVERSITY AND STRUCTURAL ORGANIZATION OF MOLLUSK COMMUNITIES IN THE MIDLITTORAL COASTAL AREA BETWEEN BOUZEDJAR AND ARZEW (WESTERN ALGERIA)

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ABSTRACT

The study presents an inventory and assessing the space-time organization of mollusk communities in the midlittoral coastal area between Bouzedjar and Arzew in western Algeria. A total of 32 species of Mollusca were identified at 5 sampling stations (systematic monthly sampling) during 2016/2017. Ecological indices such as the abundance of organisms (from 1167 to 2856 ind. m^{-2}), number of species (15 Gastropoda, 3 Bivalvia, and 1 Placophora), diversity (H'), Evenness (J'), applied to the data, indicate the coastal ecosystem is disturbed and unbalanced (particularly in Arzew) because of numerous human activities impacting this area. Thus, this study contributes to providing a distribution map and a database for the management, biomonitoring, and subsequent conservation of coastal ecosystems.

Key words: Benthic Mollusca, midlittoral, inventory, population dynamics, Algeria

BIODIVERSITÀ E ORGANIZZAZIONE STRUTTURALE DELLE COMUNITÀ DI MOLLUSCHI DEL PIANO MEDIOLITORALE NELLA ZONA TRA BOUZEDJAR E ARZEW (ALGERIA OCCIDENTALE)

SINTESI

Lo studio presenta un inventario e la valutazione dell'organizzazione spazio-temporale delle comunità di molluschi del piano mediolitorale nella zona costiera tra Bouzedjar e Arzew nell'Algeria occidentale. Un totale di 32 specie di Mollusca sono state identificate in 5 stazioni di campionamento (campionamento sistematico mensile) durante il periodo 2016/2017. Gli indici ecologici come l'abbondanza di organismi (da 1167 a 2856 ind. m^{-2}), il numero di specie (15 Gastropoda, 3 Bivalvia, e 1 Placophora), la diversità (H'), l'uniformità (J'), applicati ai dati, indicano che l'ecosistema costiero è disturbato e squilibrato (soprattutto in Arzew) a causa delle numerose attività umane che impattano questa zona. Questo studio pertanto contribuisce a fornire una mappa di distribuzione e un database per la gestione, il biomonitoraggio e la successiva conservazione degli ecosistemi costieri.

Parole chiave: molluschi bentonici, mediolitorale, inventario, dinamiche di popolazione, Algeria

INTRODUCTION

Marine mollusca play an important role in the structure and function of many coastal marine environments. Since their pelagic larval stages are associated with the life cycle of many species, they can rapidly disperse over large areas (Bourdages *et al.,* 2012). They are also considered to be an important part in the coastal food chain (Mastellar, 1987). Specific diversity largely depends upon coastal morphology (rocky, sandy, mixed shorelines), hydrodynamics (Guibout, 1987; Aminot *et al.,* 1994; Bouras *et al.,* 2007; Bouras, 2013), climate mechanisms, and nutrient levels (Redfield *et al.,* 1963; Belhadj, 2001). If abiotic factors constrain the distribution of the species, especially at large spatial scales (Pearson & Dawson, 2003), biotic interactions such as competition, predation, mutualism, facilitation, or parasitism are equally important in explaining their presence in habitat at different spatial scales (Boulangeat *et al.,* 2012; Kissling *et al.,* 2012; Wisz *et al.,* 2013).

The studied coastal zone is a particularly fragile and sensitive complex of habitats, subject to strong demographic and economic pressures (Kies & Taibi, 2011; Belhadj, 2001). To assess the different statuses of coastal communities, it is necessary to provide information on the biodiversity and functioning of ecosystems. This kind of information is required to establish biological importance of coastal zones and monitor the impact of disturbance factors (Adam *et al.*, 2015; Chabot *et al.,* 2007). A variety of biological indicators are used: at community level, the occurrence or absence of certain species, which is indicative of a variety of impacting factors; at ecosystem level, the structure of communities (species richness, abundance, biomass, structural indicators), biological processes (primary and secondary production, nutrient cycles) and food chain; structures and landscape heterogeneity, fragmentation or pollution can all be important environmental status indicators as well (Christine & Romain, 2010).

This study uses Mollusca data collected from the Algerian coast to provide an updated account of specific richness, distribution area, abundance, and biological diversity of mollusks in intertidal zones along the Oran coast for the purpose of assessing and monitoring the ecological status of this marine area. The aim is to provide a factual basis for supporting enhanced environmental action (effective and sustainable measures to be recommended for the conservation of endangered species in this region).

MATERIAL AND METHODS

The study area concerns the west Algerian coast, specifically the over 120 km long area along the meridional Mediterranean coast. Monitoring focused on five stations (Fig. 1). The sites were chosen from a selection of geographical locations representative of the entire coastline of Oran, notably taking the nearby ports (Bouzedjar and Arzew) and urban areas (La Madrague and Arzew) as centers of pollution sources and disturbance processes. These areas clearly contribute a variety of negative impacts associated with human activities, but the magnitude of spatial and temporal impacts on the coastal ecosystems is less clear. The principal characteristics of each sampled station are grouped in Table 1.

Monitoring and sampling

Systematic sampling at each station was carried out monthly during the period March 2016–February 2017. The adopted method for observing both biotic and abiotic parameters in the field involved sampling three 100 m long parallel linear transects (transects parallel to the coast) at each station.

A total of 5 quadrats of 1 m² in surface area marked at 20 m intervals along each of the three transect lines were used, resulting in a total of 15 quadrats for each monthly sampling. In order to carry out non-destructive sampling and respect the environment, large size Mollusca (limpets, mussels, and gastropods) were identified and counted on the spot while small size species were collected and stored in 5% formalin.

Mollusca species identification was based on the work by Bucquoy *et al.* (1887), Locard (1891), Norsieck (1982), Fisher *et al.* (1987), Riedl (1991), Lindner (2012), Hayward *et al.* (2014), and consulted for confirmation with the museum reference collection at the Scientific Institute of Rabat. The scientific names established follow the World Register Marine Species (WoRMS).

Ecological indices and data processing

Various indices were applied to assess the diversity characteristics of the Mollusca community in the space-time. Ecological indices were calculated according to the following formula:

- **Species richness index***:* ***S*** = *total number of species per site;*
- **Shannon diversity index***:* **H′** = $-\Sigma p_i \log_2 p_i$;
- **Evenness index***:* **J′** = $H' / Hmax = H' / \log_2 S$ *(it can be expressed as a percentage %)*

where: Hmax = maximum diversity or equifrequency; pi = (nj / N): relative frequency of species; nj: relative frequency of species j in the sampling unit; N: sum of specific relative frequencies (Shannon & Weaver, 1963).

The main diversity indices, with the Shannon-Wiener followed by the equitability index, are used to

Tab. 1: Principal characteristics of sampling stations.
Tab. 1: Glavne značilnosti vzorčevalnih postaj.

Stations	**Pollution**	**Remarks**
Bouzedjar Bay (S1)	The coastal environment is experiencing high levels of pollution: urbanization too close to the shore, discharges of domestic wastewater from the Bouzedjar agglomeration in the sea without prior treatment, as well as the wild degassing of fishing vessels and the discharge of defective packaging into adjacent coastal waters, contribute significantly to the deterioration of the beach and its bathing waters (Ghodbani, 2017).	Limited by two rocky advances: the headland of Jebel Moul-el-Bhar in the east and Cape Figalo in the west. The bay opens to a depth of about 700 m and a length of 2 km. Presence of tar concretion on rocks and sand, because of its proximity to ports.
Madagh (S2)	(Non-impacted area) being relatively distant from urban and industrial anthropogenic pressures (Kherraz, 2004; Allal, 2007; Benali, 2009)	Considered as reference station
La madrague (S3)	Close to centre of human activities (PDAU, 1995).	Urban areas with high perturbance by fishermen
Kristel (S4)	High attendance by fishermen and national tourists during the spring and summer period.	Considered as reference station
Gulf of Arzew (S5)	Close to centre of human activities (PDAU, 1995).	Presence of tar concretion on rocks and sand, because of its proximity to ports.

quantify both the taxonomic richness and the distributions of the community's taxa. These indices have also been used to make a comparison among the communities of the different stations and to study temporal changes in diversity related to pollution reduction (Pearson & Rosenberg, 1978). These main indices of equitability most often consist in establishing the relationship between the measured diversity and the maximum theoretical diversity for a given sample size and number of species (Grall & Coïc, 2006).

