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STATUS OF *POSIDONIA OCEANICA* MEADOWS ALONG THE EASTERN COAST OF TUNISIA

Abstract

Posidonia oceanica *meadows at four sites along the eastern Tunisian coast (Hergla, El Kantaoui, Monastir, Mahdia) were sampled at three depths (-2, -5 and -10 m) between June and October 2004. They were compared by means of shoot density and biomass measurements as well as morphological and lepidochronological observations. The status of the seagrass was examined in view of local stresses, coastal constructions, fish farming and other anthropogenic impacts. Shoot density and lepidochronology showed a tendency towards degeneration of the meadows exposed to high levels of anthropogenic impacts (El Kantaoui, Monastir and Hergla). The Mahdia meadow displayed the highest values of shoot density and rhizome growth whereas El Kantaoui appeared to be the most stressed site exhibiting the lowest rhizome growth and shoot density values. Leaf and epiphyte biomasses of* P. oceanica *were related to the status of the meadow and anthropogenic disturbances. The El Kantaoui meadow exhibited an epiphyte biomass higher than leaf biomass and showed a trend towards degradation. A cluster analysis of similarity, taking into account all these parameters, allowed identification of three main groups of sites according to the degree of anthropogenic disturbance.*

Key-words: Posidonia oceanica*, anthropogenic disturbance, shoot density, lepidochronology, Tunisia.*

Introduction

Meadows of *Posidonia oceanica*, a marine phanerogam endemic to the Mediterranean Sea, are used as a bio-indicator for coastal water quality and as a quality element under the European Water Framework Directive (Romero *et al.*, 2005). Although widespread along the Tunisian coast, these meadows are particularly sensitive to pollution and to the impact of human activity.

P. oceanica beds in Tunisia have been the object of relatively few and scattered studies (Ben Mustapha and Hattour, 1992; Djellouli-Al Asmi, 2004; Zakhama and Charfi, 2005), compared to the studies in the Gabes Gulf (Ramos-Espla *et al.*, 2000; Ben Mustapha *et al.*, 2002a; 2002b). Le Danois (1925) was the first author to record the presence of *P. oceanica* on the eastern coast of Tunisia. A more complete description of this seagrass is in Ben Mustapha and Hattour study (1992) describing the *P. oceanica* beds in this area as in good health status.

The aims of our study were: a) to update the distribution of *P. oceanica* along the eastern coast of Tunisia; b) to assess the vitality of the meadows using phenological and lepidochronological approaches and c) to classify the meadows investigated according to their "ecological status."

Materials and methods

Posidonia oceanica orthotropic rhizomes were sampled by SCUBA diving in October 2004 in four meadows along the eastern coast of Tunisia: Hergla, El

Kantaoui, Monastir and Madhia (Fig. 1). Hergla (36°02'165"N, 10°30'595"E) is a small coastal village, with a traditional fishing port, a fish farm and an offshore tuna farm. El Kantaoui (35°53'606"N, 10°30'052"E) is among the most attractive tourist cities in Tunisia with many popular developments and a marina. A drainage channel, located at Hammam Sousse, occurs 3 km south of the El Kantaoui sampling site. Monastir (35°47'266"N, 10°49'963"E) is also a coastal tourist city with a marina and a fishing port. Finally, Mahdia (35°30'500"N, 11°04'979"E) is a coastal tourist city with an important fishing port and archaeological vestiges. sampling was performed near the archeological site.

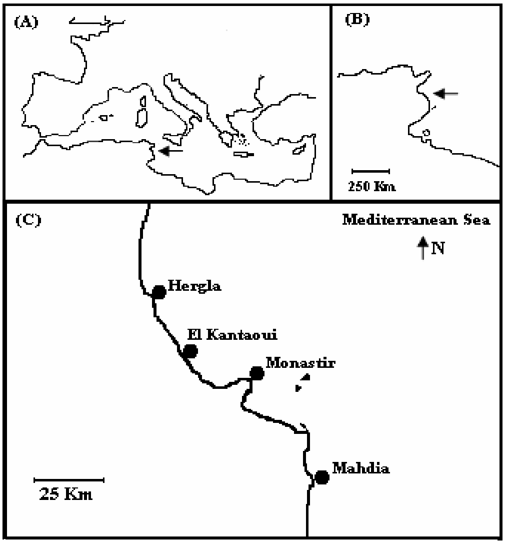

Fig. 1 - Map showing Tunisia location (A), the study area (B), and (C) the four *P. oceanica* meadows sampled.

