POSIDONIA OCEANICA MEADOWS ALONG THE EASTERN COAST OF TUNISIA: FEATURE AND HEALTH STATUS

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ملخص

المؤشرات الصحية لمعشبات البوزيدونيا بالسواحل الشرقية للبلاد التونسية تمت دراسة التركيبة والمقاييس ونمو معشبات البوزيدونيا في أربعة مواقع من الساحل الشرقي للبلاد التونسية وهي هرقلة والقنطاوي والمنستير والمهدية. سجل تباين كثافة حزم البوزيدونيا ونسبة التغطية والمقاييس بين مختلف المعشبات وحسب العمق ويرجع هذا إلى إختلاف الضغط البشري على مختلف هذه المواقع . سجلت الكثافة والمقاييس الأعلى لنبات البوزيدونيا في المهدية حيث تراوحت الكثافة بين 441 و984 حزمة بوزيدونيا في المتر المربع الواحد بينما تراوح المؤشر الورقي بين 8.5 إلى 13 متر من البوزيدونيا في المتر المربع الواحد بينما لم يسجل إختلافا بين عدد الأوراق المنتجة سنويا في مختلف المواقع والأعماق. ويعتبر نمو جذع البوزيدونيا الأعلى نسبة بالمهدية وهرقلة مقارنة بالمنستير والقنطاوي إذا ما تؤخذ بعين الإعتبار العينات المتأتية من عمق 2م. تتناقص نسبة نمو الجذوع كلما ازداد العمق في كل من القنطاوي والمنستير . إن هذه الدراسة تقدم معلومات جديدة على الحالة الصحية الحالية لنبات البوزيدونيا في منطقة جغرافية تنقصنا فيها المعلومات.

كلمات المفاتيح : الأعشاب البحرية ، معشبات البوزيدونيا ، كثافة حزم، تونس

RESUME

Les herbiers à *Posidonia oceanica* au niveau du centre Est de la Tunisie : Caractéristiques et état de vitalité. La structure, la phénologie et la croissance des faisceaux des herbiers à *Posidonia oceanica* ont été étudiées dans quatre sites au niveau du centre Est de la Tunisie (Hergla, El Kantaoui, Monastir et Mahdia). La densité des faisceaux, le recouvrement et les paramètres phénologiques présentent une différence significative entre les sites et les profondeurs en relation avec l'intensité des activités humaines. Les herbiers les plus denses (441 à 984 faisceaux m^{-2}) et les indices foliaires les plus élevés (8,5 à 13m2 m^{-2})) ont été enregistrés à Mahdia. Le nombre moyen des feuilles produites annuellement ne montre pas de différence significative entre les sites et les profondeurs étudiées. La croissance du rhizome de *Posidonia oceanica* est considérablement plus importante à Mahdia et à Hergla qu'à Monastir et à El Kantaoui à l'exception des stations les moins profondes (-2m), alors que la croissance des rhizomes et la profondeur sont négativement corrélées à El Kantaoui et à Monastir. L'étude fournit de nouvelles informations sur l'état de santé actuelle des herbiers à *Posidonia oceanica* au niveau d'une aire géographique peu étudiée.

Mots clés: Phanérogames marines, *Posidonia oceanica*, densité des faisceaux, Lépidochronologie, Tunisie.

ABSTRACT

The structure, phenology and shoot growth of *Posidonia oceanica* meadows were assessed in four sites along the eastern Tunisian coast (Hergla, El Kantaoui, Monastir, Mahdia). The shoots densities, percentage of meadow cover and phenological studied parameters differed significantly between localities and depths according to human activities disturbances. *P. oceanica* developed the densest meadows (from 441 to 984 shoots m^{-2}) and the highest value of Leaf Area Index (8.5 to 13 m^2 m^{-2}) in Mahdia. There was no significant difference on the annual leaf production between the studied localities and sampling stations. Except at -2m depth, the rhizome growth was significantly greater at Mahdia and Hergla than Monastir and El Kantaoui. The rhizome growth was negatively related to the depth at El Kantaoui and Monastir. The study provides useful data on the state of health of P. oceanica in an area of the southern side of the Mediterranean Sea still for long time unknown.

