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Research Article

A Comparison of Abundance and Diversity of Epiphytic Microalgal Assemblages on the Leaves of the Seagrasses *Posidonia oceanica* (L.) and *Cymodocea nodosa* (Ucria) Asch in Eastern Tunisia

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We studied spatial patterns in assemblages of epiphytic microalgae on the leaves of two seagrass species with different morphologies and longevity, *Cymodocea nodosa* and *Posidonia oceanica*, which cooccur in Chebba in Eastern Tunisia. Epiphyte assemblages were described for each species in summer. Epiphyte microalgal assemblages were more abundant on the leaves of *C. nodosa* but more diversified on the leaves of *P. oceanica*. We suggest that the differences in species composition and abundance between those seagrass species may reflect an interaction of timescales of seagrass longevity with timescales of algal reproductive biology. Short-lived *C. nodosa* was dominated by fast growing species such as the cyanobacteria species *Oscillatoria* sp., while *P. oceanica* leaves were colonized by more mature and diversified species such as Prorocentrales. Local environmental conditions (hydrodynamics, light penetration), host characteristics (meadow type, shapes forms of leaves, life span, and growth rate), and grazing effect seem also to be responsible for these dissimilarities in epiphytic microalgae communities.

1. Introduction

The habitats of marine Magnoliophyta *Posidonia* and *Cymodocea* are, with the coral, the most important marine ecosystems of the Mediterranean. Their leaves provide substrates suitable for the establishment and growth of a number of micro- and macrocolonizers which form laminates assemblages characterized by high species diversity [1].

Previous studies showed that epiphytic community structure is influenced by biotic factors such as leaf age, seasonal cycle of the host, and grazing pressure by herbivores [2–5], as well as by abiotic factors such as light, temperature, nutrients, and water motion [6–8]. The density of the seagrass canopy and shoot size can significantly modify epiphytic biomass, presumably due to effects of light penetration [9, 10], whereas shoot morphology, leaf, and stem ages can influence epiphyte distribution and abundance due to differences in the surface area that is available for epiphyte settlement [11, 12].

Epiphytic microalgae include many toxic species [13–16]. Knowledge of the epiphytes and potentially toxic species of microalgae is necessary to assess the influence of those species on fisheries exploitation and human health. Moreover, various studies have documented a good correlation between the abundance of those toxic species in the water column and their abundance on macrophytes [15, 17]. Although a good number of surveys have focused on the epiphytic community in the north basin of the Mediterranean Sea, the south part has received little attention.

The purpose of this study is to investigate the diversity and species abundance of leaf epiphytic microalgae on *Posidonia oceanica* (L.) and *Cymodocea nodosa* (Ucria) Asch in eastern Tunisia where several fish farms have recently been installed.

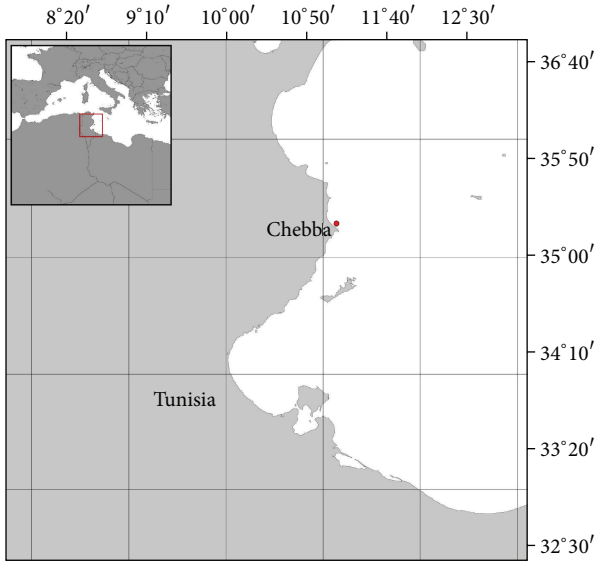


Figure 1: Map of the study area, showing the sampling stations.

