SCIENTIA MARINA

Variations of the macrobenthic community in a seagrass transplanted area of the Lagoon of Venice*

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SUMMARY: Modifications in a benthic community, induced by an experimental transplant of seagrass (*Cymodocea nodosa* Ucria), were studied in an area located in the southern basin of the Lagoon of Venice. Two surveys, carried out in March and September 1996, indicated that species composition and numerical dominants changed with season, with increasing dissimilarity between the transplanted meadow and the surrounding area. The latter was used as a control area and was characterised by the presence of pleustophytic algae (*Ulva rigida, Gracilaria verrucosa, Chaetomorpha linum*). Comparison with a natural *C. nodosa* bed showed that, only two vegetative seasons after transplant, seagrass performance and the structure of the macrobenthic community were quite similar to those recorded in a natural meadow. The experiment demonstrated the importance of *C. nodosa* transplant in the Lagoon of Venice and the changes induced in the whole benthic community by the introduction of seagrass in an area previously lacking it.

Key words: macrobenthic community, seagrass, *Cymodocea nodosa*, Lagoon of Venice.

INTRODUCTION

The importance of seagrass within coastal marine and lagoon ecosystems has been widely described (Den Hartog, 1977; Larkum *et al.*, 1989). When compared with neighbouring areas, the meadows reveal higher animal and algal biomasses and abundances, with greater specific richness (Homziak *et al.*, 1982; Edgar *et al.*, 1994; Boström and Bonsdorff, 1997). The main factors contributing to this improvement in biodiversity may be summarised as increased: i) availability of microhabitat, ii) protection from predators, iii) trophic resources, iv) sediment settling, v) hydro-

dynamic force reduction (Lewis, 1984). Meadows do strongly affect local water flows by significantly reducing current speed (Harlin *et al.*, 1982; Fonseca *et al.*, 1983) and by producing a typical relative increase in the sediment fine fraction (Orth, 1977; Peterson *et al.*, 1984). Moreover, these habitats often act as nursery areas for many fish species, since they offer protection and shelter from predators (Blunden and Kennedy, 1982; Connolly, 1994).

In the last decade, the whole ecosystem of the Lagoon of Venice has been subjected to increasing anthropogenic stress, mainly due to 'free-access' exploitation of the short-necked clam *Tapes philippinarum* (Pranovi and Giovanardi, 1994; Giovanardi and Pranovi, 1999), which has produced a reduc-

tion in seagrass. In an attempt to test procedures which may prove to be useful tools in future 'restoration' projects aiming at counteracting these stress effects, an experimental transplant of *Cymodocea nodosa* (Ucria) was carried out in the southern basin of the Lagoon. The purpose of the study was to assess the feasibility of transplanting *C. nodosa* by means of the 'turf technique' and to describe the changes and developments occurring in phyto- and zoobenthos in the artificial meadow.

MATERIALS AND METHODS

The study site is located in the southern basin of the Lagoon of Venice (Fig. 1), on a 2-metre deep silty-sandy bottom (Barillari, 1981), in an area where the hydrodynamic pattern has recently been modified by restoration of neighbouring channels. The experimental area, located close to a natural *Cymodocea nodosa* meadow, typically contained pleustophytic algae, which have a clear seasonal cycle, with low biomass in autumn and winter and very abundant biomass in spring and summer (Curiel *et al.*, 1995).

The *C. nodosa* transplant, made during spring 1995, involved an area of roughly 30 m^2 and was performed using the 'turf technique' (Phillips, 1974), 56 pieces of turf ($\varnothing$=23 cm, height=30 cm) being inserted into the bottom.

Data collection

In March and September 1996, samples of phyto- and zoobenthos were collected inside the transplant-ed area (treated plot) and all around it outside (con-trol area).

The shoot density of the transplanted meadow was measured *in situ* using a 30 x 30 cm^2 square in 10 replicates. Ten shoots of *C. nodosa* were collect-ed, to evaluate the number of leaves per shoot and the length of leaves. The photosynthetically-active surface (LAI – leaf area index) was determined by multiplying the mean surface area of one-shoot leaves (only one face) by meadow shoot density.