Keywords: Seagrasses, *Posidonia oceanica*, Shoot density, Lepidochronology, Tunisia.

INTRODUCTION

Extensive beds of seagrasses provide valuable resources in shallow coastal waters worldwide (Short and Neckles, 1999). The endemic seagrass *Posidonia oceanica* (L.) Delile represents one of the most important primary producers of the coastal zone in the Mediterranean basin (Ott, 1980). It forms widespread meadows extending from the surface to about 40 m depth (Pérès and Picard, 1964) and covers about 2.5±5 millions of hectares of the Mediterranean (Pergent et al., 1995). P. oceanica meadows play a key role in the Mediterranean Sea, hosting very diverse animal and algal communities (Mazzella et al., 1989), and representing an important nursery grounds for several species (Francour et al., 1999; Sanchez-Jerez et al., 2000). Its role is important in the stability of coastal sediments and consequently in the protection of beaches from erosion (Blanc and Jeudy de Grissac, 1984; Jeudy de Grissac and Boudouresque, 1985). Furthermore, P. oceanica is very sensitive to disturbances (Francour et al., 1999; Ruiz and Romero, 2003). Moreover, it is considered as an excellent bioindicator (Boudouresque et al., 2000; Pergent-Martini and Pergent, 2000).

P. oceanica is very common along the Tunisian coast (Le Danois, 1925). However, as other cities in the Mediterranean Sea, the marine costal ecosystem in Tunisia is deeply affected by the loss of seagrass meadows over extensive areas during the last decades, particularly, P. oceanica meadows (Ben Mustapha et al., 1999) and has been attributed to the impact from human activities. In fact, the most damaging impacts are industrial and domestic effluents and shoreline constructions enhancing an increase of nutrients and organic matter load and an imbalance in the sediment budget (Pergent and Kempf, 1993; Ben Mustapha et al., 1999) with direct aggressions as results from illegal trawling on those meadows (Ben Mustapha et al., 1999)

The status of *P. oceanica* meadows along the eastern Tunisian coasts is still poorly known; the aim of the present study is to evaluate the health status of four Tunisian P. oceanica meadows using structural, morphological and shoot growth parameters in order to detect differences among the meadows at different depths and potentially subjected to anthropogenic impact.

MATERIAL AND METHODS

Study site and sampling procedures

Study was conducted by scuba diving in October 2004 in four meadows along the eastern coast of Tunisia: Hergla, El Kantaoui, Monastir and Madhia. Three stations were selected at each meadow in the following depths: -2, -5 and -10m (Fig. 1, Table I).

Hergla is a coastal village, with a small coastal port (3.2 ha) constructed in 1984 and an offshore tuna farm installed in 2003 (Hattour, 2005). The farm produces 400-700 tons of fish per year and is situated at approximately 2.7 MN from the shore over a bottom depth of 40 m.

El Kantaoui is among the most attractive touristic resort in Tunisia with many touristic plants (more than 15 hotels) and a busy marina (4 ha) established in 1979 accommodating about 340 boats of different categories. In 1993, a seawage was built at 2 km South of the sampling site. The facility includes physical, chemical and biological processes to treat domestic effluents produced by a population of 100000 equivalent inhabitants (reaching 140000 during summer due to the increase of the touristic activities due to the presence of tourists). The seawage is located at 0.8 MN from the coast and at 14 m depth. The estimated outflow is about 0.3 m3 s-1, fluctuated varies according to the season; the suspended particulate matter concentration is 40 mg l-1 and a high concentration of organic carbon (more than 291mg g-1) and micropollution was detected in the sediment near the water treatment plant (Pavoni et al., 2000).

Monastir is a coastal touristic city with a marina built in 1980 accommodating 440 boats in a 4 ha marina and a fishing port (8 ha) built in 1984, 1.45 MN south of the marina.

