

# Nutrient impact on *Posidonia oceanica* seagrass meadows : preliminary data

*Impact des nutriments sur les herbiers à Posidonia oceanica :  
données préliminaires*

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## ABSTRACT

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Over the last decades, massive declines of *Posidonia oceanica* meadows have been observed in the vicinity of major urban and industrial centres. These declines have often been attributed to turbidity and the effects of chemical pollutants (hydrocarbons, PCB's, heavy metals, etc). The effect of nutrients, however, has rarely been considered despite their overall increasing concentrations within the environment. In order to estimate the impact of nutrients on *Posidonia oceanica*, measurements of seagrass meadow densities were performed at a site exposed to intensive human pressure (Plateau des Chèvres, Marseille). It would appear that there exists a relationship between the distribution of *Posidonia oceanica* shoots (e.g. patchiness) and the levels of certain nutrients (e.g. ammonium, nitrites). In addition, artificial fertilization experiments were also carried out at an oligotrophic site (Bay of Calvi - Corsica) in order to assess the possible impact of massive inputs of fertilizer (N, P, K) on *Posidonia oceanica*. It was observed that the addition of these nutrients had a negative impact on the growth of *Posidonia oceanica* and, in some cases, resulted in the death of the leaf shoots. Plant-epiphyte competition may be the cause of this mortality.

## RÉSUMÉ

Pergent-Martini C., V. Rico-Raimondino, G. Pergent, 1995 - [Impact des nutriments sur les herbiers à *Posidonia oceanica* : données préliminaires]. Mar. Life, 5 (2) : 3 - 9.

Depuis de nombreuses années les herbiers à *Posidonia oceanica* présentent des régressions massives à proximité des grands centres urbains et industriels. L'origine de ces régressions a souvent été imputée à la turbidité ou à l'action de polluants chimiques (hydrocarbures, PCB, métaux lourds...). En revanche, l'action des nutriments a rarement été prise en compte, et ce, malgré l'augmentation générale de leur concentration dans le milieu. Aussi afin d'estimer l'impact des nutriments sur l'herbier à *Posidonia oceanica*, des mesures de densité d'herbier et de concentrations du sédiment en nutriments sont effectuées dans une station anthropisée (Plateau des Chèvres, Marseille). Il semble qu'il y a une relation entre la répartition des faisceaux de *Posidonia oceanica* (par ex., patchiness) et les teneurs de certains nutriments (par ex., Ammonium, Nitrites). En complément des essais de fertilisations artificielles sont réalisés dans un secteur oligotrophe (Baie de Calvi - Corse) de manière à rechercher l'impact éventuel d'un apport massif de fertilisants (N, P, K) sur *Posidonia oceanica*. Ces ajouts se sont traduits par un effet négatif sur la croissance de *Posidonia oceanica* pouvant même entraîner la mort des faisceaux foliaires. Un phénomène de compétition plante-épiphyte semble être à l'origine de cette mortalité.

## INTRODUCTION

Leaf production in *Posidonia oceanica* (L.) Delile, a phanerogam endemic to the Mediterranean, exhibits substantial variability within the Mediterranean basin. Although annual foliar production for this species ranges between 1.8 and 2.5 g dry weight per shoot in Spain and along the continental French coasts (Bedhomme et al., 1983; Romero, 1989), this production drops to 0.7 g dry weight per shoot per year in Sardinian waters (Pergent-Martini et al., 1994). These variations in the level of production are statistically different depending on the site examined (Pergent-Martini et al., 1994). In addition, for a given station, *Posidonia oceanica* shoot densities (number of shoots per m<sup>2</sup>) exhibit a certain degree of heterogeneity despite the apparent homogeneity of the environmental conditions.

Similar observations have been recorded for other phanerogams and would seem to be related to the nutrient concentrations within the environment (Kenworthy et al., 1982; Romero-Martinengo, 1985; Powell et al., 1989). The input of nutrients (balanced N, P, K) to cultures of *Zostera marina* Linnaeus plantlets was seen to enhance the lengthening of the leaves and to bring about an increase in the number of shoots (Roberts et al., 1984). Similarly, *in situ* nutrient enrichments (N and P) of the sediment in *Heterozostera tasmanica* Martens ex Aschers.

seagrass meadows was seen to have repercussions on foliar biomass and densities (Bulthuis, Woelkerling, 1981). It would therefore be of interest to verify the existence of similar phenomena for *Posidonia oceanica*. To this end, density measurements were taken together with nutrient levels present in the sediment at a site where nutrient availability is high (anthropogenic area). *In situ* fertilizations were also carried out in an oligotrophic environment in order to determine the effect of massive nutrient inputs.

