In situ estimations of uptake and release of material by oysters in the Bay of Marennes-Oléron (France)*

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Abstract

The uptake and release of material by oysters (*Crassostrea gigas*) in the intertidal zone were estimated *in situ* in the Bay of Marennes-Oléron (France) in spring and autumn. 10 m long plexiglass tunnels were placed over small tables with bags containing oysters or empty oyster shells (control).

Although in the very turbid conditions of the water column sedimentation of suspended particulate material could be observed in control experiments, higher fluxes (uptake) of seston, POC and PON and especially chlorophyll occurred in the presence of live animals.

Release of dissolved nutrients was not evident from the tunnel with oysters, which is in contrast with studies in other areas with bivalves. This is ascribed to limited mineralization of biodeposits as an effect of resuspension and consequent loss of a significant fraction of biodeposits from the tunnel.

Keywords: material uptake, nutrient release, oysters, seston, chlorophyll.

Introduction

In coastal ecosystems dense communities of suspension-feeding bivalves can play a dominant role in sedimentation of organic matter by their high filtration activity (Sornin *et al.* 1983, 1986, Smaal *et al.* 1986, Kautsky & Evans 1987). Accumulated biodeposits can be mineralized and release nutrients to the overlying water for use in planktonic primary production. In this way, recycling of nutrients in estuaries is highly affected by the presence of dense populations of suspension-feeding bivalves (Dame *et al.* 1991).

In the Bay of Marennes-Oléron (France) oysters (*Crassostrea gigas*) are cultivated extensively. Within the framework of a project on the trophic capacity of the estuarine ecosystem of the Bay of Marennes-Oléron we investigated the uptake and release of material by oyster beds. The Benthic EcoSystem Tunnel (BEST) was used, developed by Dame *et al.* (1984) and applied on oyster and mussel beds by Dame *et al.* (1989, 1991), Dame & Dankers (1988) and Prins & Smaal (1990). Here we present the first results obtained in spring (May) and autumn (October).

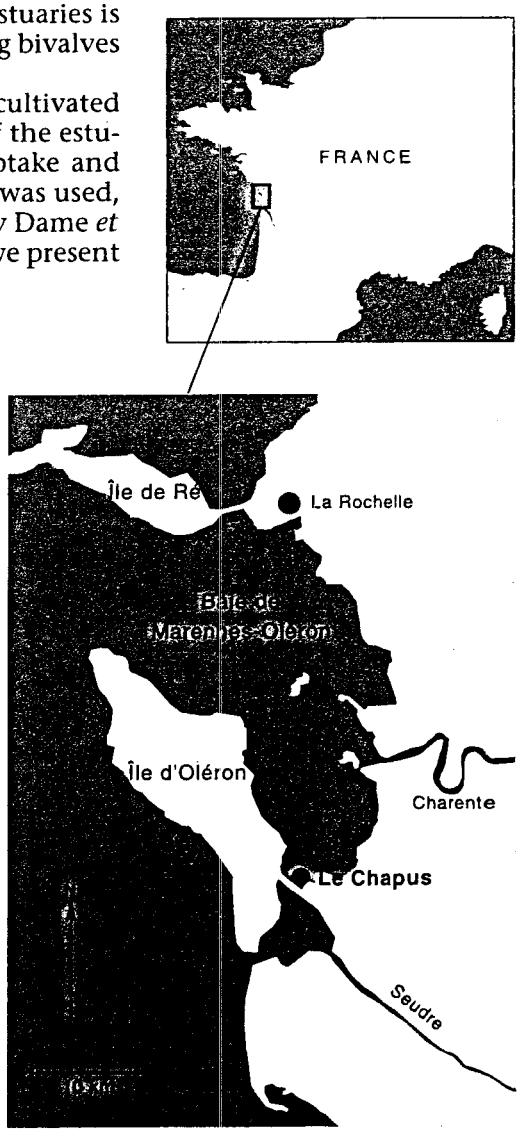
Material and methods

Fluxes of dissolved and suspended materials were determined with two Benthic Ecosystem Tunnels, one as described by Dame & Dankers (1988), the other based on the same principles as described by Prins & Smaal (1990). Both tunnels were used in parallel over oysters or empty oyster shells (control). From earlier experiments it appeared that both tunnels, although slightly different in construction and external dimensions, give comparable results (Prins & Smaal 1990). The tunnels are made of plexiglass plates, joined together by neoprene strips. Approximate measures of the tunnels are: total length between sampling points 10 m, width 0.80 m and cross-sectional area 0.23 m^2. About 8 m^2 of bottom area with or without animals were covered.

