Seagrass regression caused by fish cultures in Fornells Bay (Menorca, Western Mediterranean)

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ABSTRACT

A three year monitoring programme (1988-1990) of embayment habitats dominated by the seagrasses *Posidonia oceanica* and *Cymodocea nodosa* was carried out in Fornells Bay (Menorca, Western Mediterranean), where gilthead seabream (*Sparus auratus*) was artificially reared. Responses ranging from shoot density decrease to total seagrass demise were observed. *Posidonia oceanica* was more drastically and quickly affected than *Cymodocea nodosa*. In 1990, a total of 2 ha of seagrass were significantly degraded. Increased light attenuation, sedimentation rates, and grazing pressure are proposed as the principal factors accounting for seagrass regression.

RÉSUMÉ

Régression des herbiers à phanérogames marines causée par l'élevage des poissons dans la Baie de Fornells (Minorque, Méditerranée Occidentale).

Les changements des herbiers à *Posidonia oceanica* et à *Cymodocea nodosa* de la Baie de Fornells (Minorque, Méditerranée Occidentale) ont été suivis pendant trois années (1988-1990) après l'installation de cages d'aquaculture pour l'engraissement des dorades (*Sparus auratus*). La dégradation des herbiers a été constatée principalement par une diminution de la densité des faisceaux et par une disparition totale dans les sites les plus affectés. Les herbiers à *Posidonia oceanica* ont été davantage et plus rapidement dégradés que ceux à *Cymodocea nodosa*. Après trois années, 2 ha d'herbier étaient significativement dégradés. A notre avis, les facteurs majeurs responsables de cette régression ont été l'augmentation de la turbidité des eaux et celles de la sédimentation et de l'herbivorisme.

INTRODUCTION

The regression of Mediterranean seagrass meadows due to human activities is reported to be mainly caused by water eutrophication, i.e. as a consequence of waste water discharge, and mechanical damage, i.e. trawl fishing, sand dredging, marina construction, etc. (Maggi, 1973; Pérès and Picard, 1975; Meinesz and Lefevre, 1978; Jeudy de Grissac, 1984; Meinesz et al., 1981; Bourcier, 1989). However, the effects of fish farming on seagrasses have been poorly studied. Intensive fish culture produces large amounts of organic waste from uneaten fodder and faeces, leading to changes in water quality and in benthic communities.

In this paper we report on the changes observed in the seagrass beds dominated by Posidonia oceanica (L.) Delile and Cymodocea nodosa (Ucria) Ascherson, after the beginning of fish farming, in a previously pristine Mediterranean bay covered by dense and healthy meadows of these two species.

MATERIAL AND METHODS

Study site

Fornells Bay, situated on the north coast of Menorca (Balearic Islands, Western Mediterranean) (Fig. 1), is a semi-enclosed bay 4.4 km long and 1.5 km wide, with an average depth of 5.5 m, opened to the north by a 300 m diameter entrance. Strong and frequent north winds determine the hydrodynamics of the bay, as evidenced by the sediment distribution (Fornòs et al., 1992). Benthic communities are characterized by the seagrasses Posidonia oceanica and Cymodocea nodosa, of high to very high density. Green algae such as Halimeda tuna (Ellis et Solander) Lamouroux, Caulerpa prolifera (Forsskål) Lamouroux, Dasycladus vermicularis (Scopoli) Krasser, and Flabellia petiolata (Turra) Nizamuddin, are intermingled with the seagrasses. Rocky bottoms shelter the photophilic algal communities from Mediterranean warm areas (Verlaque, 1987).