Three stations were selected at each site at depths of -2, -5 and -10 m in order to assess the seagrass quality; shoot density was estimated *in situ* at each station by counting the number of shoots present in a 40x40 cm quadrat with ten replicates. Twenty rhizomes were collected at each station.

In the laboratory, *P. oceanica* morphometric parameters were estimated by 1) separating the leaves from the rhizomes 2) classifying them according to Giraud's (1979) classification as 'adult', 'intermediate' or 'juvenile' and 3) counting the number of leaves belonging to each class. Leaf widths and lengths (±1 mm) were recorded for the different leaf categories. The Leaf Area Index (LAI) and the Coefficient A (a percent of broken leaves) were estimated for each station. The epiphytic biomass was estimated by scraping epiphytes from the leaves using a blunt blade and weighing after drying in an oven at 70 °C for 48 h. The scraped leaves were also dried at 70 °C for 48 h and weighed (± 0.1 mg) to estimate mean shoot dry weight at each station. The annual rhizome elongation (cm year^{-1}) and leaf formation rate (number of leaves year^{-1}) were determined following the standardized procedure of the lepidochronological analysis (Pergent *et al.*, 1995). For each rhizome, dead sheaths were detached starting from the older to the more recent ones (near the living tissue) and the thickness of each sheath was measured

Tab. 1 - Shoot density, number of leaves per shoot, 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, mean leaf length (intermediate), leaf area index (m^2 m^{-2}), coefficient A, shoot biomass, epiphyte weight, mean number of leaves per year, and mean rhizome growth, in four Tunisian *Posidonia oceanica* meadows.