Measurements were carried out in the Bay of Marennes-Oléron (France) at Le Chapus (see Figure 1) in autumn (October 1991) and spring (May 1992). Local temperatures and salinities were about 12°C and 30 psu in October and 16°C and 32 psu in May. The tunnels were placed on a tidal flat in north–south direction which is locally the main direction of the current at high water. In our experiments the current at the inside was principally unidirectional during submersion of the tunnels. The level of water came to about 4 m over the tunnel at high tide (spring-tides).

Oysters in plastic bags were placed on small tables, made of iron frames as used by the local cultivators, 5 cm above the sediment. Empty oyster shells in plastic bags served as controls. The tables with oysters were prepared at the experimental site about two weeks before the tunnels were placed over the animals.

Figure 1.
Location of the experimental site Le Chapus in the Bay of Marennes-Oléron (France).



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Sampling procedure

Each experiment lasted two consecutive tidal cycles. The tunnels were submersed for 8-10 h during each tidal cycle. From a small boat lying between the tunnels water samples of 1 l volume were taken at the inflow and the outflow with battery-driven pumps every 30 min during the period of submersion. Samples were analysed for seston, particulate organic carbon (POC) and nitrogen (PON), chlorophyll-*a* and dissolved inorganic nutrients (phosphate, silicate, ammonium, nitrate and nitrite). Details of the analytical methods have been described by Prins & Smaal (1990) and Dame *et al.* (1991).

After each experiment specimens from the bags with oysters were taken and dried for at least 48 h at 70°C. Subsequently the samples were dried for 4 h at 520°C for the determination of the ash-free dry weight.

The biomass of oysters was 129 g AFDW · m^{-2} (174 individuals · m^{-2}) in October 1991 and 139 g (183 individuals) in May 1992.

Calculation of fluxes and statistical treatment of the results

Water flow through the tunnels was calculated from current velocity data continuously recorded by induction flow meters (Marsh McBirney 201M or NSW Meerestechnik) placed in the centre of the tunnels. Earlier calibration studies were used to correlate the current measured at a single point to water flow (Dame *et al.* 1984, Prins & Smaal 1990). The fluxes of material were calculated from water flow times the difference between the inflow and outflow concentrations. Fluxes of control and experimental tunnels were compared by the Mann-Whitney *U*-test. Fluxes occurring at current speeds lower than 2 cm · s^{-1} were excluded as vertical mixing of the water within the tunnel might not be complete. The residence time of the water within the tunnels can be calculated to be less than 8 min at current speeds higher than 2 cm · s^{-1}.