Our aim was to examine the following hypothesis: (1) due to their large leaves, epiphytic microalgae on the leaves of *Posidonia oceanica* may be more diverse and more abundant than those on *Cymodocea nodosa* leaves; (2) variation of the phenological parameters of the host plant may explain the pattern of microepiphyte abundance; (3) some potentially toxic species are likely to be found among the epiphytic community on the *Posidonia oceanica* and *Cymodocea nodosa* leaves.

2. Materiel and Methods

2.1. Study Area. This study was conducted in the locality of Oued Lafrann (35°15′18″ N, 11.07′28″ E) in the region of Chebba (east of Tunisia) where 32 aquaculture cages of sea beam have been recently installed. The climate is semiarid (average precipitation: 350 mm per year) and sunny with strong northerly winds. This area is under consideration as a marine protected area (submitted in Italo-Tunisian project iTunES) because of its biocenotic richness and its distinctive ecosystems especially macrophytes, mainly *Cymodocea nodosa,* that occur near *Posidonia oceanica* bed, *Halophila stipulacea,* and many macroalgae.

Surveying and sampling were conducted during September 2013 by SCUBA diving in two stations about 1 km apart (Figure 1): *Posidonia oceanica* meadow (P) and *Cymodocea nodosa* meadow (C). To reduce habitat variability in the present study, all samples were collected at the same depth of 5 m. Sampling was conducted in the same day, water temperature was 22°C, water salinity was 38.2 ± 0.2 g·L^{-1} (mean ± SD), and wind speed was about 20 km/h. Because of the proximity of sampling stations, measurements of physicochemical parameters are not carried out.

3. Sampling Treatment

To study the epiphytic microalgae on *Posidonia oceanica* and *Cymodocea nodosa* leaves, shoots were collected using a metal square quadrat with a 40 cm inner edge. The quadrat was randomly placed over the shoots, which were all carefully collected. At each station, six replicate quadrats were sampled. The shoot density of *P. oceanica* and *C. nodosa* was measured in six replicates of 0.25 m^2 and expressed as number of shoots·m^{-2}.

In the laboratory, from each quadrate, leaves were removed from 15 shoots in distichous order of insertion and separated into the various categories defined by Giraud [18]. For each shoot, the following leaf traits were scored: (1) total number of standing leaves, (2) total number and (3) length of adult and intermediate leaves, and (4) leaf width. Leaf area index (LAI, m^2·m^{-2}) was determined as product of leaf surface area (total leaf length × mean leaf width, cm^2·shoot^{-2}) and shoot density.

To detach the leaf microepiphytic communities, from each quadrat, leaves were detached from their sheet and weighed to 100 g with an electronic precision balance [19]. The epiphytes were then separated from the weighted leaves by vigorous shaking and washing with filtered seawater. This procedure was repeated several times to ensure that most of the attached organisms were separated. This method was used by previous researchers to remove microepiphytic species [15, 20–23]. The filtered material was then passed through 250 and 100 μm mesh sieves to remove large particles and was fixed with Lugol's solution and finally preserved in 5% formalin and its volume (V) was noted. All filtered materials were kept in the dark at ambient temperature until their microscopic observation. Settling long glass tubes used for sedimentation procedure were 2 cm wide by 21 cm long and have a base plate that contains a coverslip into which the algae settle. To mix the sample, the bottle was gently tilted back and forth 10 times before pouring. A 50 mL subsample was poured into the settling chamber and left to settle for 24 h. Subsamples were examined in an inverted microscope at medium (×200) magnification by scanning the entire surface of the settling chamber to enumerate epiphytic microalgae [24]. The total number of microalgae individuals (N) contained in 100 g of fresh weight *Posidonia* (expressed as number of individual per 100 g of fresh weight of *Posidonia* (fwm)) is obtained by the following conversion: $N = (n \times V)/v$; with n = number of individuals counted, V = volume of the filtered material, and v = volume of the sedimentation chamber (50 mL). The identified taxa were divided into groups (diatoms, dinoflagellates, and cyanobacteria).

4. Data Analysis

Data were tested for normality using the Kolmogorov-Smirnov goodness of fit test and for heterogeneity using Cochran's C Test and then transformed if necessary [25].