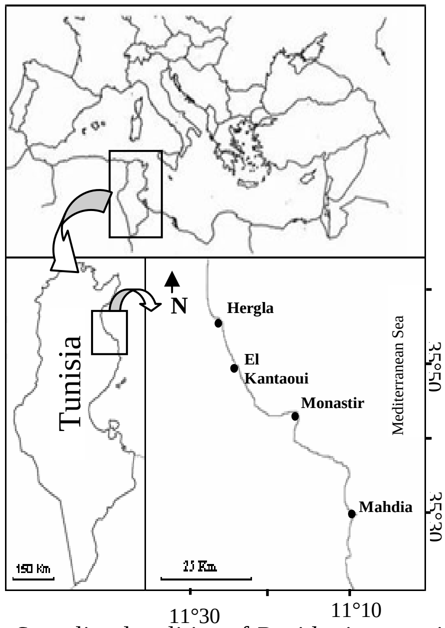

Figure 1. Sampling localities of *Posidonia oceanica* meadows.

Mahdia is a coastal tourist city with an important fishing port (9.75 ha) established in 1967 and some protected archaeological vestiges.

Shoot density was estimated *in situ* at each station by counting the number of shoots present in a 40 cm x 40 cm quadrat with ten replicates. Percentage cover was estimated using 1 m^2 quadrat (divided into four 0.5m x 0.5m squares) with three replicates. Twenty *P. oceanica* orthotropic rhizomes were sampled at random in each station for laboratory analysis.

Morphological and biometrical data

Leaf length and width were measured According to Giraud (1979), leaves were detached from each shoot and their length and width were measured to be divided in the following categories: adult leaves (length greater than 50 mm with sheath), intermediate leaves (length

Table I. *Posidonia oceanica*: features of sampling stations, sediment type, meadow type and potential stress resources (He: Hergla; EK: El Kantaoui; Mo: Monastir; Ma: Mahdia).

		GPS location				
	Depth (m)	**N**	**E**	**Sediment type**	**Meadow type**	**Potential stress**
He	2	36° 02' 165"	10° 30' 595"	Sand	Barrier reef, presence of micro-atoll	Offshore tuna farm
	5	36° 02' 226"	10° 30' 654"	Sand	Undulating meadow	Coastal port
	10	36° 02' 596"	10° 30' 877"	Sand	Continuous meadow	
EK	2	35° 53' 606"	10° 36' 052"	Sand	Continuous meadow, presence of dead matte	Marina
	5	35° 53' 912"	10° 36' 540"	Sand	Continuous meadow	Coastal constructions
	10	35° 53' 920"	10° 36' 556"	Sand	Continuous meadow	Water treatment plant
Mo	2	35° 47' 194"	10° 49' 593"	Sand	Continuous meadow	Marina
	5	35° 47' 182"	10° 50' 080"	Sand	Continuous meadow	Coastal constructions
	10	35° 47' 199"	10° 50' 520"	Sand	Continuous meadow	Sea port
Ma	2	35° 30' 500"	11° 04' 979"	rock	Continuous meadow	Coastal constructions
	5	35° 30' 640"	11° 04' 481"	Sand	Continuous meadow	Sea port
	10	35° 30' 485"	11° 04' 258"	Sand	Continuous meadow	

greater than 50 mm without sheath) and juvenile leaves (length less than 50 mm without sheath).

Two leaf indices were calculated:

• The *leaf Area Index*, which corresponds to the leaf surface area for 1 m2 meadows (in m2 m-2);

• The *coefficient A*, which indicates the number of leaves having lost their apex (due to grazing by herbivores or due to hydrodynamic action).

The epiphytic biomass was estimated after scraping epiphytes from the leaves using a razor blade. Then, epiphytes were dried in an oven at 70°C for 48 h and weighed. The scraped leaves were then dried at 70°C for 48 h and weighed (± 0.1 mg) in order to estimate mean shoot dry weight.