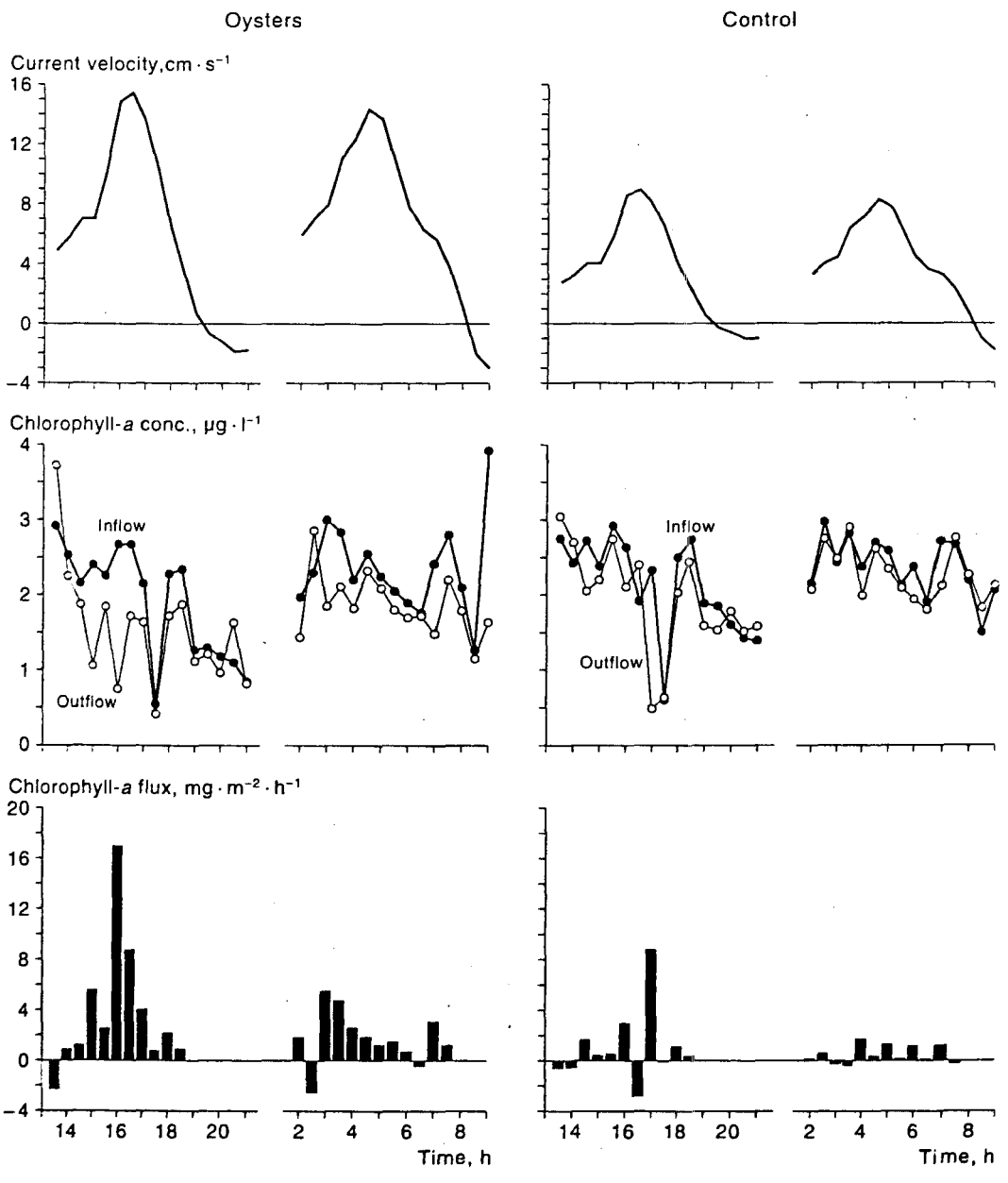

Figure 2.
Chlorophyll fluxes in the benthic ecosystem tunnels with oysters and oyster shells (control) during two consecutive tidal cycles on 8 and 9 October 1991.
Upper part: current velocities measured in the centre of the tunnels. When no values are indicated, the tunnels were not submersed by water.
Middle part: chlorophyll-*a* concentrations at the inflow and the outflow of the tunnels.
Lower part: Calculated chlorophyll fluxes.

Results

The calculated fluxes of seston, POC, PON and chlorophyll (means over one tidal cycle) observed in the experiments are shown for six tidal cycles in Table 1. As an example Figure 2 shows the calculation of chlorophyll fluxes in October 1991. The upper part presents a typical pattern of the current speeds measured during spring-tides at the site of experimentation at Le Chapus. The tunnels were installed in such a way that the current always came from the same direction, except for the start of flood-tide and end of ebb-tide. The outflow concentrations of chlorophyll of the tunnel with oysters were generally lower than those at the inflow during the two tidal cycles shown, which was less apparent in the control tunnel. The calculated fluxes at each moment of sampling are shown in the lower part of the figure. For the second tidal cycle the fluxes in the tunnel with oysters were significantly higher than in the control tunnel ($p < 0.05$; Table 1).

