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Need for restricting bivalve culture in the southern basin of the Lagoon of Venice

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Abstract

At present, one of the environmental emergencies in the Lagoon of Venice is the impact of short-necked clam (*Tapes philippinarum*) fishery, which is practically an unregulated fishery. Although one of the proposed solutions would be the restriction of *Tapes* fishery to licensed areas, high seeding density can cause undesired effects on the environment. In this study several hydrobiological variables are compared between small areas of the Lagoon of Venice traditionally used for bivalve culture (clam, *T. philippinarum* and mussel, *Mytilus galloprovincialis*), and areas in the southern basin with seagrass meadows. Labile and suspended organic matter in the water was higher in areas with bivalve farming than in *Zostera* areas (undisturbed control). The same pattern was recorded for contents of total organic matter and acid volatile sulphides. The biomass of microplankton in farming areas was quite high (0.8–2.7 g m^{-3}). Mesozooplankton was extremely abundant, particularly at night, when its biomass was 1–2 orders of magnitude higher than during the day. Its composition was different in the culture areas and in *Zostera* areas. The biomass of *Tapes* in culture beds and their filtering capacity were also estimated.

Introduction

As in the 1980s in the Po Delta lagoons, the beginning of the 1990s marked a progressive increase in production of short-necked clam (*Tapes philippinarum*) in the Lagoon of Venice. In 1995, according to assessments by the Ministry of Agriculture (‘Ministero delle Risorse Agricole’, 1997), production exceeded 40 000 tons. Almost all the yield is obtained from fishing, often carried out with unauthorised dredging equipment. Attempts to shift the fishery from harvest of natural stock to aquaculture in licensed areas have not been successful yet, due to difficulties with management and fishermen. The problem has now become a social one, and is of considerable proportions because, according to recent assessments, this activity involves more than 2000 fishermen with a yearly turnover of US $100 million. Only recently in the southern basin of the Lagoon some small areas have been set aside for *Tapes* farming, by seeding juvenile clams collected from natural beds and harvesting at commercial size. Actually the intensive fishing activity causes serious environmental impact in a sensitive area like the Lagoon. The problems are mainly due to the coarsening of the size distribution of surficial sediments, contributing to ongoing erosive processes (Consorzio Venezia Nuova, 1993), and alteration of the benthic biocenosis over large areas (Pranovi & Giovanardi, 1994). A strategy which would limit productive activity to restricted areas would make it possible to reduce the areal extent of these impacts.

However, problems linked to the reduction of specific diversity (which is also observable in the case of fishing on natural banks) and high farming density

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(e.g. outbreaks of pathologies and effects on the environment of bivalve trophic activity at densities of about 1000 specimens m^{-2}) may arise.

The effects of shellfish farming on the environment are well known. Dense bivalve culture causes increased biosedimentation (Jaramillo et al., 1992; Hatcher et al., 1994), eutrophication, enhancement of nutrient flow, sulphate reduction and sulphide accumulation in sediments (Danebach & Gunnerson, 1981; Westrich & Berner, 1984; Kaspar et al., 1985; Loo & Rosenberg, 1989; Alliot et al., 1990; Baudinet et al., 1990; Dame, 1993; Gilbert et al., 1997).

Bivalve culture fields create a powerful biofilter in the Lagoon. Organic matter sedimentation by this artificially created biofilter may fuel sulphate reduction, an anaerobic process which usually induces the building-up of labile sulphide in sediments. This process is one of the most damaging for the ecological quality of coastal marine habitats.

The aim of this work is to analyse the effects of bivalve farming (traditional suspended mussel, *Mytilus galloprovincialis*, culture on lines along poles and clam culture on bottom fields) on plankton, sediment chemistry, and suspended and labile organic matter in the water.

The Lagoon of Venice is a ‘fragile’ ecosystem subjected to heavy anthropic pressure. As remarked above, today short-necked clam fishery produces a most severe impact on the Lagoon bottom. One solution, proposed by local authorities, is to start a wide clam-farming activity, but even this exploitation strategy could produce impact on the ecosystem. Here, we collect information to better evaluate the trade-off between these two activities.