The Shannon index (H'), derived from information theory, is considered as a heterogeneity index of diversity and is more sensitive to rare species than Simpson's index. H' usually varies between 1 and 4.5 bits. The Shannon-Wiener index tends to 0 (minimum) when all individuals in a population belong to a single species (low values indicating the preponderant species), and to 1 (maximum) when all individuals are equally distributed over all species (Grall & Coïc, 2006). According to Picard & Courtial (2015), the Piélou evenness index (J') measures the distribution of individuals within species, regardless of species richness. The value of Piélou equitability index varies from 0 (single species dominance) to 1 (equidistribution of individuals over all species). The more this index J' tends to 1, the more the population is scarcely contrasted (the species is distributed in an equiprobable sample), the more it tends to 0, the more this stand is contrasted (a very varied quantitative representation of the species in the sample). For example, a value of J' = 0.40 will mean that randomly selected individuals have only a 40% probability of being different and a 60% chance of being of the same species, therefore the population is not very diversified. Consequently, a high value of H' can only be interpreted as stand disturbance if it is accompanied by the evenness index (J'). In fact, it is necessary to take both values into account concomitantly in order to accurately assess the state of an environment, while assigning thresholds to the value of H' alone is relatively inappropriate (Grall & Coïc, 2006);

- PCA:

Principal component analysis (PCA) consists in finding the best simultaneous representation of two sets constituting the rows and columns of a contingency table: observation points (stations) and variable points (species). The distributions are expressed in percentages so that the distances make sense. The data in the matrix can undergo a Log or double square root transformation in order to stabilize the variances by giving importance to rare species. The distance used is that of Chi-square. The graphs used represent a simultaneous projection of column points (stations) and line points (species) in a space having as many dimensions as there are measured variables (Ménesguen, 1980).

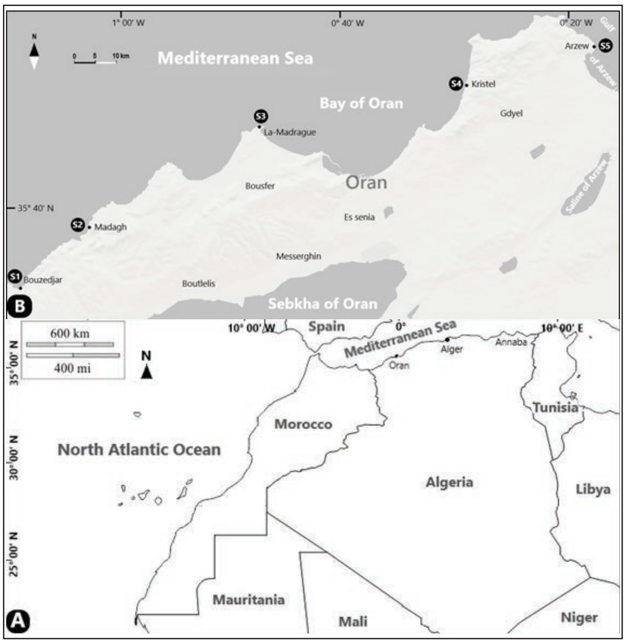

Fig. 1: Location of study sites. A. Location of Oran on the North African coast; B. Oran coast; Sampling stations: S1 (Bouzedjar), S2 (Madagh), S3 (La Madrague), S4 (Kristel), and S5 (Arzew).
Sl. 1: Zemljevid obravnavanega območja. A. Oran na severnoafriški obali; B. oranska obala; Vzorčevalne postaje: S1 (Bouzedjar), S2 (Madagh), S3 (La Madrague), S4 (Kristel), in S5 (Arzew).

In general, we use a representation of the planes formed by two orthogonal axes, with the latter representing a maximum of variance for the analysis (most of the time, the first two or three axes are used). The results are interpreted in terms of proximity between stations, between species, or between stations and species. The relative or absolute contributions of each station or species on each axis provide essential elements for interpretation, while their squares of cosine reflect a greater or lesser representativeness of the axis for the variable considered.

Hierarchical ascendant classification (HAC) consists of grouping the closest species in the form of a dendrogram, whose length of branches represents the average or total distance between the species and groups of species, *i.e.*, their percentage of similarity. The hierarchical classification is particularly interesting in analyzing differences in community structure along enrichment gradients in organic matter. Easy to calculate and interpret, it has allowed for the development of several theories concerning the spatial and/or temporal evolution of the benthic fauna following pollution. While dendrograms are simple to use, they have four disadvantages (Field *et al.*, 1982):

- The hierarchy is irreversible: once a sample has been placed in a group, it loses its identity;
- Dendrograms only show intergroup relations. The level of similarity indicated is that of the average of the intergroup values;
- The sequence of the samples in a dendrogram is arbitrary, and two adjacent samples belonging to different groups are not necessarily the most similar;
- Dendrograms emphasize discontinuities and force continuous series to be organized into discrete classes.

Data analyses

The quantitative data table was processed using R software (version: 3.4.3, year: 2017), univariate: abundance (A), number of species (S), Shannon diversity (H′) and evenness (J′), and multivariate: PCA and HAC.

To establish a comparison of the different indices of ecological diversity, ANOVA analysis was chosen. ANOVA (analysis of variance) is a statistical test well suited for comparisons of means for sample numbers > 30 (Underwood, 1997). Prior to applying ANOVA, tests of normality and homogeneity of variances were checked using the Bartlett and Levene tests, respectively. Whenever the homogeneity of variances was significant (a significant difference for a protection factor of 0.5%), the one-factor ANOVA test was performed.

To estimate the influence of environment characteristics (Oran's coastline) on Mollusca benthic species and to visualize multidimensional data in graphics, a table of taxonomic abundances was compiled using Principal Component Analysis (PCA) and Ascending Hierarchical Classification (HAC).

RESULTS

Assessment of coastal water and sediment quality to determine human activity impact on the marine environment involves measurement of physicochemical and eco-toxicological parameters. However, since these parameters may vary naturally between different habitats, they only have descriptive value, portraying an ecosystem at a particular time, which can make it difficult to deduce the impacts of anthropogenic activities on benthic communities. Hence, biological criteria need to be considered in order to evaluate ecosystem statues (Dauer, 1993). Compiling baseline biological information usually begins with diversity.

A total of 32 species of mollusks were identified at the 5 monitored stations; the species and the related Mollusca families are indicated in Table 2 as follows:

Tab. 2: Mean density (ind. m⁻²) of species at 5 stations of Oran littoral, between March 2016 and February 2017.
Tab. 2: Srednja gostota (os. m⁻²) vrst na 5 postajah na oranski obali med marcem 2026 in februarjem 2017.

Family	Species	Codes	S1	S2	S3	S4	S5
Aplysidae	*Aplysia punctata* (Cuvier, 1803)	e 20			<1		
Calliostomatidae	*Calliostoma ziziphinum* (Linnaeus, 1758)	e 21	<1	<1		<1	<1
Carditidae	*Cardita calyculata* (Linnaeus, 1758)	e 25			<1	1-10	<1
Cerithiidae	*Cerithium lividulum* (Risso, 1826)	e 18			<1		11-50
	Bittium reticulatum (Da Costa, 17778)	e 22		<1	<1	<1	<1
Chitonidae	*Chiton olivaceus* (Sopengler, 1797)	e 3	1-10	1-10	11-50	11-50	1-10
Columbellidae	*Columbella rustica* (Linnaeus, 1758)	e 15	<1	<1		<1	<1
Conidae	*Conus ventricosus* (Gmelin, 1791)	e 17		<1	<1		<1
Costellariidae	*Pusia ebenus* (Lamark, 1819)	e 29		<1			
	Pusia tricolor (Gmelin, 1791)	e 30					<1
Epithoniidae	*Gyroscalla lamellosa* (Lamark, 1822)	e 27		<1			
Fissurellidae	*Fissurella nubecula* (Linnaeus, 1758)	e 9	<1	<1	1-10	<1	<1
Littorinidae	*Melarhaphe neritoides* (Linnaeus, 1758)	e 1	51-300	301-1000	>1000	301-1000	>1000
	Echinolittorina punctata (Gmelin, 1791)	e 2	51-300	301-1000	51-300	>1000	1-10
Muricidae	*Stramonita heamastoma* (Linnaeus, 1758)	e 19	<1	<1	<1	<1	
	Hexaplex trunculus (Linnaeus, 1758)	e 31				<1	
Mytilidae	*Mytilus galloprovincialis* (Lamark, 1819)	e 23	1-10	11-50	51-300	51-300	1-10
Patellidae	*Patella caerulea* (Linnaeus, 1758)	e 5	1-10	11-50	1-10	1-10	1-10
	Patella ulyssiponensis (Gmelin, 1791)	e 6	1-10	11-50	1-10	1-10	1-10
	Patella ferruginea (Gmelin, 1791)	e 7	1-10	1-10	1-10	1-10	<1
	Patella rustica (Linnaeus, 1758)	e 8	1-10	1-10	11-50	1-10	<1
	Cymbula safiana (Lamark, 1819)	e 10	<1				
Pisaniidae	*Pisania striata* (Gmelin, 1791)	e 16		<1		<1	<1
	Aplus dorbignyi (Payraudeau, 1826)	e 26				<1	<1
Rissoidae	*Alvania cimex* (Linnaeus, 1758)	e 28					<1
	Peringiella denticulata	e 32				<1	<1
Siphonariidae	*Siphonaria pectinata* (Linnaeus, 1758)	e 4	11-50	1-10	11-50	11-50	11-50
Trochidae	*Phorcus turbinatus* (Born, 1778)	e 11	1-10	11-50	11-50	1-10	1-10
	Phorcus articulatus (Lamark, 1822)	e 12		<1	1-10		11-50
	Phorcus richardi (Payraudeau, 1826)	e 14		1-10	<1		<1
	Steromphala rurilineata (Michaud, 1829)	e 13		<1	<1	1-10	<1
Veneridae	*Calista chione* (Linnaeus, 1758)	e 24		<1	<1	<1	<1

Codes: Species number; Stations: S1 (Bouzedjar); S2 (Madagh); S3 (La Madrague); S4: (Kristel); S5 (Arzew); gaps: indicate the species was absent · <1 ; ● 1-10 ; ● 11-50 ; ● 51-300 ; ◉ 301-1000 ; ◯ >1000 ind m-²

- **Gastropoda (15)**: Aplysiidae, Calliostomatidae, Cerithiidae, Columbellidae, Conidae, Costellariidae, Epitoniidae, Fissurellidae, Littorinidae, Muricidae, Patellidae, Pisaniidae, Rissoidae, Siphonariidae, Trochidae;
- **Bivalvia (3)**: Mytilidae, Carditidae, Veneridae;
- **Polyplacophora** (1): Chitonidae.