The annual rhizome growth (cm year-1) and the leaf formation rate (number of leaves year-1) were determined for the last decade (1994-2003) following the standardized procedure of lepidochronology analysis (Pergent and Pergent-Martini, 1991; Pergent et al., 1995).

Statistical analysis

The two-way ANOVA was performed for the meadows (four levels, random) and depths (three levels, orthogonal to meadows) for the variables (shoot density, number of adult leaves per shoot, number of intermediate leaves per shoot, number of juvenile leaves per shoot, mean adult leaf length, mean adult leaf width, Leaf Area Index, coefficient A, shoot biomass, epiphyte weight, annual leaf production and rhizome growth). For significant difference among variables were analyzed with Tukey's multiple comparison tests to determine which variables were significantly different. Data were tested for normality and homogeneity of variance by Kolmogorov-Smirnov test (Sokal and Rohlf, 1981) to meet the assumptions for parametric statistics.

RESULTS

Structural, morphological and shoot growth parameters of *P. oceanica* of the four Tunisian meadows are presented in Table II. Data on shoot density and meadow cover differed significantly among localities and depths. El Kantaoui showed the lowest densities and cover.

Number of adult, intermediate and juvenile leaves per shoot differed significantly between localities with less than three photosynthetically active leaves per shoot at -10 m at El Kantaoui (2.8 ± 0.4 leaves per shoot).

The number of intermediate leaves was significantly lower at El Kantaoui meadow, as opposed to the number of juvenile ones, the most abundant.

Significant differences were found in adult leaves length and width both between localities and depth (Table III). El Kantaoui and Monastir meadows showed the shortest adult leaf length while Mahdia exhibited the longest one, except at -2m depth (Table III).

The leaf width decreased with the depth at El Kantaoui and increased at Mahdia. El Kantaoui and Monastir showed the widest leaves at -2m.

The LAI differed significantly between localities and depth; indeed, a significant interaction between localities and depth was observed. LAI was significantly low at El Kantaoui, the highest value was recorded at Mahdia meadows at the three depths (Table IV). Coefficient A showed difference among localities, with Monastir showing less damaged leaves (Table IV).

The shoot biomass and epiphyte weight per shoot showed differences both among localities and depth (Table IV). Mahdia exhibited the highest values of shoot biomass at -5m and -10m and El Kantaoui the lowest one and at - 2m. Hergla showed the highest shoot biomass and Monastir the lowest shoot biomass.

The highest epiphytic biomass was recorded at El Kantaoui whereas the lowest one was observed at Mahdia. No significant differences were found in annual leaf production among localities or depths.

Rhizome growth showed significant differences among localities (Table IV). Mahdia and Hergla had rhizome growing faster than Monastir and El Kantaoui.

DISCUSSION

Data on structure, morphology and shoot growth of *P. oceanica* along the eastern Tunisian coast have been lacking until now except of scarce studies (El Asmi-Djellouli ., 2004; Pergent and Zaouali, 1992; Pergent and Pergent-Martini, 1990).

Particular and rare structures of *P. oceanica* were observed in the upper limit of Hergla. These more or less circular spot of *P. oceanica* in very shallow water were called 'micro-atolls'. These particulars structures can be linked to hydrodynamic action, currents and/or water temperature (Boudouresque et al., 2006). Micro-atolls have been also found in four sites in the Mediterranean Sea, Turkey (Boudouresque et al., 1990), Marsala (western Sicily) (Calvo and Fradà-Orestano, 1984), Saint-Florent (Corsica) (Pasqualini et al., 1995), Bibane Lagoon (Riveill et al., 2006) and Ain Al-Ghazala (Libya) (Pergent et al., 2007).