Materials and methods

The study area is located in the southern basin of the Lagoon of Venice, near the city of Chioggia (Figure 1). It is characterised by the presence of mixed seagrass meadows – *Zostera noltii* and *Z. marina* – (Caniglia et al., 1992), a mean depth of around 1 m (with the exception of the deep-water channel) and it is subjected to tidal currents (between 0.1 and 1 m sec^{-1}). Sampling stations were located in an area of suspended mussel culture extending along the slopes of a channel at a depth of 2–3 m, an area of short-necked clam culture (0.5–1.5 m deep), a surrounding shallow area partially covered by seagrass (1.5 m deep), and in the middle of the deep-water channel (7–8 m).

In order to determine the composition of benthic macrofauna, sediment samples were collected with a Van Veen grab.

The effect of bivalve culture on the plankton were tested by collecting zooplankton samples during the second half of August 1995, partially replicated in October 1996. Fifty liters of subsurface water were filtered through a 60-μm-mesh plankton net, both during the day and at night, in order to take demersal components into account. Epifluorescence microscopy was used for the quantification and sizing of bacteria, picoplanktonic algae <3 μm, nanoplanktonic algae, nanoheterotrophs and nanociliates (Caron, 1983). Bacterioplankton was counted on 0.2 μm pore filters stained with acridine orange (Hobbie et al., 1977). Microalgae >30 μm and the larger fraction of ciliates were counted in untreated water samples in glass chambers of 15 ml capacity, according to Sorokin (1980).

The decomposition rate of organic matter in water was measured by the decrease in oxygen content in incubated dark bottles (250 ml capacity) for 24 h at *in situ* temperature. Oxygen was estimated by Winkler titration. The content of labile organic matter (LOM) accessible for microbial decomposition was estimated as BOD_{30}, accounting for the use of part of it for biosynthesis of the bacterial biomass: LOM = $BOD_{30} \times 0.55$ mg C l^{-1}, where BOD_{30} is expressed in oxygen units (Sorokin & Mamaeva, 1980). The turnover time of LOM was estimated as its ratio to the decomposition rate per day expressedin the same carbon units. The carbon content of suspended matter was analysed by wet chromic combustion after digestion of chlorides with phosphoric acid. The content of phosphorus in sediments was measured by standard methods (Parsons et al., 1984). Acid volatile sulphides (AVS) in sediments were analysed by H_2S distillation from gently acidified sediments fixed with a mixed solution of $ZnSO_4$ + Na_2CO_3, after Sorokin (1982).

In order to compare chemical variables recorded in the subareas (*Zostera*, *Tapes*, *Mytilus*) a LSD *post hoc* test was applied to 1995 and 1996 data.

Results

Chemical and dynamical variables

Results of chemical analyses are given in Tables 1 and 2. The concentration of labile organic matter (LOM) in water varied between 1.18 mg C l^{-1} in the channel