Seagrass biomass (g d.w. m^{-2}) was measured from samples collected with a manual corer ($\varnothing$ 23 cm) in 5 replicates, by separating leaves, roots and rhizomes, after removing sediment. For every core, 10 shoots were also collected in order to study epi-phytic macroalgae and to estimate their biomass and coverage percentage.
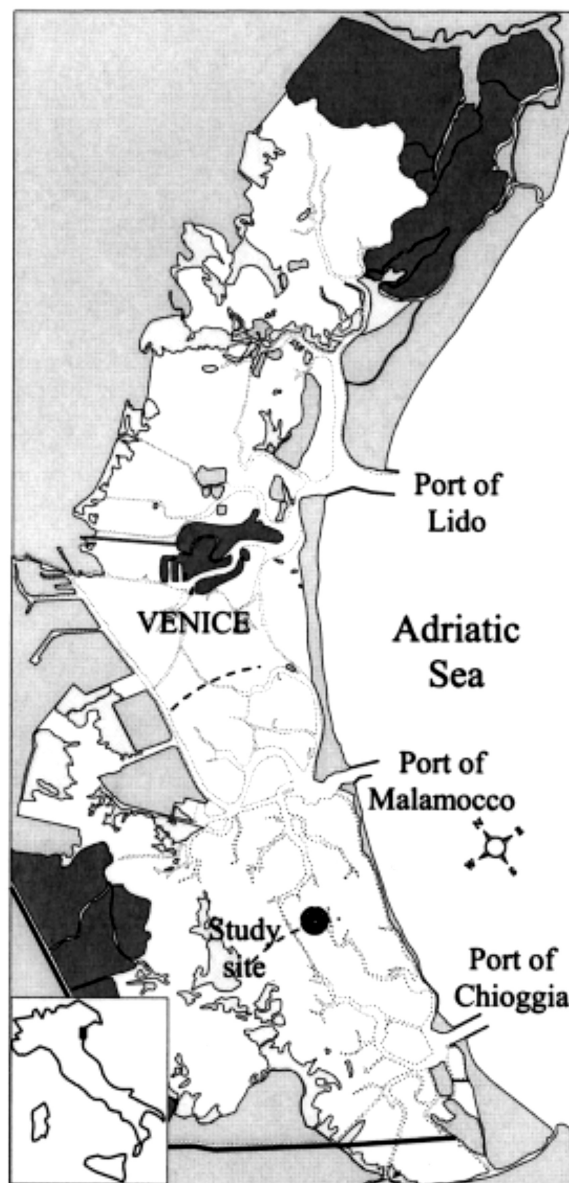

FIG. 1. – Location of study site (dark zones: salt marsh and urban areas)

Macroalgal biomass (g d.w. m^{-2}) and coverage percentage were measured by collecting material inside a 1m x 1m frame in 5 replicates per plot. The diversity index based on Shannon's formula modi-fied by Boudouresque (1970) was calculated.

Macrobenthos samples were collected with a manual corer ($\varnothing$ 23 cm, 5 replicates per plot) and separated from sediment through a 1-mm-mesh sieve. Organisms were classified to their lowest pos-sible taxonomic level, and wet biomass was deter-mined for each *taxon*.

The micro-mesobenthos of the surface sediment layer was sampled with an air lift sampler with 3 replicates per plot.

TABLE 1. – Macroalgae collected during surveys.

| | treated plot | | control area | |
	March	September	March	September
RHODOPHYTA				
Auduinella sp.	x	x		
Bangia atropurpurea (Roth) C. Agardh	x	x		
Callithamnion corymbosum (Smith) Lyngbye		x		
Ceramium diaphanum auctorum		x		
Gracilaria verrucosa (Hudson) Papenfuss		x	x	x
Hydrolithon farinosum (Lamour.) Penrose et Chamberlain	x	x		
Spyridia filamentosa (Wulfen) Harvey		x		
Stylonema alsidii (Zanardini) Drew	x	x		
PHAEOPHYTA				
Ectocarpus siliculosus (Dillwyn) Lyngb. *var. siliculosus*	x			
Hincksia sp.	x			
Stilophora rhizodes (Turner) J. Agardh	x	x	x	
CHLOROPHYTA				
Chaetomorpha linum (O.F. Müller) Kützing	x	x	x	x
Cladophora hutchinsiae (Dillwyn) Kützing		x		
Cladophora sp.			x	
Enteromorpha intestinalis (L.) Nees	x	x	x	x
Entocladia viridis Reinke		x		
Ulvaria oxysperma (Kützing) Bliding		x		
Ulvella lens P.L. et H.M. Crouan		x		
Ulva rigida C. Agardh	x	x	x	x
Shannon index	1.83	2.33	0.95	1.09

Data analysis

Species diversity in treated and control areas was estimated by the Shannon Weaver (H') and Margalef (d) indices.