## MATERIAL AND METHODS

The density and nutrient level measurements were taken in proximity to the sewage outlet of the city of Marseille (Cortiou), at the level of the Plateau des Chèvres and at a depth of -10 m. The *in situ* fertilizations were performed in Corsica, in the Bay of Calvi (La Revellata), at the same depth as above (figure 1).

Density measurements were performed in June and December by using a 35 cm quadrat. For each seagrass bed type (table I), three sediment core samples were taken and placed on ice for transport to the laboratory. The core samples were sliced into three layers: 0 - 2 cm; 2 - 4 cm; 4 - 10 cm. Following extraction with KCl, the nitrate and ammonium levels were determined using the colorimetric/staining techniques of Bendschneider, Robinson

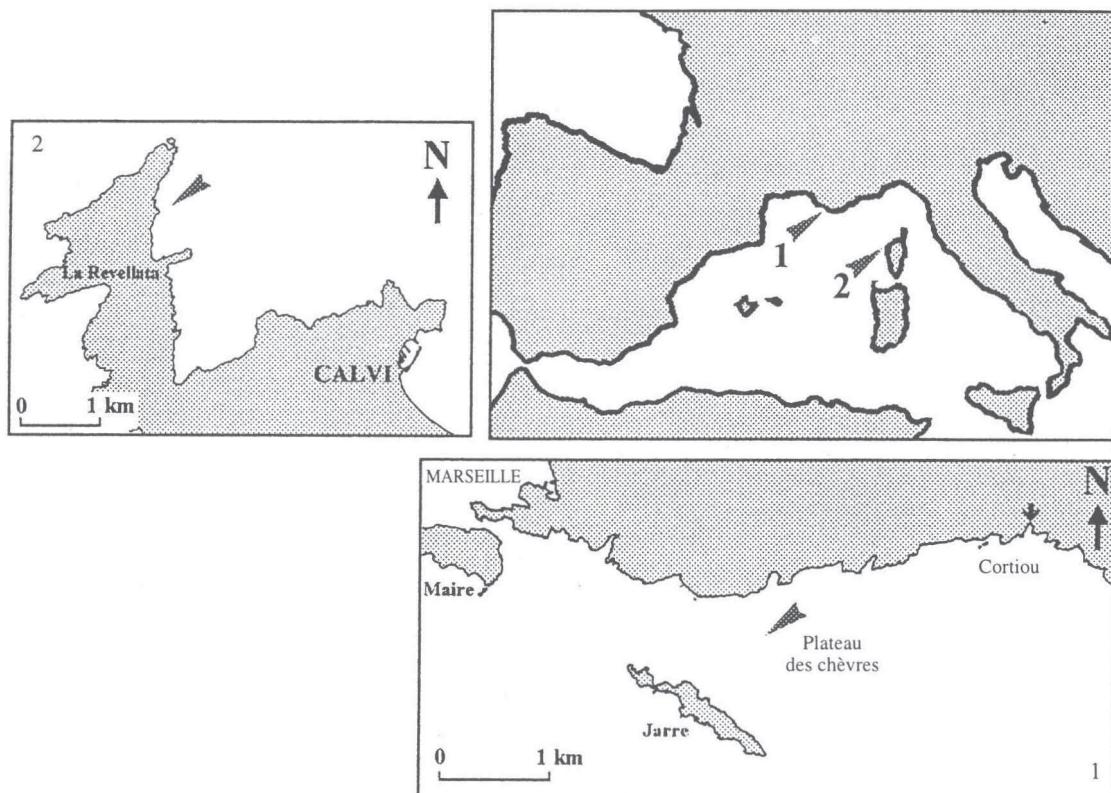


Figure 1 - Location of study sites / Localisation des sites d'étude.

Table I - The different types of *Posidonia oceanica* seagrass meadows based on their density according to Giraud (1977). Below 50 shoots per m<sup>2</sup>, the term isolated shoots is used. / Les différents types d'herbiers à *Posidonia oceanica* en fonction de leur densité, selon la classification de Giraud (1977). Au-dessous de 50 faîseaux par m<sup>2</sup>, on ne parle plus d'herbier mais de tiges isolées.