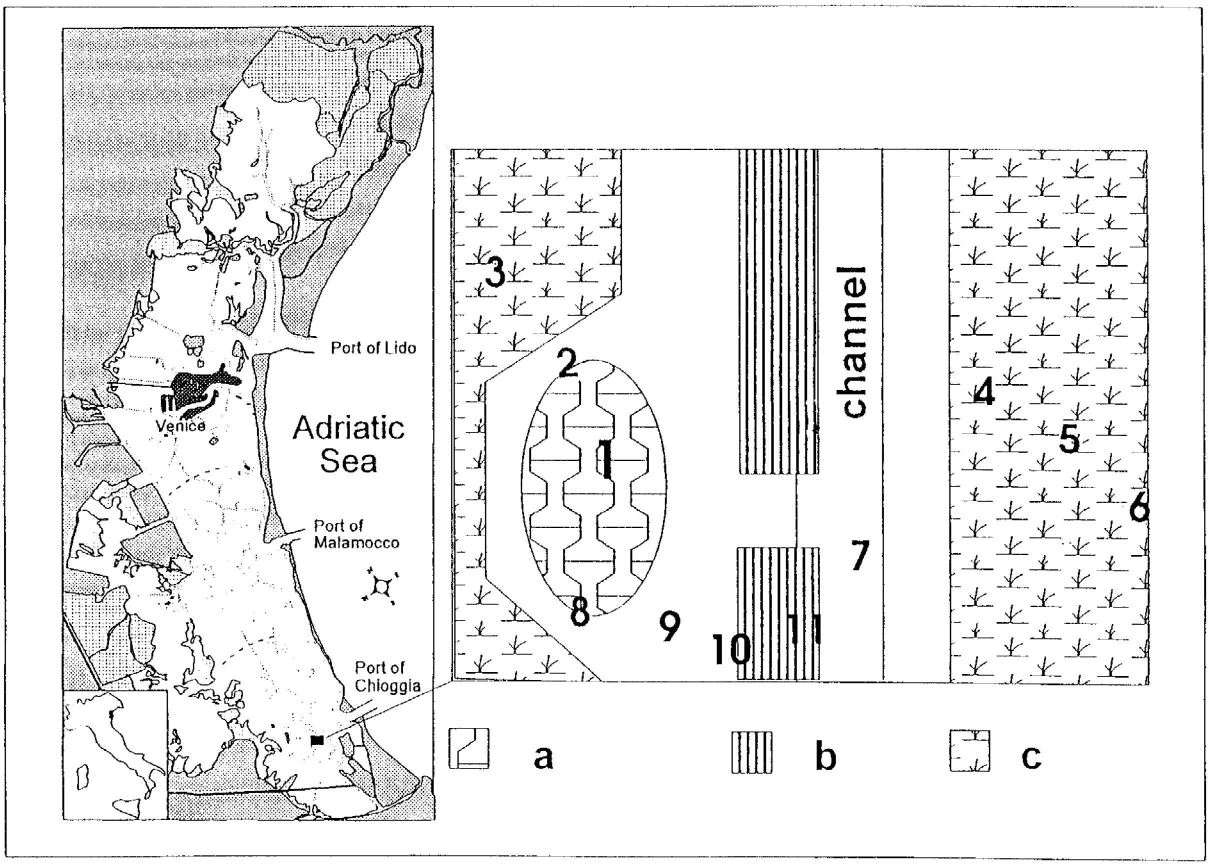

Figure 1. Location of sampling stations (enlargement not to scale) in southern basin of Lagoon of Venice. **a**, *Tapes* fields; **b**, *Mytilus* fields; **c**, *Zostera* meadows.

driving sea water into the shallow areas of the lagoon, and 2.7 mg C l^{-1} in the culture fields. Over the *Zostera* grounds it was significantly lower: 1.3–1.5 mg C l^{-1}. LOM was quite rapidly decomposed and recycled by bacterioplankton. The turnover time of the LOM stock was estimated at 6–10 days, which indicates the time required for complete biological self-purification of water in a given site (Sorokin & Mamaeva, 1980). The decomposition rates of organic matter in water in the sampled stations varied between 0.45 and 1.13 mg O_2 $l^{-1}d^{-1}$, being higher in waters over the *Tapes* fields and significantly higher over *Mytilus* fields.

The content of suspended organic matter in water was high: 1.2–1.5 in the clam fields and 0.7–1.2 mg C l^{-1} in the channel and over the *Zostera* meadows. The values over the clam fields were significantly higher and probably caused by high microplankton density (see Tables 2 and 3) and resuspension of particles accumulated by the dense clam population. Data on total microplankton biomass (Tables 1 and 3) allow calculation of the percentage of living organic matter with respect to total suspended organic matter. This percentage was greater in the *Mytilus* fields (stations 10–11), where it reached 12–18% (Table 1). It was 7.9–8.7% over the *Tapes* fields and 4.5–8.2% over the *Zostera* meadows.

The percentage of organic carbon in bottom sediments varied between 1 and 4% of dry sediment weight in the *Zostera* meadow. In areas of *Tapes* culture it rose to 5–6%, and in those of *Mytilus* it was 8.4%, which is high, even for lagoon sediments. These data highlight the self-eutrophication caused by the filtering activity of dense bivalve populations. Due to shallow waters in the *Tapes* fields the phenomenon is masked by hydrodynamic resuspension of sedimented matter, but even in this case it appears pronounced. The same may be said of the content of total phosphorus calculated in the upper layer of sediments (0–3 cm) in terms of dry weight (Table 1).