Changes in the number of species, total number of individuals, diversity indices and total wet biomass were analysed by one-way ANOVA.

The Abundance Biomass Comparison -ABC- method (Warwick, 1986) was applied in order to evaluate the level of disturbance of the macrobenthic community in the treated and control areas. Differences among macrobenthic assemblages were assessed using the multidimensional scaling technique, based on the Bray-Curtis similarity matrix (Clarke and Warwick, 1994). Differences in assemblage composition between treatments and data were assessed by ANOSIM, a randomization/permutation procedure which tests for differences in the ranked similarity matrix (Clarke and Green, 1988).

RESULTS

Macroalgae

The algal component of the two plots showed many differences in *taxon* composition and specific richness (Table 1). The total number of recorded species in the treated plot was 18, but only 6 in the control area.

The temporal pattern of specific richness also showed an opposite trend in the two plots: in the treated plot it increased from 10 taxa in March to 16 in September, whereas in the control area it decreased from 6 to 4 (Table 1). This also influenced the Shannon Weaver index, which was relatively stable in the control area (0.95 in March and 1.09 in September) but increased from 1.83 (March) to 2.33 (September) in the treated plot.

In the control area, the highest values of biomass and covering percentage were recorded in March (Table 2), when macroalgae, mainly *Ulva rigida*, *Gracilaria verrucosa* and *Chaetomorpha linum*, formed a homogeneous and contiguous mat at least 10 cm thick on the bottom. In September, lower values were recorded as the consequence of a remark-

TABLE 2. – Macroalgal species, covering percentage and biomass (g d.w. m^{-2}) recorded in control area and total macroalgae covering percentage in treated plot.

| | March | | September | |
	covering	biomass	covering	biomass
Ulva rigida	100	410	60	105
Gracilaria verrucosa	30	95	40	89
Chaetomorpha linum	10	15	30	42
Cladophora sp.	5	0.5	—-	—-
Enteromorpha intestinalis	<1	0.2	<1	<0.1
Stilophora rhizodes	<1	0.2	—-	—-
Total other algae in treated plot	3	5.1	5	15.4

TABLE 3. – Phenological features of *Cymodocea nodosa* in treated plot and in natural bed.

	March mean (sd)	September mean (sd)	natural bed min-max
Shoots density m^{-2}	860 (15)	1618 (101)	1137-2570
LAI (m^{2}m^{-2})	0.28	2.85	0.3-8.7
Number of leaves shoot^{-1}	2.4	5	1-5
Shoot height (cm)	11.4 (2)	81 (15)	0-90
Leaf biomass (g d.w. m^{-2})	51 (15)	382 (46)	50-667
Rhizome biomass (g d.w. m^{-2})	445 (27)	415 (37)	431-648
Root biomass (g d.w. m^{-2})	154 (14)	180 (8)	102-220

TABLE 4. – Meso-microbenthos collected during surveys.

	treated plot		control area	
	March	September	March	September
Amphipoda		x	x	x
Polychaeta	x	x		x
Nematoda	x	x	x	x
Ciliata	x	x		x
Benthic diatoms			x	
Foraminifera	x	x	x	x
Ostracoda		x		
Briozoa		x		
Bacterial flocculent material	x		x	x
Vegetal detritus	x	x	x	x

TABLE 5. – Macrobenthic *taxa* collected during surveys and diversity measures (mean and s.d.).