	Density (Nb. shoots./m <sup>2</sup> )	Description
Type I	over 700	Very dense beds
Type II	400 to 700	Dense beds
Type III	300 to 400	Sparse beds
Type IV	150 to 300	Very sparse beds

(1952) and Solorzano (1969), respectively. The nitrate and nitrite concentrations were estimated using a Technicon II auto-analyser (Tréguer, Le Corre, 1975) and ammonium levels were obtained using a spectrophotometer ( $\lambda = 630$  nm).

Fertilization was performed from May to September in two one-meter-long cages, the cages being separated by a distance of 5 m. Two other cages, also separated by 5 m, were used as controls and were situated 50 m from the first experimental cages. Nutrient input was performed by providing an NPK 18.8.13 fertilizer (nitrogen 18 %, phosphate 8 %, potassium 13 %) mixed with a binding agent (Guar Gum). This method allows a progressive diffusion of nutrients into the environment. These fertilizers were placed *in situ*, in bags suspended just above the leaves.

Every month, 15 shoots were sampled from each cage and brought back to the laboratory. The leaves were removed while at the same time respecting their distichous order of insertion based on the method of Giraud (1977). The number of leaves (adult and intermediate), the foliar biometric, the "Coefficient A" (percentage of leaves having lost their apex according to Giraud, 1977) and the leaf surface per shoot or per m<sup>2</sup> (Drew, 1971) were recorded. The leaves were then scraped in order to remove all epiphytes. The epiphytes collected in this way were placed in a drying oven (60° C - 48 h) and weighed (Metler B scale, 1/10 mg precision).

## RESULTS AND DISCUSSION

### Nutrient levels in the sediment

The results obtained vary considerably depending on the sampling period. These variations can be explained (i) by the variations in the annual cycles observed for nutrient concentrations in the water column (Arfi, 1978; Bay, 1978) and in the sediment (Joanny, 1993), (ii) by the plant's biological cycle (Caye, Rossignol, 1983) and (iii) by the seasonal input of organic matter (e.g. litter in Romero *et al.*, 1992).

Significant differences were also observed between the different sediment layers. For the two periods examined (June and December), a decrease

in nitrate concentrations was observed between the superficial layer (14.5±2.6 µM.I<sup>-1</sup>) and the deeper layers (4.2±1.7 µM.I<sup>-1</sup>) which is comparable to results observed by Sorensen (1978). In addition, this progressive decrease in nitrate concentrations with depth was observed for all of the seagrass meadows examined (figure 2).

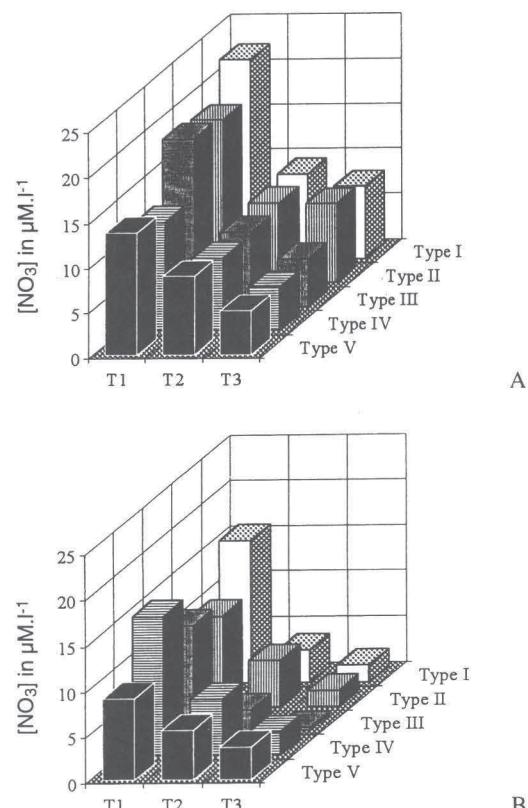


Figure 2 - Nitrate concentrations in the different sediment layers (T1 to T3) according to seagrass meadow density (Types I to V) at the Cortiou site in June (A) and December (B) 1993. T1 = 0 - 2 cm; T2 = 2 - 4 cm; T3 = 4 - 10 cm. / Concentration en nitrates dans les différentes tranches de sédiment (T1 à T3), aux mois de juin (A) et décembre (B) 1993, en fonction de la densité de l'herbier (Types I à V) dans le secteur de Cortiou. T1 = 0 - 2 cm ; T2 = 2 - 4 cm ; T3 = 4 - 10 cm.