Twelve species were common along all the studied littoral transects: *Melarhaphe neritoides, Echinolittorina punctata, Chiton olivaceus, Siphonaria pectinata, Pattela caerulea, P. ulyssiponensis, P. ferruginea, P. rustica, Fissurella nubecula, Phorcus turbinatus, Stramonita haemastoma,* and *Mytilus galloprovincialis*.

Thirteen species less common species only occurred at some of the stations: *Phorcus articulatus, Steromphala rarilineata, Phorcus richardi, Columbella rustica, Pisania striata, Conus ventricosus, Cerithium lividulum, Calliostoma zizyphinum, Bittium reticulatum, Callista chione, Cardita calyculata, Aplus dorbignyi,* and *Peringiella denticulata*.

Seven species were present at one station only: *Cymbula safiana, Pusia ebenus, Gyroscala lamellosa, Aplysia punctata, Hexaplex trunculus, Pusia tricolor,* and *Alvania cimex*.

Mollusca assemblages

The relative abundances of different taxonomic groups (Fig. 2) highlight the similarities and differences in specific composition between the studied sites. These are commented upon as follows:

Bouzedjar (S1) displayed a low global number of species (S = 15). *Melarhaphe neritoides* was abundant (54%), followed by *Echinolittorina punctata* (30%). (*M. neritoides* and *E. punctata* were common and abundant all along the studied coast [84%]). *Mytilus galloprovincialis* (6%) ranked 3rd but with a very low frequency of occurrence (f = 3%). *Siphonaria*

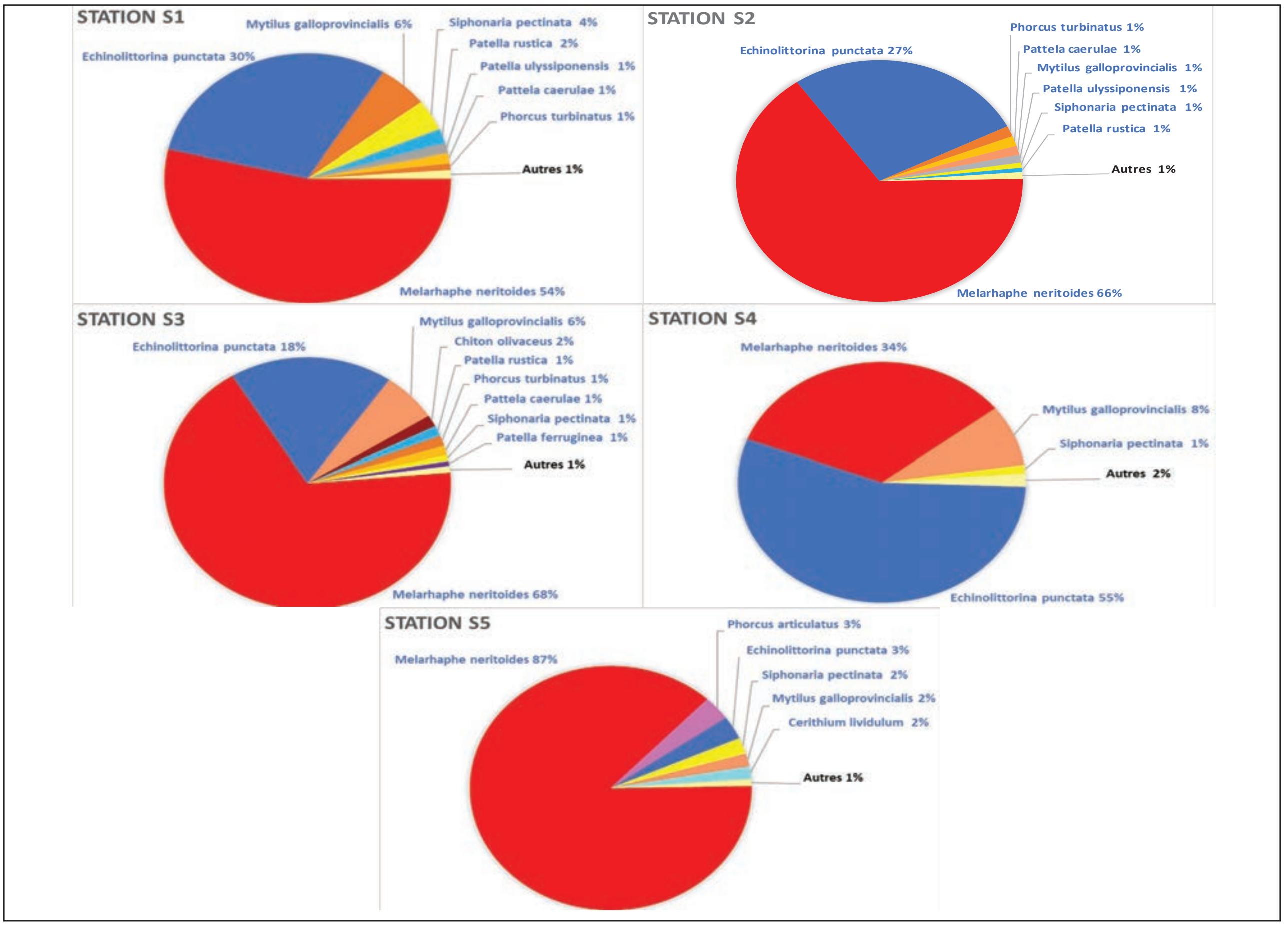

Fig. 2: Spatial distribution (%) of Mollusca species in the midlittoral zone of Oran between March 2016 and February 2017.
Sl. 2: Prostorska razširjenost (%) mehkužcev v bibavičnem pasu pri Oranu med marcem 2016 in februarjem 2017.

Tab. 3: Results from the ANOVA analysis on the spatial variation of Mollusca general descriptors (total density, number of species, Shannon-Wiener diversity index and Pielou's evenness [J'] of density of all Mollusca taxa) between March 2016 and February 2017.
Tab. 3: Rezultati prostorske variabilnosti glavnih deskriptorjev (celotna gostota, število vrst, Shannon-Wiennerjev diverzitetni indeks in Pieloujev indeks enakomernosti porazdelitve [J']) na podlagi analize ANOVA.

Sources	Df	Sum Sq	Mean Sq	F	Pr(>F)
Total density					
Stations	4	36700948	9175237	30.76	1.87e-13 ***
Residuals	55	16406493	298300		
Significant values	S1(a); S2(b); S3(b); S4(c); S5(b)				
Number of species (S)					
Stations	4	249.9	62.47	13.87	0.0000000696 ***
Residuals	55	247.8	4.51		
Significant values	S1(a); S2(a); S3(a); S4(a); S5(b)				
Diversity (H')					
Stations	4	3.834	0.9586	9.675	0.00000536 ***
Residuals	55	5.450	0.0991		
Significant values	S1(b); S2(b); S3(b); S4(b); S5(a);				
Evenness (J')					
Stations	4	0.3817	.09543	15.13	0.0000000211 ***
Residuals	55	0.3468	0.00631		
Significant values	S1(c); S2(bc); S3(b); S4(b); S5(a);				

- Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
- significant values have different letter (a, b, c); Df: degrees of freedom, Sum Sq: summer square, Mean Sq: mean square; F statistic; Pr(<F): probability level; S1, S2, S3, S4, S5: Stations.

pectinata was also observed in high abundance (4%) at S1 and in a similar abundance at S5 (2%). The species present at S1 were: *Patella rustica* (2%), then *P. ulyssiponensis, P. caerulea, Phorcus turbinatus, Stramonita haemastoma* and *Mytilus galloprovincialis* (≈1% each species). The remaining species, each representing less than 1% of the total Mollusca biodiversity, were (in descending order): *Patella ferruginea, Chiton olivaceus, Fissurella nubecula, Cymbula safiana, Stramonita haemastoma, Columbella rustica, Calliostoma zizyphinum*.