Table 1. Chemical and dynamical parameters in water and upper (0–5 cm) layer of bottom sediments, measured in August 1995

Treatment	Stations	Sediment	Depth m	C org % of dry sediments	P org in sediments		AVS in sediments mg S dm^{-3}	SOM		LOM mg C l^{-1}	D mg O$_2$ l^{-1} d^{-1}	T days
					% of dry sediments	g m^{-2} (in upper 0–3 cm layer)		mg C l^{-1}	C org of plankton % tot. SOM C			
Tapes	1	Silty sand	1.0	5.96	0.023	4.84	1190	1.40	8.2	2.37	0.91	7.0
	2	Silty sand	0.5	5.05	0.024	5.01	870	1.35	8.7	2.39	0.65	10.0
	8	Black mud	1.5	4.00	0.022	4.10	1185	1.50	7.9	1.33	0.50	5.1
Mytilus	10	Black mud	2.0	6.50	0.028	5.68	1280	1.50	14.4	1.63	0.72	6.0
	11	Black mud	3.0	8.40	0.030	6.28	1450	1.18	18.3	2.69	1.13	6.4
Zostera	3	Silty sand	1.5	1.02	0.024	5.01	320	1.17	4.5	1.57	0.56	7.4
	4	Silty sand	1.5	3.10	0.025	5.28	460	0.80	8.2	1.32	0.52	6.8
	5	Silty sand	1.5	4.20	0.020	4.23	380	1.20	5.5	1.56	0.48	8.7
Channel	7	Black mud	8.0	8.40	0.023	4.84	1160	0.88	7.9	1.18	0.45	7.0
Intermediate	9	Black mud	3.5	6.30	0.024	5.20	1225	0.70	12.0	1.46	0.56	6.9

Abbreviations: AVS – acid volatile sulphides; SOM – suspended organic matter; LOM – content of labile organic matter in water; D – decomposition rate of organic matter in water; T – turnover time of labile organic matter (LOM/D) value of D expressed in carbon units (D x 0.375).

Table 2. Chemical and dynamical parameters and microplankton densities, measured in October 1996

Treatment	Station	AVS sediments mg S dm^{-3}	SOM		LOM mg C l^{-1}	D mg O$_2$l^{-1} d^{-1}	T		Microplankton				WPB g m^{-3}
			mg C l^{-1}	WPB SOM^{-1} (%)			days	Phytoplankton B	Bacterioplankton N	Bacterioplankton B	Protozoa B	Total biomass	
Tapes	1	480	2.50	4	1.92	1.08	6.6	276	2.70	406	121	803	0.85
	2	316	1.13	11	2.05	1.13	8.8	637	3.03	485	102	1204	1.00
Mytilus	11	738	1.90	8	2.97	1.45	8.9	470	3.15	495	95	1106	1.28
Zostera	3	220	1.50	8	1.28	0.98	4.9	310	2.66	313	113	736	0.97
	5	310	1.70	7	2.35	1.39	6.2	366	2.20	350	114	830	0.93
Channel	7	510	1.40	12	1.89	0.95	7.1	510	2.54	403	79	992	1.36
Intermediate	9	680	2.62	3	4.70	2.62	6.6	350	2.55	383	82	815	0.56

Abbreviations: N – numerical density, 10^6 ml^{-1}; B – wet biomass, mg m^{-3}; WPB – whole plankton biomass. For other abbreviations, see table 1

The acid volatile sulphides (AVS) value in the upper layer of bottom sediments represents one of the most important indicators of the quality of a lagoon environment. In a pristine lagoon, it generally does not exceed 200–300 mg S dm^{-3} of wet silt. If it exceeds 500–600 mg S dm^{-3}, artificial input of labile organic matter, which fuels microbial sulphate reduction in sediments, must be inferred. Our data seems to be in agreement with this hypothesis: in the sediment of *Zostera* meadow, AVS ranged between 320 and 460 mg S dm^{-3}, but in bivalve culture areas it was always significantly higher (870–1450 mg S dm^{-3}). These high values may also induce nocturnal anoxia and the appearance of free H_2S in the water column. Samplings carried out the following year (1996) show that some of the observed values sometimes change considerably (Table 2), mainly due to seasonal fluctuations; only AVS remains significantly higher in *Tapes* field than in *Zostera* meadow.