In June, the mean nitrite and ammonium concentrations in the sediment decreased significantly ( $r_{(NO_2)} = 0.84$ ;  $r_{(NH_4)} = 0.97$ ) with increasing seagrass density (figure 3). This decrease was observed regardless of the sediment layer examined (figure 4).

Conversely, no clearly discernable tendency was observed in December. This could be due to the hydrodynamic conditions occurring at this time of the year which may favour the homogenisation of nutrients in the superficial layer of the sediment.

When seagrass density is high, a large amount of plant litter is generated resulting in high organic matter levels (Romero *et al.*, 1992). The

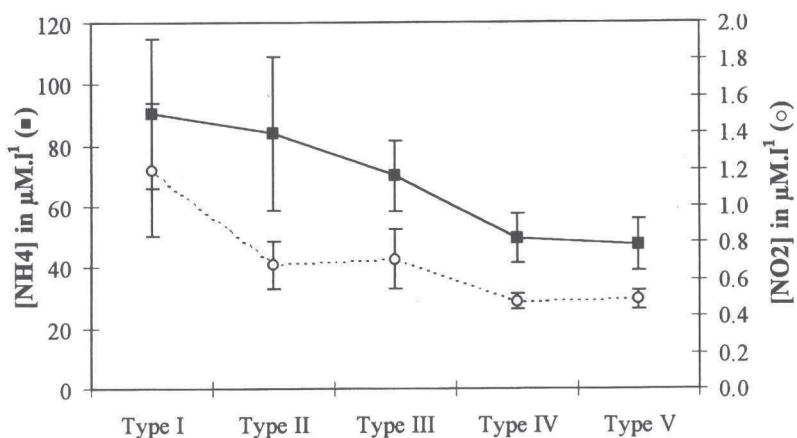


Figure 3 - Ammonium and nitrite concentrations in the sediment according to seagrass meadow density at the Cortiou site in June 1993. Confidence interval (5 %) is given. / Concentration en ammonium et en nitrites dans le sédiment au mois de Juin 1993, en fonction de la densité de l'herbier, dans le secteur de Cortiou. L'intervalle de confiance (5 %) est indiqué.

mineralisation of this plant litter (organic matter) by a multitude of micro-organisms, or in other words the decomposition of biogenic organic matter into inorganic matter (Marty *et al.*, 1989), leads to an influx of ammonium. This compound is transformed by bacteria into nitrites and, subsequently, nitrates (Fenchel, 1977).

Although it is difficult to determine whether the "patchiness" phenomenon observed in *Posidonia oceanica* meadows results directly from sediment nutrient levels, the results observed in the present study can be compared to those obtained for *Zostera marina* and *Thalassia testudinum* Banks ex König. For these species, the level of available nitrate in the sediment has been shown to be the limiting factor responsible for the observed variations in shoot densities (Kenworthy *et al.*, 1982; Powell *et al.*, 1989).

#### Fertilization effects

After one month of fertilization, a massive development of epiphytes was observed within the experimental cages while the control cages maintained an aspect comparable to that observed at the beginning of the experiment. So as not to modify the environmental conditions within the experimental cages (light and water movement), the epiphytes present on these structures were removed regularly. The development of epiphytes was observed to occur on shoots inside as well as within a 30 to 40 cm radius of the cages. The epiphytic biomass (per unit foliar surface area) on shoots within the experimental cages recorded in May was already significantly different from that observed in the control cages and remained so throughout the experiment.

From May to June, length of the adult leaves in the control cages did not differ significantly from that measured in the experimental fertilization cages (table II). From July onward, however, leaf

length in experimental cages decreased and became significantly shorter than that measured in the control cages between August and September. The length of intermediate leaves exhibited a similar growth pattern with a significantly shorter length in the experimental cages beginning in June. Foliar surface area presented a similar tendency (figure 5).