At Madagh (S2) global species richness was high: 23 species. The most abundant in this Mollusca community were Littorina species (93%). Also abundant were *Melarhaphe neritoides* (66%), followed by *Echinolittorina punctata* (27%). *Phorcus turbinatus, Pattela caerulea, Mytilus galloprovincialis, Patella ulyssiponensis, Pattela rustica* and *Siphonaria pectinata* were occasionally observed (Tab. 1, Fig. 2). The remaining species, representing only 1% of the totality, appeared in the following descending order: *Patella ferruginea, Chiton olivaceus, Steromphala rarilineata, Fissurella nubecula, Phorcus articulatus, P. richardi, Stramonita haemastoma, Columbella rustica, Pisania striata, Callista chione, Conus ventricosus, Calliostoma zizyphinum, Gyroscala lamellosa, Pusia ebenus, Bittium reticulatum, Cymbula safiana*.

La Madrague (S3) revealed 21 species. Overall, the Littorines predominated (86%): *more specifically, Melarhaphe neritoides* (68%), followed by *Echinolittorina punctata* (18%), and *Mytilus galloprovincialis* (6%). Unlike in other sites, *Chiton olivaceus* (2%) was more abundant at this station. The species *Patella rustica, Phorcus turbinatus, Pattela caerulea, Siphonaria pectinata* and *Patella ferruginea* all shared the 5th position. The remaining species, representing only 1% of all Mollusca, occurred in the following descending order: *Patella ulyssiponensis, Phorcus articulatus, Fissurella nubecula, Stramonita*

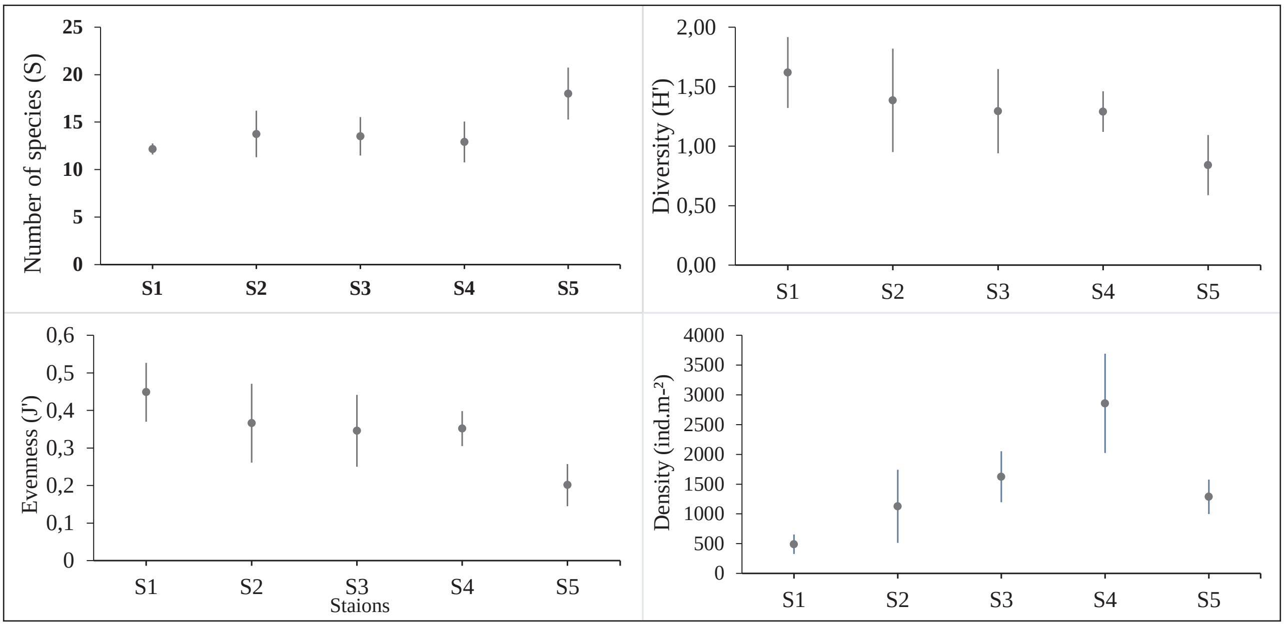

Fig. 3: Mean ±SE values of Mollusca general descriptors at each station between March 2016 and February 2017. Descriptors include total Mollusca density (number ind.m^{-2}) and number of species, the Shannon-Wiener diversity index (H'), and Pielou's evenness (J') per sample.
Sl. 3: Srednje ±SE vrednosti glavnih deskriptorjev mehkužcev na vsaki postaji med marcem 2016 in februarjem 2017. Deskriptorji vključujejo celotno gostoto mehkužcev (število osebkov na m^{-2}), število vrst, Shannon-Wienner-jev diverzitetni indeks (H'), in Pieloujev indeks enakomernosti porazdelitve (J') na posamezen vzorec.

haemastoma, Cerithium lividulum, Phorcus richardi, Aplysia punctata, Bittium reticulatum, Steromphala rarilineata, Conus ventricosus, Callista chione, Cardita calyculata.

At Kristel (S4), the global species richness was estimated at 22. The periwinkles with 89% were well represented and were the most abundant at this station. *Echinolittorina punctata* (55%) was most abundant, followed by *Melarhaphe neritoides* (34%). As in S3, *Mytilus galloprovincialis* (a little more abundant east of the Oran littoral) was the most common non- periwinkle, followed by *Siphonaria pectinata* (1%). The remaining species (2% of all Mollusca) were found in the following descending order: *Chiton olivaceus, Pattela caerulae, Phorcus turbinatus, Patella ulyssiponensis, Patella rustica, Patella ferruginea, Phorcus richardi, Stramonita haemastoma, Bittium reticulatum, Fissurella nubecula, Cardita calyculata, Pisania striata, Columbella rustica, Calliostoma zizyphinum, Callista chione, Hexaplex trunculus, Aplus dorbignyi, Peringiella denticulata*.

Arzew (S5) displayed the highest global species richness (27 species). *Melarhaphe neritoides* ranked 1st with 87%, which was the highest on the entire Oran coastline. The order afterwards changed enormously compared to other sites. For the first time *Echinolittorina punctata* occupied 3rd place, after *Phorcus articulatus* (3%) which took 2nd place. *Siphonaria pectinata, Mytilus galloprovincialis,* and *Cerithium lividulum* were similarly common at 2%. Other notable species (< 2%) were *Chiton olivaceus, Phorcus turbinatus, Patella ulyssiponensis, Patella caerulea, Bittium reticulatum, Peringiella denticulata, Patella ferruginea, Columbella rustica, Patella rustica, Calliostoma zizyphinum, Pisania striata, Phorcus richardi, Stramonita haemastoma, Fissurella nubecula, Aplus dorbignyi, Cardita calyculata, Conus ventricosus, Steromphala rarilineata, Pusia tricolor, Alvania cimex,* and *Callista chione*.

Spatial and temporal variation of general descriptors

The various diversity indices currently used make it possible to study the structure of stands with or without reference to a concrete space-time framework. They make it possible to do a quick assessment of stand biodiversity, corresponding to a single digit. The calculation of ecological indicators at the various stations allows the presence of dominant species to be identified. However, their synthetic nature can prove to be a handicap since it masks a large part of the information.

Spatial variability

Mollusca species diversity among the sampling stations, as revealed by diversity indices, is presented in Fig. 3.

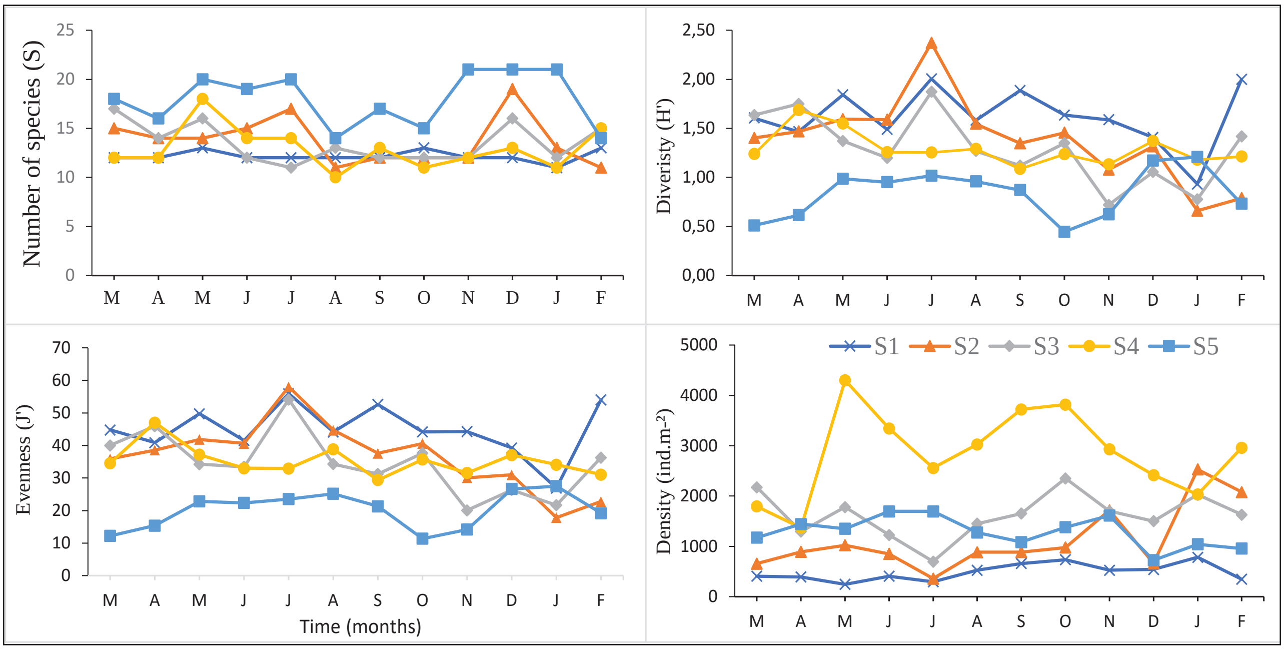

Fig. 4: Temporal variation of general descriptors (density, number of species, Shannon-Wiener diversity index and Pielou's evenness) between March 2016 and February 2017.
Sl. 4: Časovne spremembe glavnih deskriptorjev (gostota, število vrst, Shannon-Wienerjev diverzitetni indeks ter Pieloujev indeks enakomernosti porazdelitve) med marcem 2016 in februarjem 2017.