	treated plot		control area	
	March	September	March	September
PORIFERA		x		
CNIDARIA (Anthozoa)			x	x
Anemonia sulcata Pennant	x	x		
MOLLUSCA (Gastropoda)				
Gibbula adriatica (Philippi)		x		x
Calliostoma virescens (Renier)		x		
Tricolia pullus (L.)		x	x	
Cyclope neritea (L.)	x	x	x	x
Nassarius reticulatus (L.)		x	x	
MOLLUSCA (Bivalvia)				
Nucula nucleus (L.)		x		
Loripes lacteus (L.)	x	x	x	x
Abra alba (Wood W.)	x	x		
Tapes philippinarum Adams & Reeve	x	x	x	
Paphia aurea (Gmelin)		x		
ANNELIDA (Polychaeta)				
Nephtys hombergi Aud. & Milne Edw.	x	x	x	x
Eunice vittata (Delle Chiaje)	x			
E. harassi Aud. & Milne Edw	x			
Nereis pelagica L.	x			
Platynereis dumerilii (Aud. & Milne Edw)		x	x	x
Ceratonereis costae (Grube)		x		
Eunereis longissima Johnston		x		
Errantia				x
Amphitrite cirrosa (O. F. Muller)				x
Euclymene oerstedii (Clap.)	x	x		x
E. robusta Arwidsson	x			
E. lumbricoides (Quatref.)			x	x
Euclymene sp.	x			
Melimna palmata Grube		x	x	
Lagis koreni Malmgren			x	
Sedentaria		x		
TENTACULATA (Briozoa)				
Scrupocellaria sp.		x		
Bugula sp.		x		
ARTHROPODA (Crustacea)				
Upogebia pusilla (Petagna)	x		x	x
Xantho incisus (Leach)	x			
Carcinus mediterraneus Czerniavsky	x			
Brachinotus sexdentatus Risso	x			
Gammaridae		x	x	
Lysianassidae			x	x
ECHINODERMATA (Holoturoidea)				
Trachythyone elongata (Düb. Kor.)				x
n. ind. m^{-2}	192.0 (103.2)	633.6 (330.96)	172.8 (120.48)	374.4 (69.12)
g m^{-2}	53.0 (17.3)	793.4 (672.5)	158.7 (265.4)	118.8 (108.7)
Shannon index	1.31 (0.43)	1.99 (0.29)	1.20 (0.7)	1.44 (0.28)
Margalef index	6.01 (0.60)	5.69 (1.16)	5.44 (0.58)	4.11 (0.57)

able reduction in *U. rigida* biomass, due to summer degradation processes.

In the treated plot, the vegetal compartment was dominated by *C. nodosa,* and the total macroalgal biomass and covering percentage reached negligible values (Tables 2-3). The highest values of density, biomass and LAI of *C. nodosa* were recorded in September, at the end of intense summer growth; instead, the leaf component proved to be very scarce in March (Table 3) because of very low winter levels of shoot density, leaf size and leaf number per shoot, typical of environments at intermediate latitudes (Rismondo *et al.*, 1997).

Comparisons between the transplant area and a natural *C. nodosa* bed (Rismondo unpubl. data) showed that, although the growth parameters recorded in the transplanted meadow fell within normal range, they did not reach maximum values, mainly in shoot density and leaf biomass (Table 3).

Micro-meiobenthos

Qualitative analysis of micro-meiobenthic samples (Table 4) revealed the presence of vegetal detritus from the seagrasses in the treated plot and mainly *Ulva* in the control area. In both areas the highest amounts were detected in autumn. Moreover, benthic filamentous microalgae and typically Ciliate interstitial forms (*Remanella*, *Geleia*) tended to prevail in the treated plot, with abundant bacterial flocculent material in the control area, in which a complete lack of interstitial forms was noted. In September, all meiobenthic groups (Ciliates, Nematoda, micro-Polychaetes, Ostracoda) were two or three times more abundant in the control area than in the treated plot.

Macrobenthos

Details of the 35 macrobenthic taxa collected during the surveys, diversity measures (total number of individuals, Shannon and Margalef indices) and the total wet biomass are listed in Table 5. In the treated plot, all considered parameters (except the Margalef index) increased from March to September, whereas they showed a decrease in the control area.

The one-way ANOVA carried out using the diversity measures recorded in the treated and control areas (T March, T September, C March, C September) showed significant differences in total number of species, total number of individuals and total wet bio-

TABLE 6. – One-way ANOVA results on macrobenthos data (number of species, total number of individuals, Margalef and Shannon indices, total wet biomass).