A high percentage of leaf necrosis was observed beginning in August. Discoloured areas were observed on the blades whose aspect was entirely different from senescent leaves. The areas of necrosis were essentially located at the leaf apex. The "Coefficient A" value increased significantly from June (20 %) to Septembre (83 %). During this same period, the level of dead shoots observed in the experimental fertilization cages exceeded the 60 % mark. The length of still living adult and intermediate leaves was particularly low (table II).

The input of fertilizers into the environment of the present study therefore led to (i) the development of high levels of epiphytic algae and (ii) the decrease in foliar growth.

The significant increase in the level of epiphytes on the leaves is a phenomenon classically observed for a number of phanerogams subjected to a nutrient enrichment of their environment (Den Hartog, Polderman, 1975; Larkum, 1976; Cambridge, 1979; Sand-Jensen, Borum, 1983). The decrease in leaf growth seems to be linked to this high level of epiphytic development. Several authors have suggested that the leaves of phanerogams as diverse as *Thalassia hemprichii* Ehrenberg Ascherson, *Zostera capricorni* Ascherson, *Zostera marina* and *Ruppia maritima* Linnaeus become less functional and their growth is hindered when epiphytes are present as these organisms trap a large portion of the light (Taylor, Lewis, 1970; Kirkman, 1978; Borum, Wium-Andersen, 1980; Richardson, 1980). In addition, Mc Roy, Goering (1974) demonstrated that

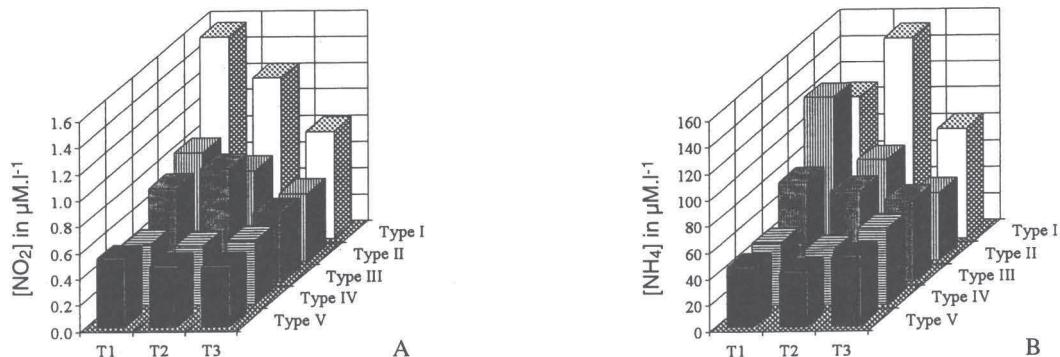


Figure 4 - Nitrite (A) and ammonium (B) concentrations in the sediment (T1 to T3), according to seagrass meadow density (Type I to V) at the Cortiou site in June 1993. T1 = 0 - 2 cm; T2 = 2 - 4 cm; T3 = 4 - 10 cm. / Concentration en nitrites (A) et en ammonium (B) dans les différentes tranches de sédiment (T1 à T3), au mois de juin 1993, en fonction de la densité de l'herbier (Types I à V) dans le secteur de Cortiou. T1 = 0 - 2 cm ; T2 = 2 - 4 cm ; T3 = 4 - 10 cm.

plant macro-epiphytes are capable of tapping nitrogen and carbonate through *Zostera sp* leaves thus acting as competitors. The studies by Caye & Rossignol (1983) on *Posidonia oceanica* and by Patriquin (1973) on *Thalassia testudinum*, attribute the foliar growth slowdown during the summer to the abundance of epiphytes during this period. It would therefore appear that extensive epiphyte leaf cover can lead to decrease in vegetative growth and an increase in blade necrosis (Rice *et al.*, 1983). Both of these conditions can seriously affect the development of the host plant (Van Montfrans *et al.*, 1984).

## CONCLUSION

The existence of patchiness within *Posidonia oceanica* beds (density, phenology) is a well documented phenomenon (Panayotidis *et al.*, 1981). Conversely, the reasons for this phenomenon are not clear although several hypotheses have been proposed like superposition of clones of different ages (Panayotidis *et al.*, 1981, Meinesz, Lefèvre, 1984, Caye, Meinesz, 1992) and nature of the substrate (e.g. local discontinuity *in Augier, Cristiani, 1984*). In light of the preliminary results of the present study, it would seem that nutrient levels in the sediment may also be capable, on a small scale, of determining the distribution of *Posidonia oceanica* seagrass beds. If this hypothesis is confirmed then

this would tend to validate the observations which have been recorded for several other species of marine phanerogam (Kenworthy *et al.*, 1982; Romeo-Martinengo, 1985; Powell *et al.*, 1989). It is clear that future studies should be carried out in order to determine the concentrations at which nutrients in the sediment are limiting.