Total density

Regarding the total density of Mollusca, this study was able to demonstrate that the community of Mollusca is heterogeneous on a spatial scale. On the one hand, stations S2 (1127 ind.m^{-2})^{b}, S3 (1624 ind.m^{-2})^{b} and S5 (1287 ind.m^{-2})^{b} proved statistically identical ($p > 0.05$). On the other hand, the ANOVA1 test (Fig. 3, Tab. 3) assigned to stations S2, S3, and S5 the same letter of significance (b), which shows that the density is statistically similar ($p > 0.05$). Still according to the ANOVA1 test, these 3 stations were very significantly different ($p < 0.001$) from S1 (489 ind.m^{-2})^{a} and S4 (2856 ind.m^{-2})^{c}. The highest heterogeneity was observed at S4, the lowest at S1. This suggests that whereas stations S2, S3, and S5 recorded more homogeneous communities of Mollusca, the latter formed very heterogeneous communities at stations S1 and S4, in terms of density. Our data have also shown an average annual density (< 1 ind.m^{-2}) and a reduced annual frequency of occurrence ($f < 10\%$) for several taxa across the entire Oran coast.

Number of species

With regard to the number of species (S), we have noticed that there are two considerably different groups of stations. The average number of species differs significantly ($p < 0.001$) between station S5 (18)^{b} and the group of stations S1 (12)^{a}, S2 (14)^{a}, S3 (14)^{a}, and S4 (13)^{a} (Tab. 3, Fig. 3).

Diversity H'

The diversity index (H') of Molluscan species follows the same pattern as that of the number of species (Fig. 2). Based on Table 3, we can see that the diversity at station S5 (0.84)^{a} is significantly lower ($p <0.001$) compared to the group of stations S1 (1.62)^{b}, S2 (1.38)^{b}, S3 (1.29)^{b}, and S4 (1.29)^{b}.

Evenness J'

Regarding evenness (J'), the results obtained from ANOVA1 test differ from other variables. ANOVA1 test (Tab. 3) assigned stations S2, S3, and S4 the same letter (b) of significance. That means that the index (J') was statistically similar ($p > 0.05$). The index (J') of station S2 (36.62)^{bc} was not significantly different from that of station S1 (44.85)^{c}; in contrast, it was very significantly different ($p < 0.001$) from S5 (0.20)^{a}. Index (J') in stations S3 (0.35)^{b} and S4 (0.35)^{b} was significantly different from that of S1 (0.45)^{c} and S5 (0.20)^{a}. Station S1 had the highest index (J'), the lowest index was encountered at station S5 (Fig. 3).

Temporal variability

The monthly results of the ecological indices of Mollusca are shown in Fig. 4.

Total density

The results show that the total density at station S4 decreases below 2000 ind.m^{-2} only in March and April, while exceeding 4000 ind.m^{-2} in May. Stations S3 and S5 have a total density comprised between 1000 and 2000 ind.m^{-2} almost year round. At station S3, the density exceeds 2000 ind.m^{-2} in March, October, and January, while at station S5 it exceeds 1500 ind.m^{-2} in June, July, and November. A density of less than 1000 ind.m^{-2} was recorded in July at station S3, as well as in December and February at S5. Station S2 has a total density of 500 to 1000 ind.m^{-2} almost year round. The density drops below 1500 ind.m^{-2} in November, January, and February, dropping below 500 ind.m^{-2} only in July. Unlike other stations, the total density at S1 is usually between 300 and 800 ind.m^{-2}, dropping below 300 ind.m^{-2} in May only.

Number of species

For stations S1 to S4 we note that the annual average number of species varies between 12 and 14. At station S1, more than 13 species have never been found (February, May, October). At S2, the number of species reached 17 and 19 in July and December, respectively. At S3, the number of species was 16 in May and December, increasing to 17 in March. The number of species at S4 decreased from 18 species in May to only 10 species in August. Exceptionally, at station S5, the annual average number of species was 18. The species richness exceeded 18 species during two three-month periods: from March to June, and between November and January. The species richness never dropped below 14 species throughout the year.

Diversity H′

From S1 to S4, the diversity (H′) recorded during most months was greater than 1. At S5, the diversity was H′ ≤ 1 most of the time, except in December and January, when H′ was 1.17 and 1.21, respectively. At S1 the diversity decreased in January to a minimum of 0.93, while a maximum of 2 was reached in July. At station S2, the diversity was 0.66 and 0.79 in January and February, respectively, while in July it reached a maximum of 2.37. At station S3, diversity fell below the value of 1 only during November and January, to 0.72 and 0.78, respectively. Unlike other stations, the value of H′ at S4 remained between 1 < H′ < 2 throughout the year.

Evenness J′

Most of the year, equitability (J′) ranged from 0.20 to 0. The weakest evenness was recorded at 0.11 in October at station S5, the highest at 0.58 in July at station S2. At station S1, the index remained ≥ 0.40 throughout the year, with the exception of January when it equaled 0.27. At S2, evenness reached its maximum in July with a value of 0.58, while its minimum, 0.18, was recorded in January. At S3, J′ reached the highest value of 0.54, also in July, and the lowest 0.22 in November. At station S4, evenness was above 0.30 for most of the year. In September, J′ reached its lowest value of 0.29, while its highest value equaled 0.47 in April. Unlike station S2, evenness at S5 remained below 0.30 throughout the year. The highest value (J′ = 0.27) was recorded in December and January, the lowest (J′ = 0.11) in October.

Multivariate analysis

Multivariate analysis makes it possible to summarize the data correlation structure described by several quantitative variables, by identifying the underlying factors common to the variables (complementary qualitative variables), and is able to explain a large part of the variability of data.

The total information given in Fig. 5 on axes 1 and 2 is 28.79% (axis 1: 18.24% and axis 2: 10.55%). In the correlation circle, the species are divided into 4 large groups, two of them are distributed with respect to axis 1, the third is positioned on axis 2, and the fourth is diagonal.

The opposing groups are negatively correlated with each other:

the first group of species is positioned on axis 1 in a positive way and is well correlated with north coast exposure (Expos. N), central location on the coast (L. C), and the tender nature of the rock (RT). These species are: *Fissurella nubecula (e11), Patella ulyssiponensis (e7), Patella ferruginea (e8), Patella caerulea (e6), Patella rustica (e9), Pattela caerulea (e5), Chiton olivaceus (e3) and slightly less Stramonita haemastoma (e19)*;

the second group is still positioned on axis 1, but opposite the first group. The species in this group are positively correlated with east coast exposure (Expos. E), extreme east location (L. EE), hard nature of the rock (RD), proximity of oil port (PPt) and fishing (PPc), and location a little further away from urban areas (ZU). These are: *Cerithium lividulum (e18), Phorcus articulatus (e12), Calliostoma zizyphinum (e21), Aplus dorbignyi (e26), Pusia tricolor (e30)*;

the third group is positioned on axis 2: the species which are positively correlated with the west location on the Oran coast (L. OC): *Pusia ebenus (e29), Gyroscala lamellosa (e27), Steromphala rarilineata (e13), Pisania striata (e16),*