Microplankton

The total biomass of microplankton, which is the basic source of food for bivalves varied between 0.87 and 2.7 g m^{-3} (Table 3), which is quite high. Even in the sites of high exploitation by an extremely dense *Tapes* population, they attained 1.5 g m^{-3}.

The share of phytoplankton in total microplankton biomass varied from 60 to 90% in deep areas to 20–50% in shallow ones (Table 3). Thus, this share seems to be related with depth and with hydrodynamic conditions: it was higher when water moves over the shallow areas, lost its phytoplankton to grazing, but accumulated microheterotrophs, which grow rapidly,

Table 3. Mean densities (mg m^{-3} wet weight) of microplankton in water samples taken in daytime, at night, and in daytime of following day (August 1995)

Treatment	*Tapes*			*Mytilus* and Channel			*Zostera*		
Time:-	Day	Night	Following day	Day	Night	Following day	Day	Night	Following day
Stations	1, 2	1, 8	2	7	7, 11	7, 11	4, 5, 6	5	5
Phototrophs	550	355	560	550	640	3100	310	270	1010
Nanoheterotrophs	32	34	45	10	10	22	10	13	13
Ciliates	63	20	25	12	63	20	52	123	11
Bacteria	785	690	420	240	335	262	570	824	750
Total biomass	1430	1490	1050	870	1050	2710	940	1230	1790
Phytoplankton (%)	38	24	53	63	61	89	33	22	56

Table 4. Taxonomic composition of net zooplankton in diurnal and nocturnal samples

Day-time samples	Nocturnal samples
Acartia clausi	*Mesopodopsis slabberi* (mysid)
Oithona nana	*Rivulogammarus* sp.
Centropages kroyeri	Nereid polychaetes
Paracalanus parvus	*Idotea baltica*
Labidocera brunenesis (pontellid)	Harpacticoid copepods
Oicopleura dioica	*Acartia clausi*
Oicopleura nana	*Oithona nana*
Sagitta setosa	*Oicopleura nana*
Penilia avirostris	*Oicopleura dioica*
nauplii and *zoea* of copepods	*Ostracoda*
	Penilia avirostris
	zoea of Macrura and Brachyura

using organic detritus and dissolved organic matter produced by benthic vegetation.

Bacterioplankton accounted for 80–90% of microheterotroph biomass (Table 3). The biomass of the protozoan microplankton (80–120 mg m^{-3}) was comparatively low in all samples (Table 2). This was probably due to intensive grazing by abundant (especially during the night) zooplankton (see below). The bacterioplankton biomass in most stations was 2–3 times higher than that of phytoplankton. It thus represented a basic food source for pelagic filter feeders such as *Penilia*, *Oicopleura* and *Paracalanus*, as well as for farmed bivalves.

Zooplankton

Zooplankton was abundant, especially at night. During the day it was dominated by copepods (*Oithona*, *Acartia*, *Centropages*, *Paracalanus*), probably driven by tides from the Adriatic (Table 4). *Sagitta*, *Oicopleura*, *Penilia*, and larval stages (*zoea* and *nauplii*) were also common. At night biomass was dominated by demersal meso- and macro-plankters: mysids, gammarids, polychaetes, harpacticoid copepods, holoplanktonic copepods, and larval stages (*zoea* and *nauplii*).

The zooplankton in all stations in 1995 was quite different in diurnal and nocturnal samples (Tables 5 and 6). The biomass of nocturnal zooplankton at stations 1, 4, 5, 8 and 10 was over 11 g m^{-3}, with a maximum of about 75 g m^{-3}(Table 6). Bioluminescence was observed during night sampling. The composition of zooplankton also differed greatly among stations. In shallow waters with *Zostera* meadows (stations 4, 5) and at stations 10 and 11, situated near or within *Mytilus* fields, the biomass was mainly composed (70–90%) of demersal forms, while in stations located in *Tapes* fields and on the outskirts of *Mytilus* fields, nocturnal swarms of holoplanktonic copepods were observed. Their biomass at night was up to 100 times that during the day. This means that holoplanktonic representatives of zooplankton tend to behave like demersal plankters in shallow biotopes. In deep waters, they migrate during the day to deeper areas, but in shallow waters a significant part of their population hides in benthic vegetation or within *Mytilus* fields.