If the direct input of fertilizers (balanced N,P,K) to the sediment seems to be beneficial to the development of leaf epiphytes, this input leads to a disequilibrium of *Posidonia oceanica* leaf growth. Initially, enrichment of the environment leads to a significant decrease in the foliar surface area, followed by the death of most of the leaves and, finally, to the death of numerous *Posidonia oceanica* shoots. The input of fertilizers therefore favours the growth of epiphytes at the expense of the host plant which generates a phenomenon of plant/epiphyte competition.

In light of these results, it would seem that the impact of nitrogen and phosphorous rich domestic wastes on *Posidonia oceanica* meadows should be reconsidered. The regression of seagrass meadows observed in the vicinity of sewage outlets has generally been attributed to the turbidity generated by these effluents, in particular at the lower limits (Boudouresque, Meinesz, 1982; Meinesz, Laurent, 1978). A substantial epiphyte cover, brought about by high nutrient levels, would appear to accelerate the regressions observed in these areas

Table II - Mean adult and intermediate leaf lengths (in mm) for *Posidonia oceanica* in different cages (confidence interval). / Longeur moyenne des feuilles adultes et intermédiaires (en mm) de *Posidonia oceanica* dans les différentes cages (Intervalle de confiance).

	Length of adult leaves (mm)		Length of intermediate leaves (mm)	
	Control Cages	Fertilized Cages	Control Cages	Fertilized Cages
May	520.2 ( $\pm 40.6$ )	493.1 ( $\pm 37.3$ )	542.3 ( $\pm 40.3$ )	539.2 ( $\pm 37.2$ )
June	608.8 ( $\pm 51.9$ )	636.9 ( $\pm 48.5$ )	616.6 ( $\pm 49.9$ )	581.2 ( $\pm 58.3$ )
July	768.7 ( $\pm 50.8$ )	736.2 ( $\pm 60.8$ )	624.0 ( $\pm 78.4$ )	482.6 ( $\pm 59.8$ )
Aug.	791.7 ( $\pm 50.8$ )	562.0 ( $\pm 65.9$ )	445.0 ( $\pm 130.2$ )	226.2 ( $\pm 114.9$ )
Sept.	766.2 ( $\pm 62.4$ )	268.3 ( $\pm 68.4$ )	68.3 ( $\pm 7.1$ )	-

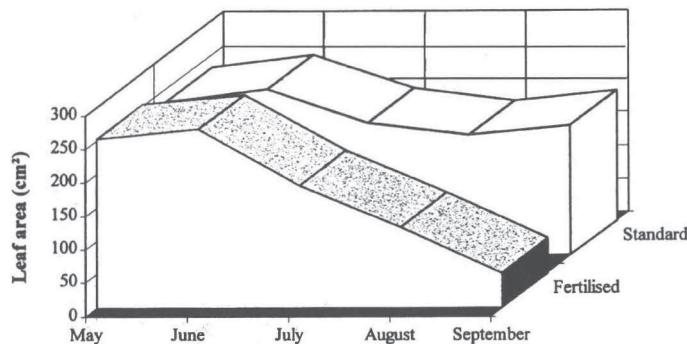


Figure 5 - Leaf surface (in cm<sup>2</sup> per shoot), in fertilized and control cages in a *Posidonia oceanica* meadow in the Bay of Calvi. / La surface foliaire (en cm<sup>2</sup> par faisceau) dans les cages fertilisées et témoins dans l'herbier à *Posidonia oceanica* de la baie de Calvi.

which are close to the compensation depth. Similarly, the seagrass bed regressions observed at the upper limits where light is not a limiting factor could be due, in part, to plant/epiphyte competition. This hypothesis would seem to be supported by the observation of a strong development of epiphytic algae on living seagrass beds which are situated in close proximity to areas subjected to high nutrient effluents: sewage outlets (Fernandez et al., 1992), aquaculture cages set up in a closed environment (Mendez, 1994).

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