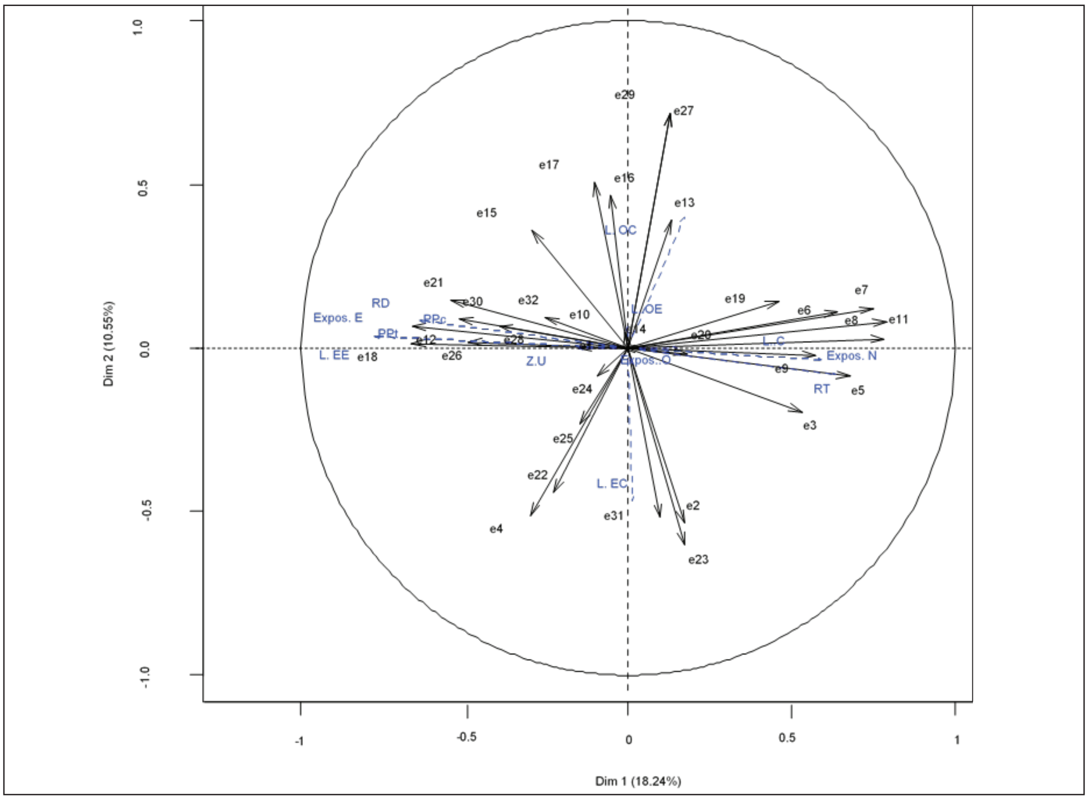

Fig. 5: Correlation circle from the principal component analysis (PCA) applied to the density of the Mollusca species with respect to environment characteristics. PPt: oil port, PPc: fishing port, ZU: urban areas, RD: hard nature of the rock, RT: tender nature (limestone) from rock L. EE: Extreme-East location, L. EC: East location, L. OC: West location, L. C: center location, L. OE: extreme-West location, Expo. E: Est exposure, Expos. O: West exposure, Expos. N: North exposure. e1, e2, …, e32: Mollusca species.
Sl. 5: Korelacijski obroč na podlagi metode PCA (principal component analysis) izračunan na temelju povezav med gostoto mehkužcev in okoljskih značilnosti. PPt: tankerska luka, PPc: ribiško pristanišče, ZU: urbana okolja, RD: trša kamnina, RT: mehkejša kamnina (apnenec), L. EE: skrajno vzhodna lokacija, L. EC: Vzhodna lokacija, L. OC: Zahodna lokacija, L. C: osrednja lokacija, L. OE: skrajno zahodna lokacija, Expo. E: vzhodna izpostavljenost, Expos. O: zahodna izpostavljenost, Expos. N: severna izpostavljenost. e1, e2, …, e32: vrste mehkužcev.

Conus ventricosus (e17). The species which are positively correlated with the east location of the Oran coast (L. EC): *Hexaplex trunculus (e31), Mytilus galloprovincialis (e23), Echinolittorina punctata (e2)*. The third group, on the other hand, is positioned relative to axis 2. It is correlated only with location (East and West), while it is indifferent to other factors. This group is divided into two subgroups;

the fourth group concerns species that are positively correlated to two axes simultaneously. Within it, two subgroups are distinguished:

Siphonaria pectinata (e4), *Bittium reticulatum (e22)*, *Cardita calyculata (e25)*. These species are not only positively correlated with (L. EC) but also positively correlated with (PPt), (PPc), (RD), (L. EE), and (Expos. E).

Columbella rustica (e15). This species is not only positively correlated with (L. OC), but also positively correlated with (PPt), (PPc), (RD), (L. EE), and (Expos. E).

Species such as *Melarhaphe neritoides (e1), Cymbula safiana (e10), Phorcus richardi (e14), Aplysia punctata (e20), Callista chione (e24), Alvania cimex (e28), Callista chione (e32)*, are too far from the correlation circle (close to the center) to be interpreted on these two axes (see other axes).

DISCUSSION

Biodiversity assessment (Spatial distribution of species diversity indices)

According to Fig. 2 and 3, the values of the Shannon index (H’) at stations S1, S2, S3, and S4 are 1.62^b, 1.38^b, 1.29^b, and 1.29^b, respectively. According to Table 2, the statistical analysis (ANOVA1) reveals no significant difference ($p > 0.05$). Compared to other stations, S5 is the most remarkable one, with a significantly lower index H' = 0.84[a] ($p < 0.001$).

Usually, an environment is considered to be unbalanced when the index remains below 0.5. The low indices observed at all stations are largely due to the abundance of two periwinkle species: *Melarhaphe neritoides* and *Echinolittorina punctata,* which colonized the wave impacted area at the mid- and supralittoral levels.

However, having the highest Shannon index H' (1.62) and the lowest Hmax (3.60), station S1 shows a rapprochement between the value of the diversity index (H') and its maximum theoretical value (Hmax). Therefore, a significantly higher evenness index (J' = 0.45)[c] confirms that this station is more balanced than the other ones.

According to Picard & Courtial (2015), a high evenness index may be due to a disturbed or recently installed ecosystem if accompanied by low biodiversity (species richness) – i.e., when the environment has a high equitability index, it is supposed to be balanced, but in the presence of low species richness this may indicate a recent environment (young). This is the case of Bouzedjar (S1), where sampling was carried out on natural rock cobs emplaced to fight the erosion of the beaches near the fishing port and at the same time prevent the silting of the port by the sand of the beach (Ghodbani, 2017). S1 is characterized (Fig. 5) mainly by the absence of *Phorcus richardi* and *Bittium reticulatum* and by a weak presence of *Melarhaphe neritoides*. It is also characterized by a strong presence of *Siphonaria pectinata* and *Cymbula safiana* compared to other stations. It should be noted that *C. safiana* is usually found in high density on harbor dykes (Frenkiel & Moueza, 1982; Rivera-Ingraham *et al.,* 2011a, c).

Regarding stations S2, S3 and S4, the statistical analysis of their respective evenness indices 0.37[bc], 0.35[b], and 0.35[b] did not show any significant difference ($p > 0.05$). This means that the Mollusca communities at these stations should be considered as similar and homogeneous. Although the absolute value of the equitability index for station S2 (J'= 0.37)[bc] seems different from that of S1 (J' = 0.45)[c], they are considered to be statistically similar ($p > 0.05$) (Tab. 3). If S2 and S4 are more or less distant from urban areas, this is not the case for S3 where dwellings are situated within a few meters of the foreshore, though most are only inhabited during the summer season.

Conversely, Arzew (S5) is visibly more polluted (Benmecheta & Belkhir, 2016). The transect area is very close to the oil and gas port of Arzew (industrial pollution). An average mercury concentration of 2.36 $\mu g\ g^{-1}$ was reported by Bouchentouf (2015) and even closer (a few meters) to housing (urban pollution). The comparison of the equitability indices revealed that station S5 (J' = 0.20) [a] had a very significant spatial heterogeneity compared to the other stations ($p < 0.001$).

On the one hand, this strong imbalance may be due to the high abundance of certain tolerant and opportunistic species, such as *Melarhaphe neritoides, Siphonaria pectinata, Phorcus articulatus,* and *Cerithium lividulum*, proliferating especially during the summer period (urban discharges). According to Pearson & Rosenberg (1978) and Grall & Coïc (2006) the peak of opportunists (with a small number of species present in high abundance) is thus expressed by low values of H' and J'. Grall & Coïc (2006) report that in the face of pollution, species will follow three types of reaction according to their sensitivity: disappear (the most sensitive), maintain abundance (the indifferent), or take advantage of the new conditions and develop (the tolerant and opportunistic). Abundance profiles over time are therefore widely used as indicators of the effects of pollutants. The profile so obtained makes it possible to identify, based on a (spatial or temporal), pollution gradient a state called "PO" corresponding to the peak of opportunists and characterized by a small number of species present in great quantities.

On the other hand, it can also correspond to an old, mature and structured stand, when a low fairness index (J' = 0.20)[a] is associated with high biodiversity (S = 21)[b]. As stated by Gosselin & Laroussinie (2004), the interpretation of the indices must always take into account the specific richness and the type of habitat. Thus, a low evenness index can correspond to a mature and structured stand with a high specific richness, while an index close to 1 can correspond to a disturbed or pioneer stand with a low specific richness.

The impact of environmental factors on species distribution (Species groupings)

The results of PCA analysis show that the presence, abundance, and proliferation of Mollusca species can be negatively or positively affected by environmental variables.

As shown in Fig. 5, the proximity of station S5 to an oil port (PPt) at the extreme east of the Oran coast (L. EE) with an east-exposure of the coast (Expos. E) and a hard rock structure (RD), favored especially tolerant and opportunistic species like *Phorcus articulatus (e12)* (A = 41 $ind.m^{-2}$, f = 52%) and *Cerithium lividulum (e18)* (A = 21 $ind.m^{-2}$, f = 39 %). These species have managed to adapt to environmental constraints, such as high concentration of organic matter, and to the tidal flats of hard rock of the upper foreshore.