According to the grading scale of Pergent et al. (1995), El Kantaoui meadow, which exhibited the lowest densities, should be qualified as abnormal. Monastir meadow, also with low shoot densities, is considered therefore from abnormal to subnormal. Hergla values range from subnormal to normal, whereas Mahdia, with the highest values, is considered as normal. *P. oceanica* meadows of Mahdia -2m, characterised by the highest density, could be the result of a different substrate (Zakhama and Charfi, 2005). In fact, rocky substrate can affect the morphological and growing variables of seagrass (Marbà and Duarte, 1997; Mils and Fonseca, 2003; Peirano et al., 2005; Di Carlo et al., 2006). The lowest density and meadow cover were recorded at El Kantaoui was probably related to pollution situation as demonstrated by the high concentration of organic carbon and micropollution detected in the sediment layer (Pavoni et al., 2000). These conditions could affect negatively the growth and survival of seagrass species (Terrados et al., 1999).

Table II. *P. oceanica* health parameters recorded in the four sampling localities at 2, 5 and 10 m of depth.

	-2m				-5m				-10m			
	He	**EK**	**Mo**	**Ma**	**He**	**EK**	**Mo**	**Ma**	**He**	**EK**	**Mo**	**Ma**
Cover (%)	95 ± 1,9	50 ± 8,5	75 ± 6,1	95± 3,7	80 ± 6,4	70 ± 11,8	75 ± 11,8	90 ± 5,3	60 ± 7,3	25 ± 7,5	50 ± 6	85 ± 9,3
Shoot density (shoot m^{-2})	631 ± 16	388 ± 42	456 ± 33	894 ± 160	496 ± 29	362 ± 14	402 ± 22	487 ± 40	267 ± 15	144 ± 20	221 ± 16	441 ± 61
Number of adult leaves per shoot	2.7 ± 0.3	2.8 ± 0.3	2.4 ± 0.5	3.4 ± 0.3	3 ± 0.4	2.7 ± 0.3	2.4 ± 0.3	3.7 ± 0.3	3 ± 0.4	2.4 ± 0.3	2.9 ± 0.2	3.7 ± 0.3
Number of intermediate leaves per shoot	2.2 ± 0.3	1 ± 0.2	3.1 ± 0.2	2.5 ± 0.5	2.1 ± 0.4	1.5 ± 0.3	2.6 ± 0.2	2.0 ± 0.2	1.8 ± 0.3	0.4 ± 0.3	2.7 ± 0.4	1.8 ± 0.3
Number of juvenile leaves per shoot	1.4 ± 0.2	2.7 ± 0.2	0.4 ± 0.2	1.0 ± 0.4	1 ± 0.2	2.2 ± 0.2	0.9 ± 0.2	0.7 ± 0.4	1.5 ± 0.4	2.5 ± 0.3	0.9 ± 0.3	0.7 ± 0.4
Mean adult leaf length (mm)	347 ± 26	242 ± 29	253 ± 17	294 ± 22	379 ± 36	159 ± 13	242 ± 12	418 ± 37	301 ± 43	200 ± 29	245 ± 22	607 ± 61
Mean adult leaf wide (mm)	9.5 ± 0.1	11 ± 0.2	10.5 ± 0.3	8 ± 0.2	9.4 ± 0.1	9.5 ± 0.1	9.5 ± 0.2	9 ± 0.1	9.7 ± 0.2	9.3 ± 0.3	10.3 ± 0.3	9.7 ± 0.3
Leaf Area Index (m^2 m^{-2})	7.8 ± 0.2	3.8 ± 0.4	4 ± 0.1	11 ± 1.4	7.2 ± 0.4	2.1 ± 0.1	2.2 ± 0.1	8.5 ± 0.5	2.6 ± 0.1	0.7 ± 0.1	1.9 ± 0.1	13 ± 1.3
Coefficient A (%)	40.7	60.8	28	70	42.3	51.5	34.8	46	48	60	26	41
Shoot biomass (g per shoot)	0.6 ± 0.03	0.4 ± 0.03	0.3 ± 0.1	0.5 ± 0.1	0.8 ± 0.04	0.25 ± 0.03	0.3 ± 0.03	0.9 ± 0.05	0.5 ± 0.03	0.25 ± 0.02	0.35 ± 0.05	1.4 ± 0.2
Epiphyte weight (mg cm^{-2})	2.5 ± 0.2	5.66 ± 0.8	1.7 ± 0.1	0.31 ± 0.1	1.4 ± 0.5	2.7 ± 0.3	0.3 ± 0.03	0.26 ± 0.01	1.6 ± 0.1	3.3 ± 0.5	0.8 ± 0.1	0.5 ± 0.06
Annual leaf production (leaves year-1)	7.3 ± 0.5	6.8 ± 0.4	7.7 ± 0.3	7.7 ± 0.3	7.5 ± 0.4	7.7 ± 0.3	7.1 ± 0.2	7.5 ± 0.4	7.8 ± 0.3	6.9 ± 0.5	7 ± 0.4	7.4 ± 0.8
Mean rhizome growth (mm year-1)	6.5 ± 0.5	6.1 ± 0.6	7.2 ± 0.6	6.1 ± 0.5	9.4 ± 1.4	4.2 ± 0.7	5.4 ± 0.5	7.7 ± 2.16	7.6 ± 0.3	3.8 ± 0.5	4.5 ± 0.4	8.1 ± 1.3