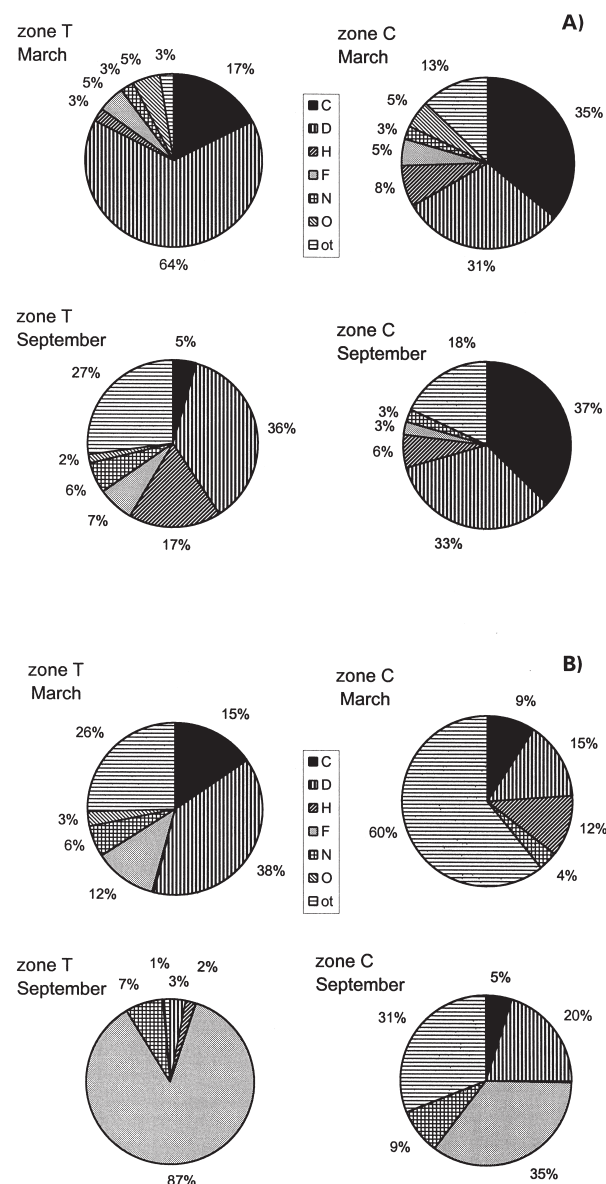|	N	F	p
Total number of species	3	3.753	0.032
Total number of individuals	3	6.554	0.004
Margalef index	3	1.872	0.175
Shannon Wiever index	3	2.878	0.069
Total wet biomass	3	4.436	0.019

FIG. 2. – A) Macrobenthos trophic structure-abundance data; B) Macrobenthos trophic structure-biomass data. (C: carnivorous; D: deposit-feeders; H: herbivorous; F: filter-feeders; N: necrophagous; O: omnivorous; ot: others).

mass (Table 6). The LSD *post hoc* test highlighted the fact that these differences were always due to the samples collected in the treated plot in September.

treated plot (March)

control area (March)

Cumulative % dominance

treated plot (September)