Among other things we note that the proliferation of *Phorcus articulates*, unlike *Phorcus turbinatus*, seems to be due to the tolerance or even preference of this species for high concentration of organic matter. The work of Shea & Chesson (2002), Leprieur *et al.* (2008), and Beisel & Lévêque (2010) shows that changes in the environment weaken sensitive species, which begin to regress, while more tolerant species may find favorable conditions for their development in the evolution of the environment. Competition, on the other hand, would only play a marginal role.

Scientific work on the genus *Phorcus* considers this species to be an effective and reliable bioindicator of pollution (Saliba & Vella, 1977; Axiak & Schembri, 1982; Bargagli *et al.,* 1985; Nicolaidou & Nott, 1990; Cubadda *et al.,* 2001). Gueddich (2006) reported that the Trochid *Phorcus articulatus* was present in relatively high abundance. Its distribution in the foreshore zone of the "Kerkennah" Islands (Tunisia) seems to confirm that this species is more abundant in areas potentially rich in organic matter of urban origin, as it is less present in uninhabited areas or areas with a very low rate of urban planning, like the north and east coasts of Chargui Island (Tunisia). However, pollution and hydrodynamics are certainly not the only factors governing the development and geographical distribution of *Phorcus articulatus*, other abiotic factors, such as temperature and salinity, as well as biotic factors, such as the availability of trophic resources and interactions with other populations, certainly play interesting roles as well (El Hasni, 2005).

Cerithiidae species, on the other hand, are adapted to crevices in the infralittoral and lower midlittoral. The presence of *C. lividulum* in tidal flats of the upper foreshore at Arzew may be related to previous stormy conditions. Grimes *et al.* (2004) confirm the hard nature of rock formations throughout the Cap Carbon area in the Arzew region.

We also note a positive correlation of some rare species (A < 1 ind.m^{-2}, 2% ≤ f ≤ 6%), such as: *Calliostoma zizyphinum (e21), Aplus dorbignyi (e26), Pusia tricolor (e30)*. As to *Alvania cimex (e28)* and *Peringiella denticulata (e32),* these show an abundance of A < 1 ind.m^{-2} and a frequency of 1 ≤ ƒ ≤ 2%. The specimens of these species could be accidental arrivals in the transect area, perhaps brought in from the depths by storm waves.

On the opposite side of axis 1, in descending order, *Chiton olivaceus (e3), Phorcus turbinatus (e11), Pattela caerulae (e5), Patella ulyssiponensis (e6), Patella ferruginea (e7), Patella rustica (e8), Stramonita haemastoma (e19),* and *Fissurella nubecula (e9)* are much less present (A < 4 ind.m^{-2}, 5% ≤ ƒ < 50%) in the Gulf of Arzew and show a negative correlation with port proximity (PPt, PPc), hard substrate (RD), extreme-east location (L. EE), east coast exposure (Expos. E) and slightly less urbanized areas (ZU). This means that the increase in pollution concentration (industrial and urban pollution) inhibits the growth and proliferation of these species. Benmecheta & Lansari (2007) explain that Arzew has a mean hydrocarbon concentration of 35 mg l^{-1} (the levels of pollution reach a maximum of 107.9730 mg.1^{-1} and a minimum of 7.0977 mg 1^{-1}). Benmecheta & Belkhir (2016) have seen that levels of hydrocarbon (HC) and suspended matter (SM) in the bay of Arzew range from about 30 mg l^{-1}. Based on these facts, these species seem to be more sensitive to the negative effects of pollution (industrial and urban). On the other hand, these same species show a stronger positive correlation (indeed an affinity) to tender rock structure of (RT), north coast exposure (expos. N) and central location of the station (L. C). In addition, from the negative effect of pollution, some species, such as *S. haemastoma, P. turbinatus*, *P. articulatus* and the Patellidae, are the fishermen's preferred bait due to their large size.

S3 is characterized by a large presence of species with a frequency of ƒ > 70% and an abundance of 10 ind.m^{-2} < A <50 ind.m^{-2}, such as: *Phorcus turbinatus (e11), Pattela caerulae (e5), Patella ferruginea (e7), Patella rustica (e8), Chiton olivaceus (e3), Patella ulyssiponensis (e6)* (< 10 ind.m^{-2}) and those with a frequency of occurrence 25% < ƒ < 30%: *Fissurella nubecula (e9)* (1 ind.m^{-2} < A < 10 ind.m^{-2}) and *Stramonita haemastoma (e19)* (A < 1 ind.m^{-2}). The high abundance of *Chiton olivaceus (e3)* at this station (or even Kristel) may be due to the calcareous nature of the rock (RT), which offers good shelter to the Chitons thanks to porosity and cracks. The presence of *Aplysia punctata (e20)* noted at this station in December 2016 seems to have been accidental (ƒ < 1% and A < 1 ind.m^{-2}). According to Bay-Nouailhat (2008), *A. punctata* (the spotted sea hare) occurs from surface to more than 20 m deep and is often found stranded on beaches, among the rocks, sometimes in large numbers during the breeding season.

According to Fig. 5, the variable (L. OC) positioned on the positive side of axis 2 corresponds well to station S2. This station is characterized by the presence of a few rare species, with an abundance of A <1 ind.m-2 and a frequency of ƒ ≤ 3%, namely *Gyroscala lamellosa (e27), Pusia ebenus (29), Pisania striata (e16),* and *Conus ventricosus (e17)*; as well as by a greater presence of *Steromphala rarilineata (e13)* (A = 1 ind.m^{-2}; ƒ = 16%). *Gyroscala lamellosa (e27)* and *Pusia ebenus (29)* are exclusive, but otherwise these two species are medium-sized predatory gastropods with a worldwide distribution in marine shallow water, from New Zealand and Australia to the Mediterranean Sea and the Atlantic Ocean (Gofas, 2010).

In contrast, the variable (L. EC) positioned on the negative side of axis 2 corresponds well to Kristel (S4). This station is distinguished by the presence of species such as *Hexaplex trunculus* (e31) (A ≤ 1 ind.m^{-2}; F ≤ 1%), *Mytilus galloprovincialis (e23)* (A = 234 ind.m^{-2}, f = 18 %), and *Echinolittorina punctata (e2)* (A = 1579 ind.m^{-2}, ƒ = 93%). Indeed, these species are more abundant at S4 than at the other stations. Unlike other sites, S4 is also characterized by the strong presence of the species *Echinolittorina punctata* compared to that of *Melarhaphe neritoides* (A = 960 ind.m^{-2}, ƒ = 79%). These two periwinkle species are the two most represented species not only at S4 but also on the whole Oran coast. The high abundance of these populations is likely due to the small size of adult specimens, as they are less affected by predation. Jacques (1976) reported that the reproduction period for these species extends over several months (March, June, September and December) and the emergence of juveniles in the biotope of adults occurs in successive cohorts during the year (according to data for the period from 20 December 1971 to 10 January 1973). *Phorcus articulatus, Steromphala rarilineata*, and *Conus ventricosus* were noted as absent, although some specimens were observed near this site. *Peringiella denticulata* was noted at S4 and S5 only, while *Hexaplex trunculus* was reported only once at S4.