Analyses of similarity (ANOSIM) randomization tests (with untransformed data) were used to test for differences in species abundance among sampling stations [26]. If differences were found using ANOSIM, then SIMPER analysis was used for identifying which species primarily accounted for observed differences in epiphytic assemblages between sampling stations. SIMPER generates a ranking of the percent

contribution of the species that are most important to the significant differences. These analyses used a matrix composed of Bray-Curtis similarity coefficients generated with $\log(x+1)$-transformed data. The calculations were performed using the statistical software PRIMER 5.0 [27].

Univariate indices, species number (S), and diversity (Shannon-Weaver index H') were calculated for each sampling station. The one-way ANOVA was used to test for overall differences between these indices and the Tukey HSD multiple comparison tests were used in pairwise comparisons between sampling stations. One-way analysis of variance (ANOVA) was used to test the hypothesis that the abundance of each of the most abundant groups varies among sampling stations. Tukey test HSD was employed for a posteriori multiple comparisons of means. The calculations were performed using the statistical software STATISTICA v10 (StatSoft, Inc.).

Relationships between epiphytic species abundance and biometric parameters (shoot density, leaf area index, and average length of adult and intermediate leaves) were examined using the RELATE procedure in PRIMER. RELATE is the equivalent of a nonparametric Mantel test [28]; it assesses the degree of correspondence between matrices and, via a randomization test, it provides a measure of statistical significance of the relationship [28]. The matrix of similarities between epiphytic species abundance (based on the Bray-Curtis coefficient from untransformed data) was compared with a matrix of the similarities between biometric parameters (based on Euclidean distance from untransformed data). The significance of any correlation between matrices was assessed with a randomization test.

Canonical correspondence analysis (CCA), a direct gradient analysis technique [29], was used to investigate the relationship between epiphytic species and biometric parameters of the two sampling macrophytes. Epiphyte abundances data were $\log(x+1)$-transformed. Downweighting for rare species was performed. We used CANOCO 4.5 (Scientia Software).

5. Results

Cymodocea nodosa exhibits the highest shoot density while *Posidonia oceanica* has the highest leaf area index (LAI) (Figure 2). The average leaf number was 7.21 ± 2.13 (mean ± standard deviation) and 3.66 ± 1.12 for *P. oceanica* and *C. nodosa,* respectively. The highest mean value of leaf length (48.57 ± 7.87 cm) was recorded for *P. oceanica*, whereas the lowest mean value (16.3 ± 4.87 cm) was observed for *C. nodosa*.

A total of 52 taxa of epiphytic microalgae were identified (Table 1). The highest number of collected species was diatoms (24), followed by dinoflagellates (22) and cyanobacteria (6). Species number and H' index of microepiphytic assemblage were high on *Posidonia oceanica* leaves (Figure 3).

Analysis of similarity (ANOSIM) of epiphytic microalgae $\log(X+1)$-transformed specie abundances showed significant difference ($R = 0.987$; $P = 0.02$) between the *P. oceanica* station and *C. nodosa* station.

Analyses of similarity percentage (SIMPER) showed that the average dissimilarity between *P. oceanica* and *C. nodosa*

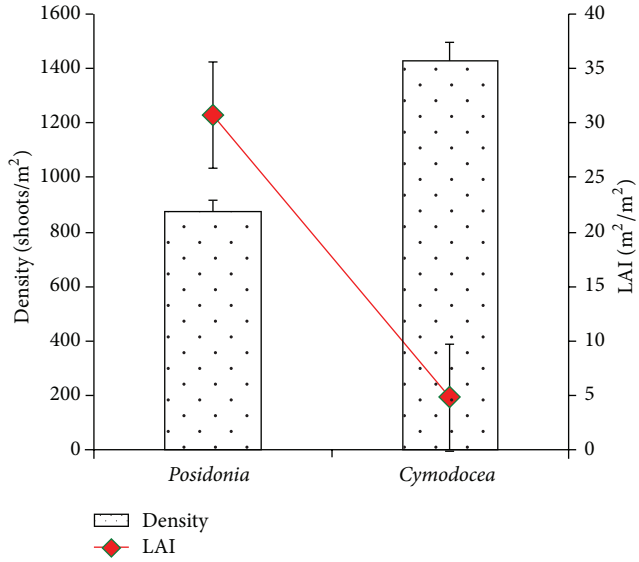


Figure 2: Average leaf area index (LAI) and shoot density of *P. oceanica* and *Cymodocea nodosa.*

epiphytes groups is high (64.44%). This procedure also allowed us to determine the species that contribute to this dissimilarity; they are *Oscillatoria* sp., *Fragilaria*, *Pseudanabaena* sp., and *Amphiprora constricta* (Table 2) that are more abundant on *C. nodosa* leaves.