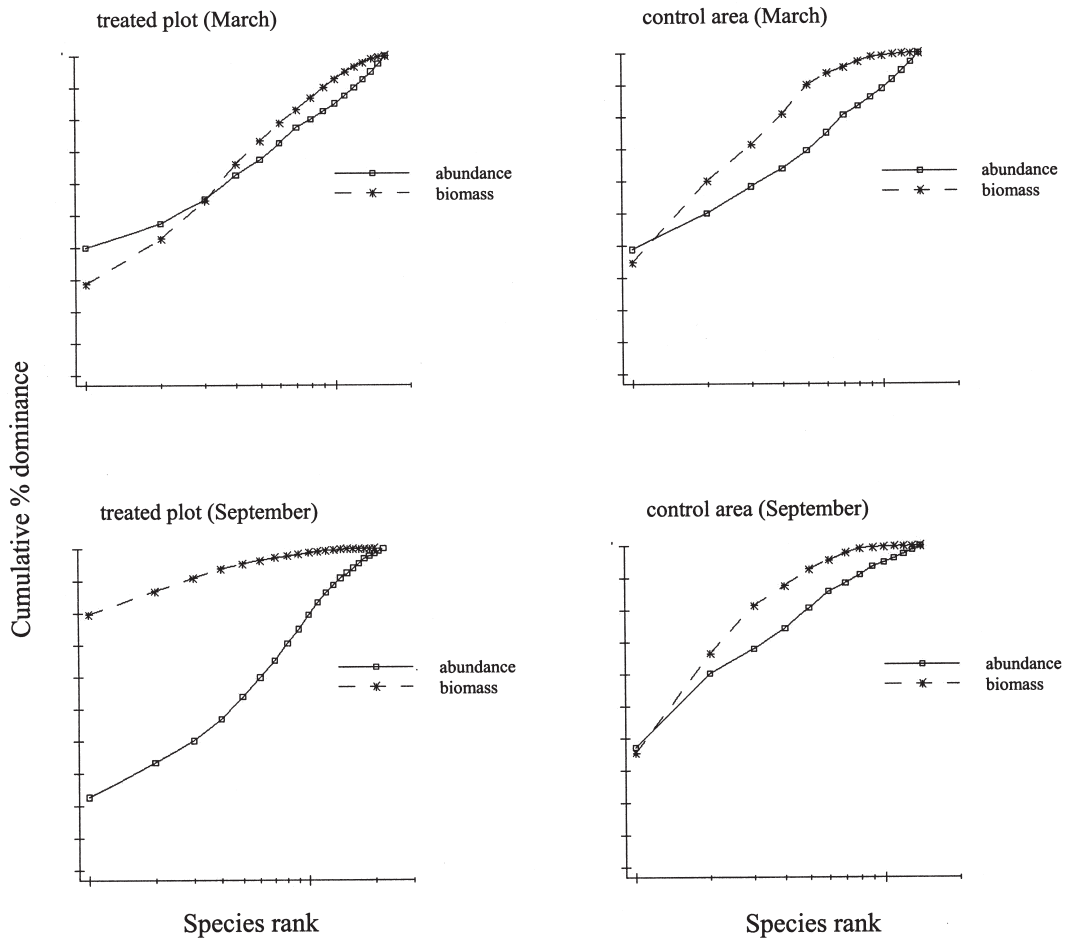control area (September)

Species rank

Species rank

FIG. 3. – Results of Abundance Biomass Comparison (ABC method).

The trophic structure of the macrobenthic community, based on abundance data (Fig. 2a), showed small changes in the control area, whereas the structure changed in autumn in the treated plot, with a more homogeneous distribution of the trophic groups: deposit feeders, almost reaching 50% in spring, decreased to 30%, while an increase was observed in the groups of herbivores (from 3% to 17%) and 'others' (all species whose trophic guild could not be identified).

Based on biomass data (Fig. 2b), both plots showed temporal variations in trophic structure: in September filter feeders were dominant (35% in control area and 87% in treated plot). The overdominance in the latter was mainly due to the *phylum* Porifera, which found a suitable substratum for growth on *Cymodocea* leaves.

The ABC plots of the control area (Fig. 3) showed a slightly stressed community, the two curves intersecting in both sampling seasons (spring W = 0.221, autumn W = 0.136). In the
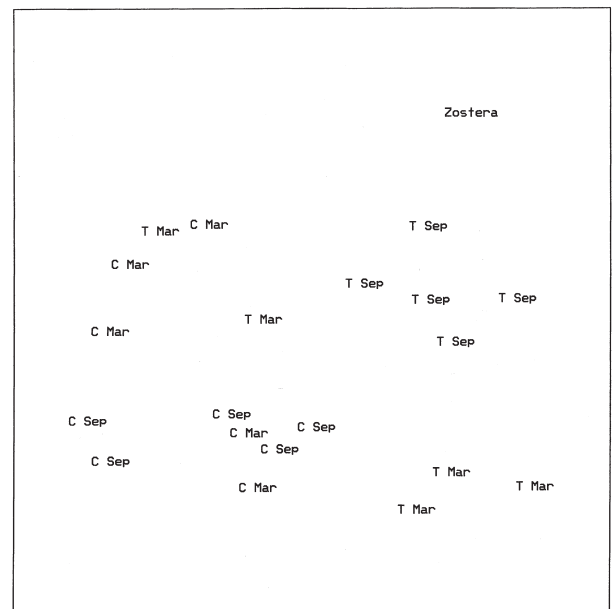