	-2m				-5m				-10m			
	El Kantaoui	Monastir	Hergla	Mahdia	El Kantaoui	Monastir	Hergla	Mahdia	El Kantaoui	Monastir	Hergla	Mahdia
Density	388 ± 41.6	456 ± 32.8	631 ± 16.3	984 ± 160	362 ± 14.3	402 ± 21.6	496 ± 29	487 ± 40.3	144 ± 20.5	221 ± 16.1	267 ± 15.1	441 ± 61.2
Number of leaves per shoot	3.8 ± 0.3	5.5 ± 0.5	4.9 ± 0.5	5.0 ± 0.6	4.1 ± 0.4	4.9 ± 0.3	5.1 ± 0.6	5.7 ± 0.4	2.8 ± 0.4	5.6 ± 0.6	4.8 ± 0.5	5.7 ± 0.4
Number of adult leaves per shoot	2.8 ± 0.3	2.4 ± 0.5	2.8 ± 0.3	3.2 ± 0.3	2.7 ± 0.3	2.4 ± 0.27	3 ± 0.4	3.5 ± 0.3	2.4 ± 0.3	2.9 ± 0.2	3 ± 0.4	3.5 ± 0.3
Number of Intermediate leaves per shoot	1 ± 0.2	3.1 ± 0.2	2.2 ± 0.35	2.7 ± 0.52	1.5 ± 0.3	2.6 ± 0.2	2.1 ± 0.4	2.2 ± 0.2	0.4 ± 0.3	2.7 ± 0.4	1.8 ± 0.3	1.7 ± 0.3
Number of juvenile leaves per shoot	2.7 ± 0.2	0.4 ± 0.2	1.4 ± 0.2	1.4 ± 0.4	2.2 ± 0.2	0.9 ± 0.2	1 ± 0.2	0.7 ± 0.4	2.5 ± 0.3	0.9 ± 0.3	1.5 ± 0.4	0.7 ± 0.4
Mean adult leaf length (mm)	242 ± 28.9	253.1 ± 17.5	346.6 ± 25.7	284 ± 22	158.9 ± 13.2	241.7 ± 12	379.2 ± 36.5	447.8 ± 37.3	200.3 ± 29.2	245.5 ± 22.5	301.5 ± 42.8	637.5 ± 61.5
Mean adult leaf wide (mm)	11 ± 0.2	10.5 ± 0.34	9.5 ± 0.1	7 ± 0.2	9.5 ± 0.1	9.5 ± 0.2	9.4 ± 0.1	9 ± 0.1	9.3 ± 0.3	10.35 ± 0.3	9.7 ± 0.2	9.7 ± 0.3
Mean intermediate leaf length (mm)	69.8 ± 4.7	146.6 ± 22.5	157.9 ± 20.8	281 ± 37.5	93.3 ± 9.4	125.5 ± 13.62	182.7 ± 25.1	337± 92.9	69.3 ± 7.7	130 ± 15.9	92.3 ± 10.5	451 ± 37.6
Leaf area index (m^2 m^{-2})	3.8 ± 0.4	4 ± 0.1	7.8 ± 0.2	10.5 ± 1.4	2.1 ± 0.1	2.2 ± 0.1	7.2 ± 0.4	8.2 ± 0.5	0.7 ± 0.1	1.9 ± 0. 1	2.6 ± 0.1	12.8 ± 1.3
Coefficient A	60.8%	28.0%	40.7%	70.0%	51.5%	34.8%	42.3%	46.0%	60.00%	25.64%	48.00%	41.00%
Shoot biomass (g $shoot^{-1}$)	0.4 ± 0.03	0.3 ± 0.1	0.6 ± 0.03	0.6 ± 0.1	0.25 ± 0.03	0.3 ± 0.03	0.8 ± 0.04	0.78 ± 0.05	0.25 ± 0.02	0.35 ± 0.05	0.5 ± 0.03	1.5 ± 0.2
Epiphyte weight (mg cm^{-2})	5.66 ± 0.8	1.7 ± 0.1	2.5 ± 0.2	0.25 ± 0.1	2.7 ± 0.3	0.3 ± 0.03	1.4 ± 0.5	0.25 ± 0.01	3.3 ± 0.5	0.8 ± 0.1	1.6 ± 0.1	0.45 ± 0.06
Mean number of leaves per year	6.8 ± 0.4	7.7 ± 0.3	7.3 ± 0.5	7.7 ± 0.3	7.7 ± 0.3	7.1 ± 0.2	7.5 ± 0.4	7.5 ± 0.4	6.9 ± 0.5	7 ± 0.4	7.8 ± 0.3	7.4 ± 0.8
Mean rhizome growth (mm $year^{-1}$)	6.1 ± 0.6	7.2 ± 0.6	6.5 ± 0.5	6.1 ± 0.5	4.2 ± 0.7	5.4 ± 0.5	9.4 ± 1.4	7.7 ± 2.16	3.8 ± 0.5	4.5 ± 0.4	7.6 ± 0.3	8.1 ± 1.3

microscopically. The number of leaves produced annually was derived from the mean number of leaf sheaths produced between two pairs of sheaths with minimum thickness in each shoot (lepidochronological year). The annual vertical rhizome elongation rate for each shoot was calculated as the length of the rhizome segment between the two sheaths of minimal thickness.

One-way analysis of variance (ANOVA) was used to test significant differences (0.05 level of significance) among the four meadows parameters between stations at the same depth. For the number of leaves, the Kruskal-Wallis test was used (0.05 level of significance).

Results

Morphological features of *P. oceanica* are reported in Table 1. At the same depths, shoot density in the four meadows was significantly different (ANOVA, $p < 0.05$). According to the classification of Pergent *et al.* (2005), the El Kantaoui meadow, exhibiting the lowest values, between 144 shoots m^{-2} at -10 m and 388 shoots at -2 m, is "bad." The Monastir and Hergla meadows also had low shoot densities (221 shoots m^{-2} at -10 m to 456 shoots m^{-2} at -2 m at Monastir and 267 shoots m^{-2} at -10 m to 631 shoots m^{-2} at -2 m at Hergla), and received a classification of "poor." Finally, Mahdia with the highest values (441 shoots m^{-2} at -10 m to 984 shoots m^{-2} at -2 m) was classified as "normal" and "good".