Fish farming

During 1985-1986 two groups of fish cages, A and B, both stocked with gilthead seabream, Sparus auratus (L.), were placed at the NE of the bay (Fig. 1). Group A consisted of nine fish cages (100 m^3 capacity each unit) in 1988, increasing to 32 cages (covering an area of 1500 m^2) in 1990. Group B consisted on eight cages (60 m^3 capacity) covering a surface of approximately 600 m^2; the number of cages remained invariable throughout the study. Dry fodder used in group A ranged from 22 metric tons in 1989 to 77 metric tons in 1990, while only 12 tons of dry fodder were used annually in group B. Fish production was estimated at 1.6 and 1 metric tons per growing cycle (two years), for A and B exploitations, respectively. Seagrass beds under the cages were dominated by Posidonia oceanica (A) and Cymodocea nodosa (B).
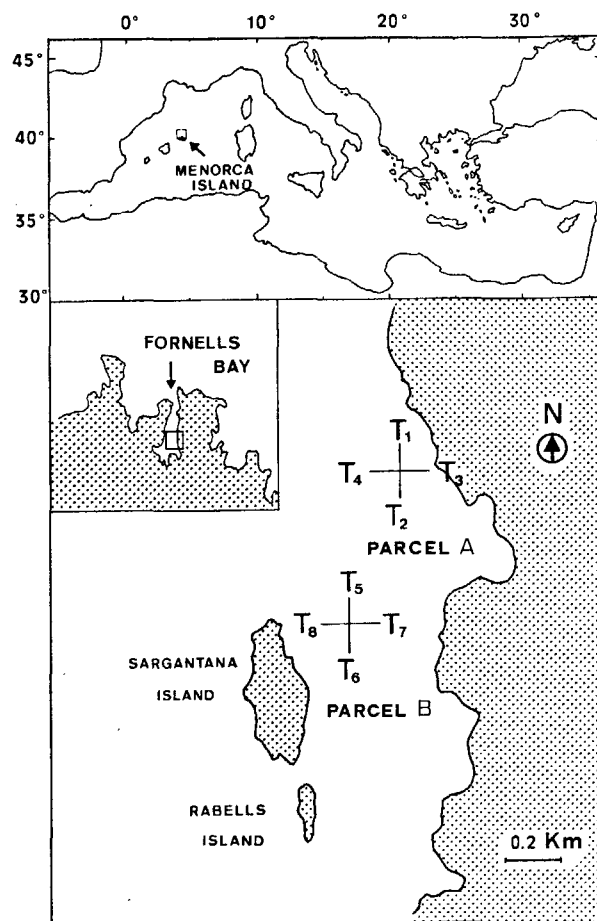

Figure 1

Study site in Fornells Bay. Location of fish culture zones, plots A and B, and the permanent transects.

Site d'étude dans la baie de Fornells. Localisation de la zone de cultures, des parcelles A et B, et des transects permanents.

Monitoring

Four transects 100 m long were permanently established under the two groups of cages, delimiting plots A and B, respectively (Fig. 1). Transects 1-4 in plot A, and transects 5-8 in plot B, were oriented by the four cardinal points. The geometrical centre of each group of cages coincided with the centre of the cross formed by the four transects (Fig. 1). Four supplementary transects (NW, SW, SE, and NE oriented) were permanently established in 1990.

Transects were visited during summer (July) in 1988, 1989 and 1990. On each occasion, some general observations were made, and the following parameters were measured:

– Detailed bathymetry of every metre of the transect, with accuracy of ±0.1 m.

– Inventory of the principal benthic communities present along the transect by direct observation. Different seagrass zones were delimited according to shoot density and leaf length (Giraud, 1977).

– Seagrass shoot density was carefully measured in ten quadrats of 20 × 20 cm (Giraud, 1977; Boudouresque et al., 1980; Romero, 1985) in the delimited zones. Two

different leaf length classes – long and short – were also established to take into account the grazing pressure on *Posidonia oceanica* and *Cymodocea nodosa* plants.

RESULTS

At the end of the survey period (July 1990), fish farming had been in operation for about five years. The principal effects on benthic communities in plots A and B are described below.

Plot A

Posidonia oceanica completely disappeared in transects 1 and 2 (N-S oriented) (Fig. 2). *Cymodocea nodosa* also completely disappeared from transect 2, while undergoing considerable reduction in shoot density in transect 1 (Fig. 2).

Seagrass regression was less drastic in transects 3 and 4 (W-E, Fig. 2) than that observed in transects 1 and 2. *Cymodocea* with short leaves covered the 35 m-50 m section of transect 3. *Posidonia* shoot density decreased in transect 4, from ~ 500 to ~ 200 shoots m^{-2}, and the leaves experienced a marked shortening in plants contained within a radius of 40 m from the cages.