Dinoflagellates, diatoms, and cyanobacteria were common epiphytes on leaves (Figure 4). Abundances of those groups were included in the univariate analyses of variances. Dinoflagellates did not differ significantly between stations ($F_{(1;10)} = 1.31$, $P = 0.279$). Significant differences were detected for Gymnodiniales and Peridiniales among stations ($F_{(1;10)} = 2868.42$, $P < 0.001$; $F_{(1;10)} = 1666.78$, $P < 0.001$, resp.) with high abundance on leaves of *Cymodocea*. In contrast, Prorocentrales were more abundant on the leaves of *Posidonia* ($F_{(1;10)} = 15.79$, $P = 0.003$; Tukey test). Epiphytic diatoms were more abundant on *Posidonia* leaves ($F_{(1;10)} = 13.64$, $P = 0.004$; Tukey test). In contrast, cyanobacteria were higher on *Cymodocea* leaves ($F_{(1;10)} = 1749.26$, $P < 0.001$; Tukey test). When the abundances of toxic species are grouped, significant differences were detected among stations ($F_{(1;10)} = 57.63$, $P < 0.001$) with high abundance on *Posidonia* leaves. Significant differences were detected for species number and for H' index ($F_{(1;10)} = 34.005$, $P < 0.001$; $F_{(1;10)} = 14.14$, $P = 0.004$); S and H' of *P. oceanica* were higher than those of *C. nodosa* (Table 3).

The results of RELATE tests indicated that there is a correlation between the biometric parameters (shoot density, LAI, and average adult and intermediate leaves) and species abundance (Spearman rank correlation statistic, Rho = 0.684; $P = 0.04$).

Canonical correspondence analysis (CCA) indicates that the axis I and axis II expressed high cumulative variance species-biometric parameters (98.1%, Table 4). Stations P and C are placed separately on the left and the right of the diagrams, respectively. Species placed closely with samples

Table 1: "Presence-absence" species list of epiphytic microalgae identified on the leaves of *P. oceanica* and of *C. nodosa* in prospected stations.

Species	*Posidonia*	*Cymodocea*
Dinoflagellates		
Amphidinium carterae Hulburt	0	1
Ceratium furca. (Ehrenberg) Claparède and Lachmann	1	0
Ceratium tripos (Müller)	1	0
Coolia monotis Meunier	0	1
Cyst of dinoflagellates	0	1
Gonyaulax spinifera	0	1
Gymnodinium sp.	0	1
Ostreopsis ovata (Fukuyo)	0	1
Polykrikos sp.	0	1
Prorocentrum concavum (Fukuyo)	1	0
Prorocentrum gracile (Schütt)	1	0
Prorocentrum lima (Ehrenberg) Dodge	1	0
Prorocentrum micans Ehrenberg	1	0
Prorocentrum minimum (Pavillard) J. Schiller	1	0
Prorocentrum rathymum (Loeblich) Shirley and Schmidt	1	0
Prorocentrum triestinum (Schiller)	1	0
Protoperidinium curtipes (Jorgensen) Balech	1	0
Protoperidinium depressum (Bailey) Balech	1	0
Protoperidinium divergens (Ehrenberg) Balech	1	0
Protoperidinium mite (Pavillard) Balech	1	0
Protoperidinium ovum (Schiller) Balech	1	0
Protoperidinium steinii (Jørgensen) Balech	1	0
*Protoperidinium*sp.	0	1
Scrippsiella sp.	1	1
Diatoms		
Amphiprora constricta Ehrenberg	1	0
Amphora sp.	1	1
Asterionellopsis glacialis (Castracane) Round	1	0
Asteromphalus flabellatus (Brébisson) Greville	1	0
*Bacillaria*sp.	1	0
Budelphia sp.	1	0
Chaetoceros sp.	1	0
Climacosphenia moniligera (Ehrenberg)	1	0
Coscinodiscus sp.	0	1
Dactyliosolen sp.	1	0
Diploneis sp.	1	0
Fragilaria sp.	1	0
Grammatophora sp.	1	0
Guinardia sp.	1	1
Licmophora sp.	1	1
Navicula sp.	1	1
Nitzschia fonticola Grunow	1	0
Pinnularia sp.	1	0
Pleurosigma sp.	1	0
Rhizosolenia styliformis Brightwell	0	1
Striatella unipunctata (Lyngbye) C. Agardh	1	0
Surirella sp.	1	0