Many morphological variables had mean values significantly different between the El Kantaoui meadow and the other sites. Indeed, values of mean total number of leaves per shoot were significantly different between stations at the same depth for the four meadows (ANOVA, $p < 0.05$). The El Kantaoui meadow exhibited a low number of leaves per shoot at the three depths (Kruskal-Wallis, $p < 0.05$) and there were less than three photosynthetically active leaves per shoot at -10 m (2.8 ± 0.4 leaves per shoot). The number of intermediate leaves was significantly lower at the El Kantaoui meadow (Kruskal-Wallis, $p < 0.05$), as opposed to the juvenile leaves which were the most abundant (Table 1). Furthermore, the El Kantaoui meadow displayed the shortest adult leaf lengths while Mahdia had the longest ones (ANOVA, $p < 0.05$). El Kantaoui and Monastir had the widest leaves at -2 m (ANOVA, $p < 0.05$). Excepting Mahdia (-2 m), the El Kantaoui meadow exhibited the highest Coefficient A. The LAI as very low (from 0.7 to 3.8 m^2m^{-2}) at El Kantaoui compared with the other stations (ANOVA, $p < 0.05$). Unlike other parameters, the highest epiphytic cover was recorded at El Kantaoui whereas the lowest was observed at Mahdia (ANOVA, $p < 0.05$).

The annual leaf production was significantly different only at -2 m (ANOVA, $p < 0.05$) where EL Kantaoui had significantly low values. Rhizomes collected in the four meadows showed an overall mean growth rate of 9.4 mm $year^{-1}$. The minimum growth rate (3.8 mm $year^{-1}$) was observed at El Kantaoui at -10 m. According to Pergent-Martini *et al.* (1999), both El Kantaoui and Monastir densities at -5 and -10 m can be considered as "sub-normal."

Discussion and conclusions

Cluster analysis of similarity between all the parameters investigated showed three main groups of meadows (Fig. 2). The first includes exclusively the three stations of Madhia, characterized by high values of density, leaf length, LAI and

shoot biomass (Table 1). The Madhia meadow can be considered therefore as the site with the best health status. The second group includes the deepest stations, with very low values of all the parameters, a group with meadows classified as bad. The third cluster includes the shallow stations except Madhia and can be divided into two subgroups:
- Hergla, characterized by intermediate values of shoot density, adult leaf length, LAI, shoot biomass and high values of rhizome growth, classified as moderate.
- The second subgroup is represented by Monastir and El Kantaoui characterized by low values of all parameters, and thus classified as poor meadows.

Our study underscores differences between meadows of *P. oceanica* along the eastern coast of Tunisia. Only Madhia meadow remains in good health; the three other meadows exhibit a tendency toward regression due to increasing anthropogenic pressure. The El Kantaoui meadow is the most degraded of the four sites, with mean values of several morphological variables significantly different from those of the other localities. Examination of the main phenological parameters reveals that El Kantaoui exhibits very low vitality. Indeed, seagrass bed density values are markedly lower than those usually recorded at the three sampling depths in the other sites.

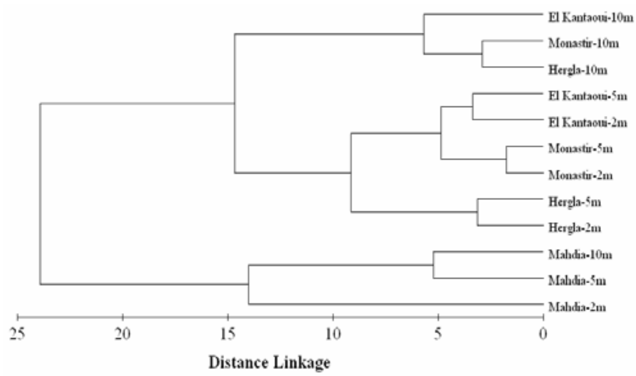

Fig. 2 - Cluster analysis of the four meadows investigated based on the similarity of all the parameters, measured through squared Euclidean distances.