Plot B

Cymodocea completely disappeared within a radius of 62 m from the cages in transect 5 (N), while showing a 50 % shoot density reduction from 62 to 100 m (Fig. 3). In transect 6 (S), *Cymodocea* regressed to 12 m from the cages, showing a very low shoot density at the 12-23 m section (<50 shoots m^{-2}) (Fig. 3). Interestingly, shoot density of *Cymodocea* increased significantly in the 23-32 m section, although a generalized shoot density decrease was observed in the rest of the transect.

Seagrass regression was less important in transects 7 and 8 (W-E) than that observed in transects 5 and 6 (N-S), a similar trend already noticed in plot A. In transects 7 and 8, *Cymodocea* completely disappeared to a distance of 19-20 m from the cages (Fig. 3). In the remainder of the transects, a generalized reduction of shoot density and leaf length was observed.

DISCUSSION

Fish farming strongly affects the seagrass meadows under the culture cages and nearby (Fig. 4). The greatest effect was located under the cages, diminishing progressively with distance from them. About 7 ha of seagrass were significantly degraded at the end of the survey period (three years). In plot A, 2 ha of *Posidonia oceanica* meadow had totally died off, and 2 ha were significantly degraded. In plot B, a little more than 0.5 ha of *Cymodocea nodosa* were lost, and approximately 2 ha were significantly degraded. The predominant N-S direction of the seagrass regression was possibly a consequence of the prevailing currents in the bay. A linear degradation rate of 10-30 m y^{-1} and a

doubling of the degraded area yearly are projected from our results.

The degradation process of the seagrass meadows is spatial and time-dependent. Similar time (or space) regression models can be postulated for *Posidonia oceanica* and *Cymodocea nodosa* meadows, despite the different degree of stress supported by both species in plots A and B. The degradation process starts with a progressive shortening of the leaves. Subsequently, there is a strong decline of shoot density which eventually leads to a denuded bottom with dead rhizomes and no blades at all.

Little research on seagrass meadow degradation as a consequence of aquaculture has been carried out previously. Nevertheless, available literature on fish farming and seagrass beds furnishes some data that can help in understanding the drastic changes observed in seagrass beds of Fornells Bay. Fish farms deliver a large quantity of food to the water. A large part of this food remains uneaten and another part is returned to the water as faeces (Phillips *et al.*, 1985). Thus, there is an increase of organic matter which settles in the bottom as particulated material and a dissolved nutrient enrichment in the water column. Increased nutrient availability typically results in greater epiphyte levels on seagrass blades (Borum, 1985; Silberstein *et al.*, 1986; Tomasko and Lapointe, 1991). In the present case, the leaves more epiphytized and loaded with sedimented material were those closest to the cages (authors' unpublished results). These elevated amount of epiphytes and uneaten fodder may be instrumental in attracting wild and escaped fishes to the cages (Locayano and Smith, 1976; Kilambi *et al.*, 1978; Carss, 1990), to feed on this extra food and on the heavily epiphytized blades. This may explain the shorter leaves found near the cages and could partially account for the shoot density decrease.

Not only grazing but also light reduction is a suggested contributor to the observed seagrass degradation. The light reaching the plants is known to be reduced directly by the cages themselves and indirectly by: (i) particulate matter input in the water column-fodder, fish faeces, sediment resuspension, and phytoplankton blooms; and (ii) epiphyte growth on the seagrass leaves. Light has been identified in numerous studies as one of the prime factors affecting the growth and local distribution of seagrasses (Larkum, 1976; Bulthuis, 1983; Dennisson, 1987; Dawes and Tomasko, 1988; Den Hartog, 1988; Neverauskas, 1988; Duarte, 1991). Seagrasses at the study site are supposed to be light oversaturated, assuming a light compensation point of 5-15% of SI (Duarte, 1991). However, epiphytes may reduce the photosynthetic rate of the plant, acting as a barrier to carbon uptake and reducing the light intensity reaching the plant (Sand Jensen, 1977; Silberstein *et al.*, 1986). Excessive epiphyte growth on the leaves of seagrasses has been reported as the most probable cause of the decline observed in some seagrass meadows in Australia and the United States (Neverauskas, 1987; Tomasko and Lapointe, 1991).