The zooplankton biomass in October 1996 was lower than in August 1995. The difference between diurnal and nocturnal biomass was also lower in 1996 (Table 7). This decrease may not only be a consequence of succession changes, but a result of general changes in the ecosystem of the southern basin of the Lagoon (Sorokin, 1998).

Table 5. Mean densities of net zooplankton in diurnal samples; stations 5b and 7b were sampled on following day (1995 data)

Stations	Depth (m)	Biomass (mg m^{-3}wet weight)			Total biomass
		Copepods	*Penilia*	*Oicopleura*	
4, 5, 6 (mean)	1.1–1.3	261	97	13	371
5b	1.0	100	5	20	125
3	1.4	246	6	3	255
1, 2 (mean)	1.2–1.5	46	5	5	56
8	3.0	210	10	40	260
9, 10 (mean)	3.5	810	7	45	862
11	6.0	3700	1890	100	5690
7	8.0	376	35	80	491
7b	8.0	810	600	120	1530

Table 6. Mean densities (B, mg m^{-3}, wet weight) of main components of net zooplankton in nocturnal samples (August, 1995)

Treatment	Station	Copepods	*Penilia* (1) Ostracoda (2)	*Oicopleura*	*Veliger*	*Zoea*	Polychaetes	Gammarids	Mysids and Stomatopods	Total biomass
Tapes	1	10 100	260 (1)	110	0	70	0	520	310	11 370
	2	1520	300 (1)	30	10	0	0	280	1980	4120
	8	57 100	460 (2)	0	20	0	1960	6500	8900	74 970
Mytilus	10	1570	30 (1)	120	0	0	0	720	14 400	16 840
	11	2050	50 (1)	20	0	30	0	270	7200	9550
Zostera	4	32	20 (1)	0	20	0	0	480	49 000	49 570
	5	520	60 (1)	0	0	180	60	1650	26 400	28 870
Channel	7	7730	70 (1)	420	0	0	0	400	6900	15 520

Table 7. Diurnal and nocturnal zooplankton biomass (mg m^{-3}); samples collected in October 1996

Treatment	Station	Day (10–13 a. m.)					Night				
		Copepods	*Penilia*	*Sagitta+zoea*	*Oicopleura*	Total	Copepods	Sagitta	Mysids	Gammarids	Total
Tapes	1	160	50	0	5	215	765	66	35	0	870
	2	37	0	10	5	52	156	36	20	0	211
	8	170	80	0	0	250	812	20	410	0	1243
Mytilus	11	105	14	20	0	139	380	0	100	450	930
Zostera	5	84	14	20	0	118	370	0	105	50	723
Channel	7	290	126	130	25	571	415	10	210	0	665
Intermediate	9	56	0	0	0	56	153	20	570	850	1593

Macrobenthos

Stations located under the mussel lines and in the channel are characterised by a low specific diversity. In stations 7 and 11, no living macrobenthos was found, not even *Mytilus*, which often fall from the lines and may be carried away by tidal currents. Inside the *Tapes* area (station 1), despite the massive presence of clams (700–750 spec. m^{-2}), the specific diversity was relatively high (14 collected species). *Tapes* constituted more than 90% of the wet biomass (3950 g m^{-2}). The other species are mainly deposit feeders or belong to necrophagous trophic groups (*Nassarius reticulatus, Loripes lacteus, Tellina* sp., *Euclymene* sp., *Ampelisca diadema, Cyclope neritea*). Instead, in station 2, although located at the edge of the licensed area, only two species, with few specimens, were found (*T. philippinarum, N. reticulatus*). This may have been due to a recent clam harvest, or to treatment of the area in anticipation of new seeding: both operations involve mixing of bottom sediments, with removal of most benthic organisms. The surrounding areas were quite different: a greater specific diversity was observed: 19 species, together with a considerable number of grazers and herbivores species (*Gibbula adriatica, Calliostoma virescens, Cerithium vulgatum, Platynereis dumerilii*) and Ophiuroids (*Ophiotrix fragilis, Amphipolis squamata*) were collected in stations 3 and 4.