The reduced mean number of intermediate leaves, associated with the high juvenile mean number of leaves at El Kantaoui has been observed in other meadows exposed to urban and industrial wastes (Balestri *et al.*, 2004). These authors argued that high intermediate shoot numbers could be the result of overproduction related to physiological responses under stressful conditions. Another hypothesis that could explain this result is a delay in *P. oceanica* leaf development and growth from the juvenile to the intermediate stage.

Leaf width was more important at El Kantaoui and Monastir at -2 m depth, and is probably a response to strong hydrodynamics (Semroud, 1993) or to a combined effect of the wealth in high nutrients and turbidity (Pergent-Martini, 1994). As for epiphyte biomass, the very high value at El Kantaoui is probably due to nutrient enrichment of the environment from urban waste (Dimech *et al.*, 2002, Cancemi *et al.*, 2003). 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 (Sand-Jensen *et al*., 1997). Abundant epiphytic cover may also help explain the greater Coefficient A in El Kantaoui (Alcoverro *et al*., 1997, Ruiz and Romero, 2003). As a whole, the distribution of *P. oceanica* along the eastern coast of Tunisia, showing a generalized state of regression, shows changes since the Ben Mustapha and Hattour study (1992). The vitality parameters of the meadows (phenological and lepidochronological approaches) show differences between localities probably due to anthropogenic disturbance. Finally, a classification of the four meadows, from poor to high quality, was established according to their "ecological status" based on several vitality parameters.

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References

ALCOVERRO T., DUARTE C.M., ROMERO J. (1997) - The influence of herbivores on *Posidonia oceanica* epiphytes. *Aquat. Bot.*, **56**: 93-104.

BALESTRI E., BENEDETTI-CECCHI L., LARDICCI C. (2004) - Variability in patterns of growth and morphology of *Posidonia oceanica* exposed to urban and industrial wastes: contrasts with two reference locations. *J. Exp. Mar. Ecol.,* **308**: 1-21.

BEN MUSTAPHA K., HATTOUR A. (1992) - Les herbiers de Posidonie du littoral tunisien: 1- le Golfe de Hammamet. *Notes Inst. Nat. Scient. Techn. Océanogr. Pêche Salammbô*, n.s., **2**: 43pp.

BEN MUSTAPHA K., KOMATSU T., SAMMARI C., HATTOUR A., ZARROUK S., EL ABED A. (2002a) - *Posidonia oceanica* L. (Delile) meadow from Messioua bank (Tunisia). *Bull. Inst. Nat. Scien. Tech. Mer de Salammbô*, **29**: 37-40.

BEN MUSTAPHA K., KOMATSU T., HATTOUR A., SAMMARI CH., ZARROUK S., SOUISSI A., EL ABED A. (2002b) - Tunisian megabenthos from infra (*Posidonia* meadows) and circalittoral (Coralligenous) sites. *Bull. Inst. Nat. Scien. Tech. Mer de Salammbô*, **29**: 23-36.

BOUDOURESQUE C.F., MEINESZ A. (1982) - Découverte de l'herbier de Posidonie. *Trav. Scient. Parc Nat. Port-Cros*, **4**: 79pp.

CANCEMI, G., DE FALCO, G., PERGENT, G. (2003) - Effects of organic matter input from a fish farming facility on a *Posidonia oceanica* meadow. *Estuar. Coast. Shelf Scie*., **56**: 961-968.

DJELLOULI-EL ASMI Z. (2004) - Effets de l'herbier à *Posidonia oceanica* sur la dynamique marine et sedimentologique littorale dans la baie de Monastir. Thèse Doctorat en Géologie, Faculté des Sciences de Tunis: 185 pp.