		Seston, $g \cdot m^{-2} \cdot h^{-1}$	POC, $g \cdot m^{-2} \cdot h^{-1}$	PON, $g \cdot m^{-2} \cdot h^{-1}$	Chlorophyll-*a*, $mg \cdot m^{-2} \cdot h^{-1}$
1991					
8 October	Oysters (n = 11)	116 (-414/279)*	2.2 (-6.9/5.3)**	0.37 (-1.04/0.92)**	3.8 (-2.3/17.0)
	Control (n = 11)	56 (-34/177)	0.6 (-2.9/2.4)	0.11 (-0.12/0.31)	1.1 (-2.9/9.1)
9 October	Oysters (n = 12)	140 (-91/379)**	2.0 (-2.9/7.1)*	0.32 (-0.11/0.95)*	1.9 (-2.4/5.6)*
	Control (n = 12)	18 (-137/154)	0.2 (-3.0/3.4)	0.05 (-0.48/0.50)	0.6 (-0.3/1.8)
10 October	Oysters (n = 12)	166 (-22/680)	3.6 (-0.1/14.3)	0.51 (-0.18/1.76)	3.0 (0.0/11.8)
	Control (n = 13)	71 (-202/548)	1.7 (-3.7/9.2)	0.14 (-0.58/0.68)	1.5 (-2.0/8.8)
11 October	Oysters (n = 13)	17 (-448/398)	0.7 (-5.2/6.9)	0.01 (-1.53/1.02)	0.2 (-0.5/1.4)
	Control (n = 10)	66 (7/164)	1.1 (-0.4/3.2)	0.20 (-0.16/0.67)	- 0.8 (-2.5/0.4)
1992					
19 May	Oysters (n = 14)	97 (-8/232)	1.0 (-1.4/3.9)	0.21 (-0.92/0.97)	14.8 (3.1/27.7)***
	Control (n = 14)	87 (-11/215)	0.7 (-0.4/2.9)	0.21 (-0.13/1.09)	3.2 (-3.7/15.6)
20 May	Oysters (n = 15)	40 (-3/139)	0.2 (-1.2/2.1)	- 0.07 (-1.07/0.53)*	4.8 (-23.2/18.0)**
	Control (n = 13)	57 (0/145)	0.7 (-0.2/2.3)	0.34 (-0.22/1.12)	0.4 (-16.6/7.5)

Table 1. (upper)
Fluxes of seston, POC, PON and chlorophyll-*a* in experimental (oyster) and control tunnels (means over one tidal cycle, minimum and maximum values, - = release, no sign = uptake). n is number of samples taken during one tidal cycle. Significant differences between experimental and control groups are indicated: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (Mann-Whitney *U*-test).

		Ammonium, $mmol \cdot m^{-2} \cdot h^{-1}$	Nitrate, $mmol \cdot m^{-2} \cdot h^{-1}$	Nitrite, $mmol \cdot m^{-2} \cdot h^{-1}$	Silicate, $mmol \cdot m^{-2} \cdot h^{-1}$	Phosphate, $mmol \cdot m^{-2} \cdot h^{-1}$
1991						
8 October	Oysters	- 1.8 (-16.1/2.9)	0.3 (-24.8/29.4)	- 0.17 (-2.68/0.90)	- 2.4 (-67.9/21.9)	0.76 (-2.12/5.33)**
	Control	- 0.0 (-1.6/2.8)	0.3 (-5.0/7.1)	0.27 (-0.27/2.38)	1.8 (-4.8/17.2)	- 0.39 (-1.43/0.00)
9 October	Oysters	- 1.2 (-7.7/6.3)	- 1.7 (-9.9/12.6)	- 0.15 (-1.55/1.33)	- 4.6 (-33.6/33.3)	- 0.18 (-0.98/1.20)
	Control	- 1.0 (-4.2/2.5)	- 0.5 (-7.2/6.7)	- 0.02 (-0.66/0.67)	- 0.9 (-17.8/17.8)	0.01 (-0.74/0.61)
10 October	Oysters	- 2.0 (-8.7/7.1)	- 2.8 (14.8/17.8)	- 0.29 (-1.74/1.18)	- 8.3 (-36.0/41.5)	- 0.38 (-2.74/1.07)
	Control	0.8 (-5.87/8.0)	1.6 (-10.9/13.8)	0.09 (-1.28/0.90)	1.7 (-28.8/25.4)	0.23 (-1.16/2.29)
11 October	Oysters	- 2.1 (-11.0/6.2)	- 3.7 (-19.1/13.2)	- 0.30 (-2.05/1.30)	- 9.6 (-47.1/19.4)	0.19 (-1.52/2.35)
	Control	- 0.2 (-10.4/4.7)	- 2.5 (-23.1/7.9)	0.01 (-1.73/1.05)	- 2.3 (-51.0/17.3)	- 0.06 (-1.30/0.87)