The recovery of the seagrass area lost in Fornells Bay if fish farming ceased, is hardly foreseeable. No *Posidonia oceanica* seagrass meadow recovery from physical disturbance or catastrophic decline has been
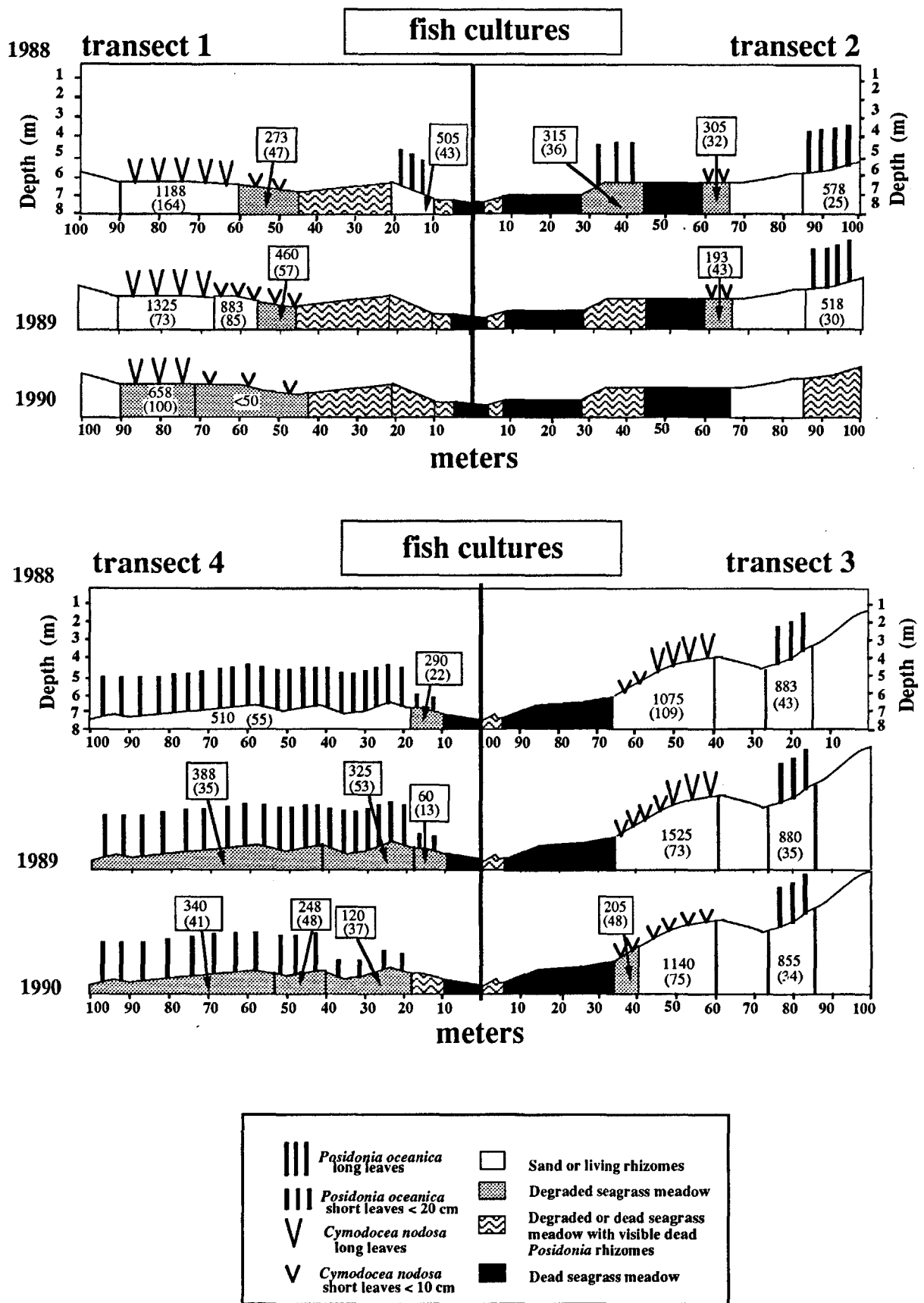
Figure 2

Evolution of the seagrass beds of plot A from 1988 to 1990. Numbers are the mean and standard deviation (in brackets) of the shoot density.