DIMECH M., BORG J.A., SCHEMBRI P.J. (2002) - Changes in the structure of *Posidonia oceanica* meadow and in the diversity of associated decapod, mollusc and echinoderm assemblages, resulting from inputs of waste from a marine fish farm (Malta Central Mediterranean). *Bull. Mar. Scie.*, **71** (3): 1309-1321.

GIRAUD G. (1977) - Contribution à la description et à la phénologie quantitative des herbiers à *Posidonia oceanica* (L.) Delile. Thèse Doctorat 3ème Cycle, Univ. Aix-Marseille II., 150.

LE DANOIS E. (1925) - Recherches sur les fonds chalutables des côtes de la Tunisie (croisières du chalutier « Tanche » en 1924). *Ann. Sta. Océanogr. Salammbô*, **1** 1-56.

PERGENT G., PERGENT-MARTINI C., BOUDERESQUE C.F. (1995) - Utilisation de l'herbier à *Posidonia oceanica* comme indicateur de la qualité du milieu littoral en Méditerranée: état de connaissance. *Mésogée*, **54**: 3-27.

PERGENT-MARTINI C., PERGENT G., FERNANDEZ C., FERRART L. (1999) - Value and use of *Posidonia oceanica* as a biological indicator. *In:* Ozhan E. (ed), Proceedings MEDCOST 99 – EMECS 99 Joint Conference " Land-ocean interactions: managing costal ecosystems ", MEDCOST, Middle East Technical Univ. Publ., Ankara, **1**: 73-90.

PERGENT G., CLABAUT P., MIMAULT B., PASQUALINI V., PERGENT-MARTINI C. (2005) - Mise en œuvre d'un Réseau de Surveillance Posidonies le long du littoral de la Corse. Deuxième phase : Porto-Vecchio / Ajaccio. Contrat Office de l'Environnement de la Corse et GIS Posidonie Centre de Corse, GIS Posidonie Publ., Cort : 1-133.

PERGENT-MARTINI C. (1994) - Impact d'un rejet d'eaux usées urbaines sur l'herbier à *Posidonia oceanica,* avant et après la mise en service d'une station d'épuration. Thèse Doctoract Univ. Corse. 190pp.

RAMOS-ESPLA A.A., OUERGUI A., BAYLE J.T., BEN MBAREK N., FERNANDEZ-TORQUEMADA Y., CUALLOUZ S., KHIDRI R., SANCHEZ-LIZASO J.L., YAMAK S. (2000) - Contribution à la caractérisation des herbiers à *Posidonia oceanica* (L.) Delile aux îles Kerkennah. *Actes du premier symposium méditerranéen sur la végétation marine*, *Mednature*: 177-181.

ROMERO J., ALCOVERRO T., MARTÍNEZ-CREGO B., PÉREZ M. (2005) - The seagrass *Posidonia oceanica* as a quality element under the Water Framework Directive: POMI, a multivariate method to assess ecological status of Catalan coastal waters. Working document of the POMI group, University of Barcelona and Centre d'Estudis Avançats de Blanes (CSIC).

RUIZ J.M., ROMERO J. (2003) - Effects of disturbances caused by coastal constructions on spatial structure, growth dynamics and photosynthesis of the seagrass *Posidonia oceanica*. *Mar. Pollut. Bull*, **46**: 1523-1533.

SAND JENSEN K. (1997) - Effect of epiphytes on eelgrass photosynthesis. *Aquat. Bot.*, **3**: 55–63.

SEMROUD R. (1993) - *Contribution à la connaissance de l'écosystème à* Posidonia oceanica *(L.) Delile dans la région d'Alger (Algérie). Etude de quelques compartiments*. Thèse Océanographie, Université des sciences et de la technologie Houari Boumédienne, Alger: 218pp.

ZAKHAMA R., CHARFI F. (2005) - Contribution à l'étude des caractéristiques de l'herbier de *Posidonia oceanica* (L.) Delile de Mahdia. *Bull. Inst. Nat. Sci. Tech. de la mer*, numéro spécial **9**: 155-158.

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