Table III. Results of two-way ANOVA (fixed factors: locality (four levels, random) and depths (three levels, orthogonal to depth)) using data of cover, shoot density, number of adult leaves per shoot, number of intermediate leaves per shoot, number of juvenile leaves per shoot, mean adult leaf length and mean adult leaf width. Tukey's HSD post hoc comparisons with respect to the depths are showed in the bottom.

		Cover	**Shoot density**	**Number of adult leaves**	**Number of intermediate leaves**	**Number of juvenile leaves**	**Adult leaf length**	**Leaf wide**
Source of variation	d.f.				P			
Locality (L)	3	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Depth (D)	2	< 0.0001	< 0.0001	0.708	< 0.0001	0.024	< 0.0001	< 0.0001
(L x D)	6	< 0.0001	< 0.0001	0.229	0.008	0.010	< 0.0001	< 0.0001
Tukey test (Depth)	2m	(He=Ma)**>Mo**>EK	Ma**>He**>Mo**=EK	Ma=Ek; EK=He=Mo; Ma**>(He.Mo)	Mo*>Ma**=He**>EK	EK**>Ma*>He**>Mo	He**>(Ma=Mo=EK)	EK**>Mo**>He**>Ma
	5m	He=Ma=Me=EK	He=Ma**>Mo*>EK	Ma**>(He=Ek=Mo)	Mo=Ma=He**>EK	EK*>(Ma=He=Mo)	Ma**>He**>(Mo=EK)	(EK. He. Mo)**>Ma
	10 m	Ma**>(He=Mo)** >EK	Ma**>He**>Mo**>EK	Ma=He=Mo. Mo=EK; (Ma=He)**>EK	Mo**>Ma**=He**>EK	EK*>He*>(Ma=Mo)	Ma**>He**>(Mo=EK)	(Ma=He=EK); Mo*>EK

(*p<0.05, **p<0.01)

Table IV. Results of two-way ANOVA (fixed factors: locality (four levels, random) and depths (three levels, orthogonal to locality)) using data of Leaf Area Index, coefficient A, shoot biomass, epiphyte weight, annual leaf production and rhizome growth. Tukey's HSD post hoc comparisons with respect to the depths are showed in the bottom.