Évolution des herbiers situés dans la parcelle A de 1988 à 1990. Les chiffres correspondent à la moyenne et à l'écart-type (entre parenthèses) de la densité des faisceaux.
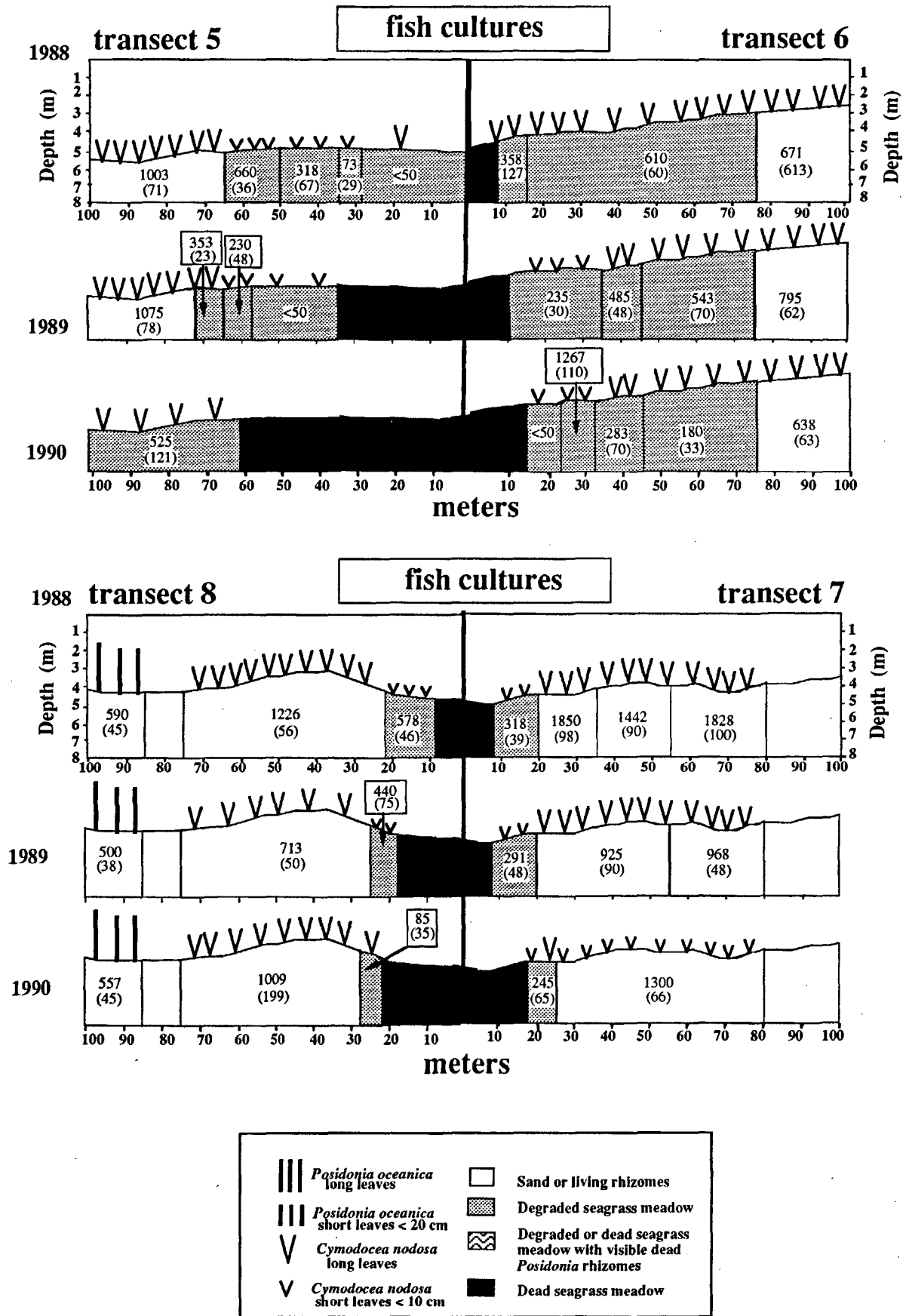
Figure 3

Evolution of the seagrass beds of plot B from 1988 to 1990. Numbers are the mean and standard deviation (in brackets) of the shoot density.

Évolution des herbiers situés dans la parcelle B depuis 1988 jusqu'à 1990. Les chiffres correspondent à la moyenne et à l'écart-type (entre parenthèses) de la densité des faisceaux.

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