Table 1: Continued.

Species	*Posidonia*	*Cymodocea*
Cyanobacteria		
Anabaena sp.	1	1
Lyngbya sp.	0	1
Merismopedia sp.	0	1
Micrococcus sp.	0	1
Oscillatoria sp.	1	1
Pseudanabaena sp.	1	0

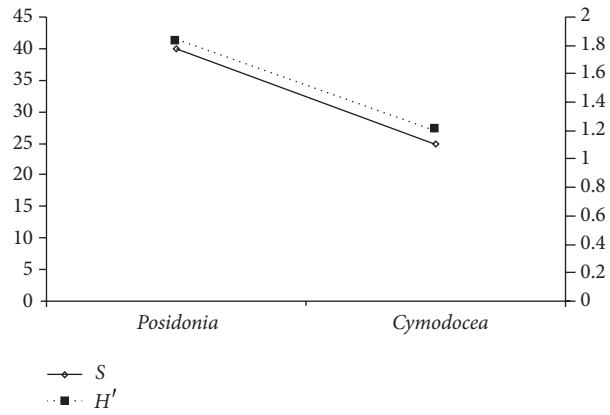


Figure 3: Mean diversity index (H') and species number (S) on leaves in prospected stations.

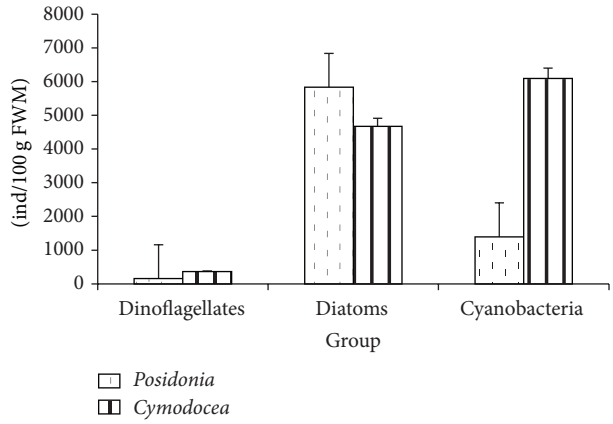


Figure 4: Average abundance of microepiphytes on leaves in prospected stations.

of *P. oceanica* (P) station belong mainly to Prorocentrales. Species closely placed near samples of *C. nodosa* station belong mainly to cyanobacteria (Figure 5).

6. Discussion

Differences between leaf epiphytic microalgae communities were found between *C. nodosa* and *P. oceanica* in our study area (East of Tunisia); leaf microepiphytic communities of *Posidonia* were more diverse than those of *C. nodosa* (S and H': Table 3). The same results were found by Mazzella et al. [30] in Adriatic Sea and by Turki [19] in Northern Tunisia. Contrary to what was expected, total abundance of epiphytic microalgae was higher on *C. nodosa*. A possible hypothesis to explain this result is that *P. oceanica* develops much larger leaf area index values than *C. nodosa* which contribute to light attenuation within the seagrass canopy by leaf self-shading [31]. Unfortunately, light measurements were not taken in this study, but previous studies have shown that light attenuation by the canopy is reduced with decreased leaf area index [32]. Therefore, the higher light availability that may occur in *C. nodosa* meadows may explain the higher abundance of epiphytic microalgae found in these meadows.