FIG. 4. – Multidimensional Scaling (T: treated plot; C: control area; Cnb: *Cymodocea* natural bed).

treated plot the macrobenthic community appeared to be quite stressed in spring (W=0.07) but was undisturbed (W=0.440) in September, a situation typical of 'mature' and 'stable' environments, with a large dominance of k-strategy species prevailing.

Multidimensional scaling of samples is shown in Figure 4. The T Sep sample group is well separated from the others and is located not far from a reference natural bed of *C. nodosa* (Rismondo, unpubl. data). The other three sample groups (T Mar, C Mar, C Sep) are partially mixed and more widespread. The distribution observed in the F igure 4 is confirmed by the ANOSIM test (p<0.001).

DISCUSSION

Our data show that seagrass transplant produces significant changes in the whole benthic community:

– the high values of macroalgal biomass and coverage recorded in the control area were not observed in the treated plot, where the specific richness of algal *taxa* trebled, mainly due to epiphytic species growing on *Cymodocea* leaves;

– as a preliminary qualitative observation, micro- and meiobenthos in the treated plot reflected a condition with a lower organic sediment load than in the control area; this is especially clear when considering the evolution of Cilate microfauna and the sub-surface interstitial colonization pattern;

– comparisons between treated and control areas showed differences in specific richness, diversity indices and trophic structure of the macrobenthic community, differences which became more pronounced in September. This pattern in the treated plot may be due to the seasonality of *C. nodosa* leaf growth and the effects of meadow density on macrobenthic organism distribution.

The structure of the macrobenthic community in the treated plot changed from early spring to autumn, with a statistically significant increase in diversity and better distribution of organisms among the trophic guilds. This was probably due to recovery of the canopy which, after winter reduction, brought the community to a 'well-structured' status, as also highlighted by the ABC results.

Instead, stress signals recorded in the macrobenthic community in the control area (see ABC results) were probably due to the detrimental effects produced on soft-substrate fauna by contiguous macroalgal mats (mainly *Ulva rigida* and *Chaetomorpha linum*), as also demonstrated by Raffaelli *et al*. (1989) and Norkko and Bonsdorff (1996).

The complete development of the canopy in September also caused increased homogeneity of the spatial distribution of organisms (Irlandi *et al*., 1995), which were more widespread and patchily distributed in March (treated plot) and in samples collected in both seasons in the control area, as highlighted by the MDS ordination.

Comparisons between the transplanted meadow and a nearby natural *C. nodosa* bed showed that, only two vegetative seasons after the experimental transplant:

– seagrass performance was similar in the two meadows. The growth rate, leaf number per shoot and shoot density of the transplanted meadow fell within the range of values recorded in the natural bed;

– in autumn, the structure of the macrobenthic community approached that of a natural bed. As demonstrated by Webster *et al*. (1998), the main factors best explaining macrobenthic community structure are leaf number per shoot and shoot density. Thus, just two vegetative seasons after transplant seem to be sufficient to build up structural complexity similar to that of a natural meadow. Another important structuring factor is the heterogeneity produced by the root-rhizome matrix (Webster *et al*., 1998), which may be very important in *C. nodosa* meadows subject to seasonal canopy reduction; our data confirmed that the belowground biomass (roots, rhizomes) of the treated plot approached that of the natural bed.

CONCLUSIONS

The experiment confirmed the feasibility and interest in *Cymodocea nodosa* transplants using the 'turf technique' in the Lagoon of Venice: the performance of the transplanted meadow quickly reached that of natural beds. Moreover, the possibility of creating or re-establishing a functioning seagrass meadow (*sensu* Kikuchi and Pérèe, 1977) could be evaluated.

Our data also revealed the key-species role played by seagrass in structuring the marine coastal ecosystem (Mazzella *et al*., 1992). This role was clearly magnified in a 'sensitive area' such as the Lagoon of Venice, subjected to growing anthropic pressure and negative impact.

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