Table 2. (lower)
Le Chapus. Nutrient fluxes in experimental (oyster) and control tunnels in $mmol \cdot m^{-2} \cdot h^{-1}$ (means over one tidal cycle, minimum and maximum values, - = release, no sign = uptake). Number of samples taken during one tidal cycle see Table 1. Significant differences between experimental and control groups are indicated: ** $p < 0.01$ (Mann-Whitney *U*-test).

In the tunnel with oysters, fluxes of seston, POC and PON in October were several times significantly higher than the fluxes in the control tunnel. For chlorophyll this was even more evident, also in May. The fluxes observed during one tidal cycle varied over a large range from negative to positive values.

In Table 2 the fluxes of nutrients are shown. For the tunnel with oysters only a phosphate uptake (October 8) and a silicate uptake (May 20) were observed, significantly different from the control tunnel. The variations in fluxes over one tidal cycle again were very large.

Discussion

The turbidity of the water column in the Bay of Marennes-Oléron is generally very high (Héral *et al.* 1983). In our experiments, carried out at spring-tides, seston concentrations ranged from about 30-300 $mg \cdot l^{-1}$. Sedimentation and erosion (resuspension) processes are very important in this bay (Bacher 1989) which can explain the range of observed fluxes of seston (and POC and PON) in the control tunnels. Averaged over the tidal cycles sedimentation was more important. The sedimentation rates found (up to 87 $g \cdot m^{-2} \cdot h^{-1}$) are of the same order as those observed by Sornin *et al.* (1986) in the Bay of Marennes-Oléron under empty culture tables.

Although some suspended material remained within the tunnels, it can be concluded from the differences between control and experimental tunnels that more material and especially chlorophyll was filtered by the oysters. This is in accordance with other *in situ* measurements of the role of bivalves in estuarine environments

(Dame & Dankers 1988, Dame *et al.* 1989, 1991, Asmus *et al.* 1990, Prins & Smaal 1990, 1994, Asmus & Asmus 1991).

These studies demonstrated, however, that in other areas high amounts of inorganic nutrients can be released from mussel beds or oyster reefs, which we were unable to show in our experiments. Mineralization of biodeposits (faeces and pseudofaeces) is believed to produce the release of the nutrients.

Formation of pseudofaeces by the oyster *C. gigas* occurs at seston concentrations above 4.6 mg $\cdot l^{-1}$ (Razet *et al.* 1990). Due to the high seston concentrations observed during our experiments large quantities of pseudofaeces should have been produced. Pseudofaeces of the oyster are formed by very fine material which could easily be carried away by resuspension. In our experiments they could have been transported out of the tunnel and could consequently be mineralized at another site. This loss of biodeposits from the experimental site might explain the absence of nutrient releases from the tunnel with oysters.

Conclusion

Oysters can contribute largely to the sedimentation of suspended material and especially chlorophyll to the bottom.

The release of nutrients is not observed from oyster assemblages which can be the effect of lack of accumulation of biodeposits in our experimental design.

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