Ours results showed that microepiphytic abundances are correlated with shoot density and phenological parameters of the host plant (RELATE procedure); prorocentrales abundance was related to leaf length and leaf area index, while cyanobacteria was related to *Cymodocea* shootdensity (CCA procedure; Figure 5). Correlation between microepiphytic species and leaf phenological parameters of the host plant has been also found by previous studies for *P. oceanic*a [5] and for *Zostera marina* [33]. Indeed, differences between leaves shapes could explain epiphytic species variability between *P. oceanica* and *C. nodosa*. The leaves of *P. oceanica* are ribbon-shaped (40 to 140 cm long, 7 to 11 mm wide) gathered together in fascicles (from 5 to 8 leaves) at the tips of the stems and have a life of between 5 and 13 months [34]. The leaves of *C. nodosa* are also ribbon-shaped but shorter than those of *Posidonia oceanica* (10 to 30 cm long, 2 to 4 mm wide), gathered together in smaller fascicles (from 2 to 5 leaves), and have a life of between 2 and 8 months [35, 36]. *Cymodocea nodosa* has the higher value of specific growth rate (up to 4.7%) than of *P. oceanica* (1.5%) [31]. The short life span *C. nodosa* could explain domination of fast growing species such as *Oscillatoria* sp. [37] and other cyanobacteria species. *Posidonia oceanica* leaves are older; they offer more time for the epiphytic species to settle and the epiphytic community will be composed of a more mature and more diverse community.

The epiphytic composition is influenced by the interaction between the lifespan of the host and the reproductive lifespan of the epiphytes [38]. Where the host is long-lived, as for *Posidonia*, local recruitment from existing epiphytes with fast reproductive strategies can continually reinforce the local composition. For instance, the density of diatoms increased relatively quickly and became dominant (after 7 to 10 weeks) in the older parts of the sheet [1, 22]. Cyanobacteria

Table 2: SIMPER results.

Species	Group *Posidonia* Av. Abund	Group *Cymodocea* Av. Abund	Av. Diss	Diss/SD	Contrib%	Cum.%
Oscillatoria sp.	500	6000	30.19	6.2	46.85	46.85
Navicula sp.	3933.33	3850	13.36	2.07	20.74	67.59
Fragilaria sp.	625	0	3.34	6.32	5.19	72.78
Pseudanabaena sp.	600	0	3.31	6.49	5.13	77.91
Amphiprora constricta	450	0	2.48	5.74	3.85	81.76
Guinardia sp.	33.33	300	1.47	5.1	2.29	84.05
*Anabaena*sp.	300	41.67	1.42	5.79	2.21	86.26
Pinnularia sp.	250	0	1.41	2.81	2.18	88.44
Amphora sp.	100	300	1.09	4.25	1.69	90.13

Table 3: Analysis of variance ANOVA of the abundances of major groups of microalgae and cyanobacteria in prospected stations.

Source	Df	MS	F	P	Tukey test
Total abundance					
Habitat	1	0.050	15.555	0.003	C > P
Residuals	10	0.003			
Dinoflagellates					
Habitat	1	0.031	1.312	0.279	n. s.
Residuals	10	0.023			
Diatoms					
Habitat	1	0.067	13.643	0.004	C < P
Residuals	10	0.005			
Cyanobacteria					
Habitat	1	1.310	1749.266	<0.001	C > P
Residuals	10	0.001			
Toxic species					
Habitat	1	1.255	57.635	<0.001	C < P
Residuals	10	0.022			
Species number (S)					
Habitat	1	1452.000	34.005	<0.001	C < P
Residuals	10	42.700			
H'					
Habitat	1	0.032	14.143	0.004	C < P
Residuals	10	0.002			

C: *Cymodocea nodosa* meadow; P: *Posidonia oceanica* meadow; n. s.: not significant. Data were $\log(x + 1)$-transformed after significant Cochran C test.

include some fast growing species such as *Oscillatoria* sp. [37]. Borowitzka et al. [38] suggest that seagrass epiphytes can be classified into groups based on their seasonal distribution: (a) epiphytes occurring throughout the year, (b) epiphytes with a distinct seasonal pattern in their occurrence, and (c) transient colonizers.