		Leaf Area Index	**Coefficient A**	**Shoot biomass**	**Epiphyte weight per shoot**	**Annual leaf production**	**Rhizome growth**
Source of variation	d.f.	P					
Locality (L)	3	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.3227	< 0.0001
Depth (D)	2	< 0.0001	0.377	< 0.0001	< 0.0001	0.6594	0.1362
(L x D)	6	< 0.0001	0.001	< 0.0001	< 0.0001	0.0348	0.0002
Tukey test (Depth)	2m	Ma**>He**>(Mo=EK)	(Ma= EK)**>He*>Mo	He**>Ma*>EK**>Mo	EK**>He**>Mo**>Ma	n.s	Mo=EK=Ma=He
	5m	Ma**>He**>(Mo=EK)	EK=Ma=He=Mo	Ma**>He**>(Mo=EK)	EK**>He**>(Mo=Ma)	n.s	(He=Ma)*>(Mo=EK)
	10m	Ma**>(He=Mo)**>EK	EK**>(Ma=He)**>Mo	Ma**>He**>(Mo=EK)	EK**>He**>(Mo=Ma)	n.s	(He=Ma)**>(Mo=EK)

(*p<0.05, **p<0.01)

A reduce mean number of intermediate leaves associated with a high juvenile ones was observed at El Kantaoui. This has been recorded in Italian meadows exposed to urban and industrial wastes (Balestri et al., 2004); the authors argued that high intermediate leaves numbers could be the result of an overproduction related to physiological plant responses under stressful conditions.

The short leaves of El Kantaoui meadows could be the result of pollution due to human activities (Short et al., 1995). Similar results were recorded near urban emissaries (Maggi et al., 1977) or fishing structures (Delgado et al., 1999; Ruiz et al., 2001). A second hypothesis may be suggested concerning the reduction of leaves size by mechanical action. In fact, the epiphytic development may (i) make the leaf apex more fragile, leading to an increased breakage and thus to a reduction in leaf length (Harlin, 1980), and (ii) generate an increase in grazing (Leoni et al., 2006; Alcoverro et al., 1997). This is argued by the coefficient A found at El Kantaoui.

The important leaf width at El Kantaoui and Monastir at -2m depth could be explained by the combined effect of the nutrient enrichment and turbidity (Pergent-Martini et al., 1996).

Moreover, the highest value of epiphyte biomass at El Kantaoui is probably due to the eutrophic environment (Dimech et al., 2002; Cancemi et al., 2003) induced by the water treatment plant (Piazzi et al. 2004). The extensive development of epiphytic organisms on the leaves of seagrasses represents a source of disturbance to the plants, limiting the quantity of light available thus of photosynthesis (Sand-Jensen, 1977; Ben Brahim et al., 2010).

Concerning lepidochronolocial approach, our results indicate differences between localities in terms of mean rhizomes growth. According to Pergent et al. (1995), the annual rhizomes growths pass from normal to subnormal at El Kantaoui and Monastir. However, Hergla and Mahdia are respectively considered as normal to subnormal and normal. Differences in the rhizome growth rate could be influenced by the several local factors, which ranges from wave exposure (Guidetti et al., 2000) and substrate nature (Marbà and Duarte, 1997; Peirano et al., 2005) to the degree of anthropogenic disturbance (Cancemi et al., 2003; Balestri et al., 2004).

As regards to the annual leaf production, Guidetti, (2001) identified a pulse reduction in mean number of leaves per shoot on *P. oceanica* decreasing nearly 20% immediately after a disturbance (the replenishment of a beach with terrigenous materials) compared to periods before the disturbance. But, at last in our case, no difference on mean production of leaves was observed between meadows; according to Pergent-Martini et al. (1999), all the meadows present normal values.

To conclude, several studies highlighted the sensitivity of *P. oceanica* to different human activities (Ruiz and Romero, 2003; Balestri et al., 2004; Gonzalez-Correa et al., 2005). The different health status observed point out to different level of disturbance along the coast. The meadow of El Kantaoui is clearly the worst of the four studied sites due to high disturbances as a result of coastal constructions (water treatment plant, marina). Mahdia meadow shows the best vitality of all the studied meadows. However, the results obtained at Hergla and Monastir meadows indicated that those meadows could be somewhat worst than expected.

Our results assess the health status of *P. oceanica* along the eastern coast of Tunisia and can be very useful to evaluate the average meadow status over the time and to monitor their feed back as results of levels of environmental changes.

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