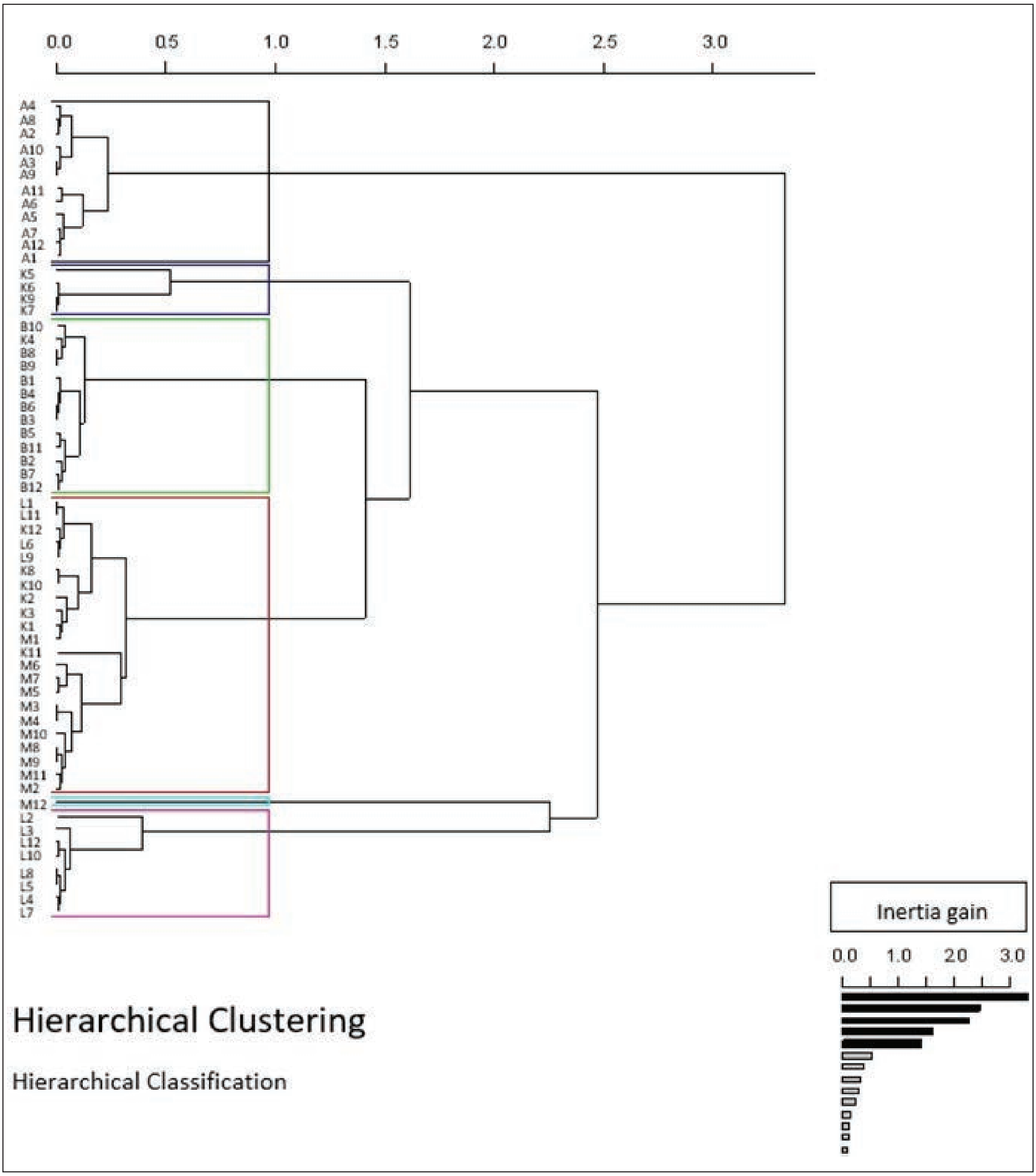

Fig. 6: Hierarchical ascendant classification (HAC) of the mollusks in Oran coast. Quadrats (sampled by month and station) are grouped together according to similarity. A: Arzew station; B: Bouzedjar station; K: Kristel station; L: La madrague station; M: Madagh station; Numbers 1, 2, 3, …, 12 : the sampling months from January to December (example: A1 is Arzew station in January).

Sl. 6: Razporeditev mehkužcev na podlagi klastrske metode HAC (Hierarchical ascendant classification) na oranski obali. Kvadrati (vzorčeni enkrat mesečno) so grupirani na podlagi podobnosti. A: vzorčevalna postaja Arzew; B: Bouzedjar; K: Kristel station; L: La madrague; M: Madagh. Številke 1, 2, 3, …, 12 : vzorčevalni meseci od januarja do decembra (primer: A1 je januarski vzorec na postaji Arzew).

As for the species *Siphonaria pectinata (e4)*, *Bittium reticulatum (e22)*, their diagonal position between two axes suggests not only a positive affinity to Kristel (L. EC) but also to Arzew (L. EE). They have a preference for the hard nature of rock (DR) and display a higher tolerance to industrial and urban pollution (PPt and PPc). On the one hand, *Siphonaria pectinata* seems to better withstand the constraints of the coastal environment since the species was often found at S1 and S5, covered with a layer of tar. On the other hand, this may be due to the nature of bedrock at these two stations, which, unlike at other stations, is hard and smooth (offers better adhesion). Steneck (1982) explains that the hardest and smoothest surfaces are the most suitable for adult individuals of certain Mollusca because they allow them to better resist the pressure of waves and predators. In addition, Rivera-Ingraham *et al.* (2011a) noted that smooth substrates had higher densities and sizes of certain species such as *C. safiana*, as opposed to heterogeneous and irregular surfaces, which can serve as shelter for young individuals and as a suitable substrate for the settlement of larvae. Finally, Boukhicha *et al.* (2014) noted that irregularities in the substrates are associated with the high recruitment rate in limpets (Patellidae) and other marine gastropod Mollusca (Littorinidae, Trochidae, etc.).

This classification groups in sets objects with a significant degree of similarity. The data studied are usually species abundances in a cross-sample/species matrix. Given the limitations of the (HAC) cited above, Fig. 6 indicates that the quadrats were grouped firstly into two groups, that of Arzew [from A1 (Arzew in January) to A12 (Arzew in December)] and that of other sites. The second group of quadrats was established according to the sites Bouzedjar, Madagh, La Madrague, and Kristel. It is clear that Arzew (left in black) is completely different from the other communities. It is also known from many studies (Boutiba, 2003; Benmecheta & Lansari, 2007; Almulsi, 2011; Meftah, 2011; and others) that Arzew is the most polluted site of the Oran coastline due to urban and industrial pollution, and the presence of petroleum port and housing nearby (a few meters away). Benmecheta & Belkhir (2016) report that despite dispersive effects, hydrocarbon (HC) concentration levels range from 90 to 180 mg/kg in surface sediments of Arzew shorelines. Sources of pollution are also found in the environmental department of the Oran province; other studies carried out on this territory of the Oran province classify the Arzew industrial zone as dangerous to environmental health. This is supported by our observations on Molluscan communities and urban discharges; oil films on sea surfaces, tar concretions on rocks, and various plastic debris were all observed during our transect survey work.

With regard to other groups, we note that station S3 in purple color, represented by quadrats L2, L3, L4, L7, L8, L10, and L12, differs from the remaining 3 groups. This site, despite the presence of nearby homes (a few meters away) remains very little frequented by summer visitors, and urban pollution is unremarkable, unlike in Arzew (S5). With regard to the last groups of quadrats, it is clear that station S1 in green color differs from the associated groups of S3 and S4 in red (Fig. 6), which, in turn, are similar. Note, however, that quadrats L1, L6, L9, and L11 for S3 are also part of this last group (consisting of stations S2 and S4).

CONCLUSIONS

As indicated by the results from the studied stations and according to the ecological indices applied, the entire Oran littoral can be considered as disturbed because the index of equitability hardly exceeds the 0.5 at any site. Despite this disturbance, results have also shown an abundance of periwinkles (very high density). These gastropods are very small and characterized by high reproduction, which considerably increases their number compared to other species. The Littorines (periwinkles) display an overall density of nearly 90% at all studied sites.

The species *Melarhaphe neritoides, Siphonaria pectinata, Phorcus articulatus,* and *Cerithium lividulum* seem to be the most resistant to adverse conditions (environmental pollution) (Gueddich, 2006) and proliferate rapidly in contrast to many other species recorded at Oran coastal stations, including *Phorcus turbinatus, Pattela caerulea, Patella ulyssiponensis, Patella Ferruginea, Patella rustica, Fissurella nubecula,* and *Cymbula safiana*. These latter species are also very sensitive to the changing environmental conditions, and can serve as an indicator of degradation of aquatic environments. Five species of Patellidae were identified in the western coast (Bouzedjar and Arzew) and 4 species in the eastern coast (Jijel and Annaba) (Beldi *et al.,* 2012; Zegaoula *et al*., 2016**;** Bouzaza, 2018; Boumaza *et al.,* 2021). *Patella ferruginosa* seems to have adapted to the Algerian western conditions area and would require further investigations in the eastern coasts.

With regard to the structure of the populations and their distributions we note that these do not only depend on the distance from the sources of pollution but also, secondarily, on the seasons (Fig. 4) and geographical coordinates of the station (Jacques, 1976; Damerdji, 2008; De Vaufleury & Gimbert, 2009; Damerdji, 2010; Diomandé, 2019).

The information presented in this document – even considering the limitations of the sampling methods increases the knowledge of the distribution and abundance of Mollusca in the Oran littoral, where pollution is identified as a key factor affecting species distributions. This new knowledge may be useful in further detailed autecology studies of Mollusca species, of species associations, and coastal ecosystem dynamics. Implementation of long-term biomonitoring in this coastal area would be of great value for the assessment of time trends related to changes in species distributions and abundances.

BIODIVERZITETA IN STRUKTURA ZDRUŽBE MEHKUŽCEV V BIBAVIČNEM OBMOČJU MED PREDELOMA BOUZEDJAR IN ARZEW (ZAHODNA ALŽIRIJA)

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POVZETEK

V raziskavi avtorji poročajo o seznamu vrst ter časovni in prostorski dinamiki združbe mehkužcev v bibavičnem pasu med predeloma Bouzedjar in Arzew v zahodni Alžiriji. V obdobju 2016 in 2017 (redna mesečna vzorčenja) so na petih vzorčevalnih postajah determinirali 32 vrst mehkužcev. Ekološki indeksi kot so abundanca (od 1167 do 2856 os. m^{-2}), število vrst (15 Gastropoda, 3 Bivalvia, in 1 Placophora), diverziteta (H') in indeks enakomernosti porazdelitve (J') kažejo, da je obalni ekosistem moten in neuravnotežen (še posebej na predelu Arzew) zaradi številnih človeških aktivnosti, ki imajo vpliv na to območje. Na podlagi raziskave je nastal zemljevid razširjenosti vrst in podatkovna baza za menedžment, biomonitoring in posledično zavarovanje obalnega ekosistema.

Ključne besede: pridneni mehkužci, bibavični pas, seznam vrst, populacijska dinamika, Alžirija

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