Difference between epiphytic compositions on the leaves of seagrass species has been studied over the world and showed that more persistent and structurally complex seagrass species tend to have more diverse epiphyte assemblages. Short-lived seagrass species such as *Heterozostera* sp. and *Halodule* sp. are likely to be relatively depauperate in epiphyte species richness compared to persistent seagrass species such as *Amphibolis* sp. [38]. The findings of Aligizaki and Nikolaidis [15] showed that the maximum abundances of epiphytic dinoflagellates were recorded in branched macroalgae, while those abundances were remarkably lower in the less leafy marine phanerogame such as *Cymodocea*.

The two species of macrophytes made different habitats depending on local environmental conditions (nutrient, substratum, current, ect.); our prospected *Posidonia* meadow is a monospecific fringing reef, whereas sampling *C. nodosa* is a continuous extensive bed. Differences of hydrodynamic forces between those two habitats and wave exposure can also be responsible for species variability of the epiphytic communities. Indeed, seagrasses are able to modify current

Table 4: Summary of canonical correspondence analysis (CCA) of the three data matrices (epiphytic microalgae, stations, and biometric parametersvariables).

	Axis 1	Axis 2
Eigenvalues	0.564	0.020
Species-environment correlations	0.992	0.760
Cumulative percentage variance of species data	69.6	72.0
Cumulative percentage variance of species-environment relation	94.8	98.1
Sum of all eigenvalues	0.810	
Sum of all canonical eigenvalues	0.595	
Explained variance by CCA	73,45%	
Intraset correlations of variables with axes		
Density	0.9581	−0.1771
Average of adult leaf length	−0.9645	−0.0258
LAI	−0.9591	−0.1494

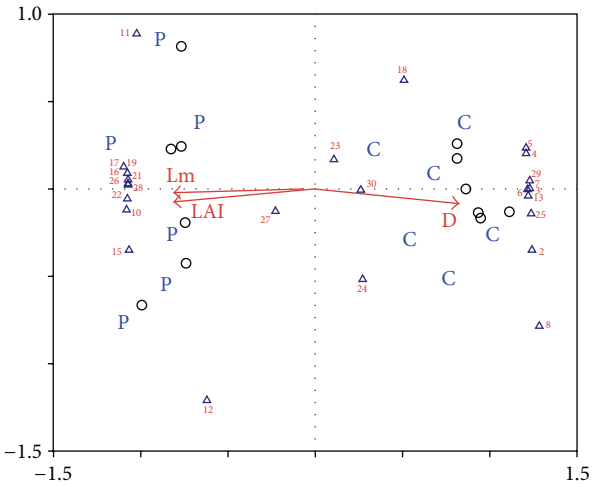


Figure 5: Diagram of canonical correspondence analysis (CCA) showing the effects of biometric parameters of the host plant on epiphytic microalgae species and their ordination according to the first and second axes. Species whose coverage and frequency are less than 10% were eliminated. Species that were grouped with Posidonia station (P) are 10: *Prorocentrum concavum,* 11: *Prorocentrum minimum,* 12: *Prorocentrum lima,* 15: *Nitzschia fonticola,* 16: *Fragilaria* sp., 17: *Surirella* sp., 19: *Diploneis* sp., 21: *Pleurosigma* sp., 23: *Pinnularia* sp., 26: *Amphiprora constricta,* 27: *Anabaena* sp., and 28: *Pseudanabaena* sp. Species that are grouped with Cymodocea (C) station are 2: *Gymnodinium* sp., 3: *Amphidinium carterae,* 4: *Gonyaulax spinifera,* 5: Cyst of dinoflagellates, 6: *Protoperidinium* sp., 8: *Coolia monotis,* 13: *Rhizosolenia styliformis,* 18: *Guinardia* sp., 24: *Amphora* sp., 25: *Nitzschia* sp., 29: *Coscinodiscus* sp., and 30: *Oscillatoria* sp.