Our data allow an evaluation of sedimentary activity in *Tapes* fields. Clam density was over 700 sp. m^{-2} and filtration rate was evaluated experimentally as 0.6–0.8 l sp.$^{-1}$ h^{-1} (Sorokin & Giovanardi, 1995). Thus, the whole *Tapes* community in such fields should filter 10–12 m^{3} of water per square meter of bottom area per day. The average content of suspended organic carbon in this area was 1.4 mg l^{-1}. Clams may assimilate 40–50% of living organic matter, whose share in total suspended organic carbon is about 10% (Table 1). In this case, they could assimilate only about 5% of suspended organic matter subject to filtration. The remaining 95% (around 13 g C, or about 30 g of dry organic matter m^{-2} d^{-1}) is deposited to the bottom. Due to the particular hydrodynamical conditions of the shallow areas only a part of the sedimented organic material is transferred to adjacent areas; a significant fraction inevitably settles within the culture field, stimulates sulphate reduction (Westrich & Berger, 1984), and leads to accumulation of sulphides.

Discussion and conclusions

The results of this investigation confirm previous observations (Sorokin et al., 1996, Sorokin, 1998), and highlight changes in the abiotic and biotic variables of the shellfish farming area.

Data on total microplankton biomass and the share of living biomass in total suspended organic matter are of special interest, since they allow the evaluation of potential food resources for filtering fauna, especially cultured bivalves. These variables are often ignored in routine plankton investigations, although their importance is considerable. Relatively high values of total microplankton biomass in areas of clam culture, where filtering is extremely active, reveal a high rate of production. The source of energy for microplankton reproduction is partly resuspended organic matter accumulating in areas of rapid sedimentation by cultured clams, evaluated by the content of labile organic matter (LOM) in water over the clam fields. LOM rapidly increased in this biotope and was intensively used by microplankton, as indicated by the high decomposition rates over the clam fields.

Data on nocturnal zooplankton show that its composition and abundance were quite different from those of daytime samples. The difference in biomass may be up to 100 times, especially in shallow areas where the bottom is covered by benthic vegetation. This clearly shows the importance of nocturnal sampling to verify the real density and composition of lagoon zooplankton. Daytime sampling leads to considerable underestimation, even of holoplanktonic forms such as *Acartia*, which exhibit demersal behaviour in shallow biotopes (Sorokin et al., 1996).

The extremely dense zooplankton community found in the areas of bivalve culture, with a biomass of up to 50 g m^{-3}, evidently cannot be supported by local primary and secondary production. One of the sources may be the organic matter accumulating in these areas by the filtering activity of the clams. The nature of sources supporting such a large zooplankton biomass needs more research.

Our results support the opinion that, within a background of widespread coastal eutrophication, expansion of *Tapes* culture may be detrimental for shallow basins in the Lagoon. Dense, powerful, biofiltering communities of clams mean that suspended organic matter is channelled to the sediments, and induce sulphide accumulation. This may have negative effects on the widely distributed macrophytes (Everett et al., 1995), in addition to the ‘spatial competition’ between seagrass meadows and clam fields in the same area. The size of clam fields in a sensitive environment, subject to heavy anthropic pressure (Sorokin, 1998), should therefore be carefully managed.

In the present, not completely defined pattern of exploitation of short-necked clam resources in the Lagoon of Venice, it seems in any case that, in general terms of cost-benefits between the two productive strategies – fishing and licensed farming areas – total production being equal, carefully controlled farming may be better in the medium-long term. This is for the following reasons:

1. The environmental impact of the harvesting equipment (mainly a local type of dredge) at present used for fishing in the lagoon is high;
2. Licensed farming in well-defined areas may be considered as relocation of the resource without a further increase in the total quantity of clams in the lagoon;
3. Controlled farming offers better chances of health control and quality certification of clam resources, which is difficult in present conditions;
4. There is a need for co-ordination among producers in order to adopt the best strategies for the market, obtaining better prices by planned, although slightly lower, production;
5. The loss of fine sediment would be restricted to few areas where the use of harvesting equipment of low environmental impact would be permitted.

However, in view of our results, even licensed production in defined areas should be monitored and regulated by restricting farming densities in the various areas, according to their characteristics and to the effects of farming. Moreover, it should be considered that clam redistribution according to their size and density is technically easy and widely performed in several places, such as the Po Delta lagoons (Rossi & Paesanti, 1992).

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