flow and this depending on species [39]. For instance, wave attenuation is the highest when seagrasses occupy a large portion of the water column such as *Posidonia oceanica* bed [40]. As a result bed with high canopy is slower than low-canopy seagrass bed [41, 42]. The canopy of *P. oceanica* tends to attenuate currents and waves thereby reducing the forces exerted on individual shoots [42]. Even at the edge of the canopy, seagrass shoots may be sheltered to a certain extent by the presence of adjacent shoots [43]. Natural fluctuations in water flow also affect the epiphytic community. If an epiphytic community develops during relatively calm conditions, species with high drag (i.e., large area exposed to the flow) may become dominant, but if the flow increases over a short period of time (e.g., storms), these epiphytes are then removed [44]. Our study is carried out in September (summer season), which is fairly quiet period since the storms intensified especially in autumn in the eastern Tunisia. Consequently, the effect of the removal of epiphytes by strong hydrodynamics would be less important.

The epiphyte-grazer interaction also plays an important role in controlling the abundance and diversity of epiphytes. Indeed, the epiphytes of marine macrophytes are a food source for a range of grazers and, in turn, they influence the diversity and abundance of epiphytes by removing the substrate and biomass of the host plant [38]. The effect of grazing is also an important factor that contributes to the variation between the two macrophytes species, as many species feed on epiphytes of *Posidonia*, including the echinoid *Paracentrotus lividus*, some decapods, and amphipods [45, 46]. In addition, about 50 species of fish are encountered in *P. oceanica* beds [47].

Grazers can be highly selective and thus may have a strong effect on the spatial pattern of the periphytic community [48]. Some grazers (scrapers) feed preferentially on tightly attached diatoms [46], whereas others (surfers) favor overstory diatoms [49]. Neckles et al. [50] have shown that number of diatoms decreased in the presence of grazers. In addition, strong currents (and/or high waves) may eliminate grazers allowing for more epiphytes to grow [51]. Cyanobacteria have different mechanisms to reduce the grazing pressure by large-bodied cladocerans. They can form colonies with sizes beyond the ingestion capacity; cyanobacteria may produce grazing deterrents and potent endotoxins that are released upon digestion, while cells that are embedded in mucus could be resistant to digestion [52].

Diatom abundance was higher in *P. oceanica*; they are dominated by the order of naviculales which includes the most abundant species present on the leaves of *P. oceanica* [53, 54]. Various studies have suggested that diatoms and bacteria are among the first organisms to colonize the submerged objects or organisms, and they shape a biofilm influencing the settlement of some invertebrate larvae [53]. The diatoms also constitute a food source for various organisms living in the *Posidonia* canopy [53–55].

Dinoflagellates were more abundant on the leaves of *P. oceanica*, especially the order of prorocentrales. Abundance of potentially toxic dinoflagellates on *Posidonia* leaves was higher than those on *C. nodosa* leaves. These findings support those of Romdhane et al. [56] and Armi et al. [57] in Tunisia and those of Aligizaki and Nikolaidis [15] in the north of the Mediterranean Sea. They are *Amphidinium carterae*, *Coolia monatis*, *Ostreopsis ovata*, *Prorocentrum concavum*, *P. minimum*, *P. rathymum, P. triestinum, P. micans,* and *P. lima*. Those species are potential toxin producers [58].

For instance, epiphytic *Prorocentrum* species are mainly associated with okadaic acid and the production of analogues [59]. These results are particularly useful in this area with the recent establishment of several fish farms because epiphytic dinoflagellates are easily resuspended in the water column [8] and that abundance of phytoplankton in vegetated areas is higher than in the unvegetated station [16]. Moreover, Marr et al. [60] concluded that the underestimation of toxic dinoflagellates associated with a toxic event may be due, in part, to the lack of sampling of the benthic and epiphytic communities. Finally, it is necessary to improve a management program to protect seagrass species and their associated epiphytes in eastern Tunisia and ovoid installation of aquaculture farm around seagrass beds whenever possible not only to preserve this vulnerable ecosystems [35] but also to ovoid a possible contamination by epiphytic potentially toxic species.

7. Conclusion

Abundance and species composition of epiphytic microalgae were different on the leaves of *P. oceanica* and *C. nodosa*. Local environmental conditions (hydrodynamics, light penetration), host characteristics (meadow type, shape forms of leaves, life span, and growth rate), and grazing effect seem to be responsible for these dissimilarities in epiphytic microalgae communities.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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