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# Uptake and Release of Particulate Materials by Suspended Oyster Culture in Hiroshima Bay: Results From Raft Study

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**Abstract** Seasonal variations of the uptake and release of particulate materials by suspended oyster culture were quantitatively investigated at a floating raft (size of 200 $m^2$) in Hiroshima Bay during October 1995 to August 1996. Samples of inflow and outflow water at the raft were analyzed for particulate matter (PM), chlorophyll *a* (Chl. *a*), and particulate organic fractions of carbon, nitrogen and phosphorus (POC, PON and PP). Sinking particles collected under the raft and ambient area (100 m away from the raft) were analyzed for sinking mass (SM) and sinking carbon, nitrogen and phosphorus (SC, SN and SP). Although the differences in C:N:P atomic ratios of particulate matter between the inflowing and outflowing waters were not significant, but materials concentration of these two waters showed significant differences. SM fluxes under the raft and the ambient area were significantly different. These results indicated the role of suspended oyster culture on materials uptake and release. In addition, the rates of uptake and release of particulate materials at the raft were found to vary with season. The uptakes of PM, Chl. *a*, POC, PON and PP were found in the range of 1.1-8.5 kg DW $raft^{-1}$ $h^{-1}$, 0.8-2.8 g $raft^{-1}$ $h^{-1}$, 6.7-43, 1.3-7.0 and 0.09-0.30 g atom $raft^{-1}$ $h^{-1}$, respectively. The uptake rates of POC and Chl. *a* by suspended oyster culture in Hiroshima Bay are comparable to those reported for densely populated natural oyster reefs and mussel bed in natural environments. The fluxes of SM, SC, SN and SP under the raft were found to be about 60-1,400 g DW $raft^{-1}$ $h^{-1}$, 1.4-12, 0.1-0.6, and 0.01-0.06 g atom $raft^{-1}$ $h^{-1}$, respectively. The results of the present study revealed the significant role of suspended oyster culture on the uptake of particulate materials from water column and the release of materials to the benthic environment of Hiroshima Bay.

**Keywords:** *Crassostrea gigas*, Hiroshima Bay, oyster culture, sinking particles

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## INTRODUCTION

Bivalves have been reported to be the important organisms involving in translocation and transformation of materials in various ecosystems including estuaries (DAME *et al.*, 1984; SHPIGEL and BLAYLOCK, 1991; DAME and LIBELS, 1993; JOSEFSEN and SCHLUTER, 1994). Filter feeding and biodeposition by bivalves are major mechanisms for the uptake of materials from the water column and the release of materials to the benthic environment (BERNARD, 1974; DAME, 1993). Bivalve metabolism actively reproduces dissolved inorganic nutrients i. e. ammonia and other dissolved organic substances into water column. The assimilation is a mechanism transferring materials in the ingested food to bivalve body.

The uptake and release of material by a dense population of bivalves alter both quantity and quality of materials in the ecosystem. In an oyster reef area, chlorophyll *a* was taken up by 23.7 g $m^{-2}$ $yr^{-1}$ (DAME *et al.*, 1992). The pacific oyster, *Crassostrea gigas*, at a density of ca. 2–3 kg $m^{-2}$ was reported to have the filtration efficiency of ca. 34–40% of daily discharged particulate nitrogen from fish pond effluent (SHPIGEL and BLAYLOCK, 1991). KAUTSKY and EVANS (1987) reported that *Mytilus edulis* in a Baltic coastal ecosystem plays an important role on the pelagic and benthic ecosystems by increasing total annual deposition of carbon (C), nitrogen (N) and phosphorus (P) by 10%, and circulating and regenerating of C, N and P by 12 and 22%, respectively. The organic content in biodeposits (30.4%) was also higher than that of natural sedimentation (24.8%). KUSUKI (1981) opined that the oyster growing grounds in Hiroshima Bay, Japan, were deteriorated by biodeposit of the cultured oysters. Mariojouls and KUSUKI (1992) estimated the rate of biodeposition under oyster raft in Hiroshima Bay as about 200 mg DW $g^{-1}$ DMW $d^{-1}$, where DW and DMW indicated dry weight and dry meat weight, respectively.

Although a few researches concerning the release of particulate matter from a floating oyster raft were carried out in the coastal area of Hiroshima Bay, no quantitative information on the uptake of particulate organic carbon (POC), particulate organic nitrogen (PON) and particulate phosphorus (PP) from water column and the release of those materials to benthic environment is available to understand the role of oyster culture. In the present study, an attempt has been made to quantitatively estimate the uptake and release of POC, PON and PP by a suspended oyster culture in Hiroshima Bay. In addition, the role of suspended oyster culture on the materials concentration and C: N: P atomic ratio in particulate matter and sinking particles were evaluated.

## MATERIALS AND METHODS

*Study area*

Hiroshima Bay is the biggest oyster culturing area in Japan with an estimated production of 20,000–30,000 tons FMW (fresh meat weight) $yr^{-1}$. About 10,000–12,000 of floating oyster rafts (20×10×8 m) are used for oyster culture in Hiroshima Bay (KIMURA, 1996). Under the raft, about 28,000 clusters of oysters are suspended using 850 wires of 8 m long. Each wire usually threads with 30–33 clusters of oyster that are separated by 20 cm long spacers. One raft generally produces about 2–3 tons oyster biomass (fresh meat weight) at the time of harvest. The present study was carried out in one of the small bays of Kurahashi Island, as this island is one of the main oyster culture areas in Hiroshima Prefecture (Fig. 1). One of the rafts in the most outer part of the small bay was chosen. The average water depth in the study area is about 10 meters. Field surveys were carried out five times during 1995–1996, i. e. in October 1995, January, April, June and August 1996, representing autumn, winter, spring, late spring and summer seasons, respectively.

*In situ measurement of water current at a floating oyster raft*

The Benthic Ecosystem Tunnel (BEST) and the Experimental Flume were reported to be suitable for the study of material flux in the oyster reef and mussel bed areas, respective-

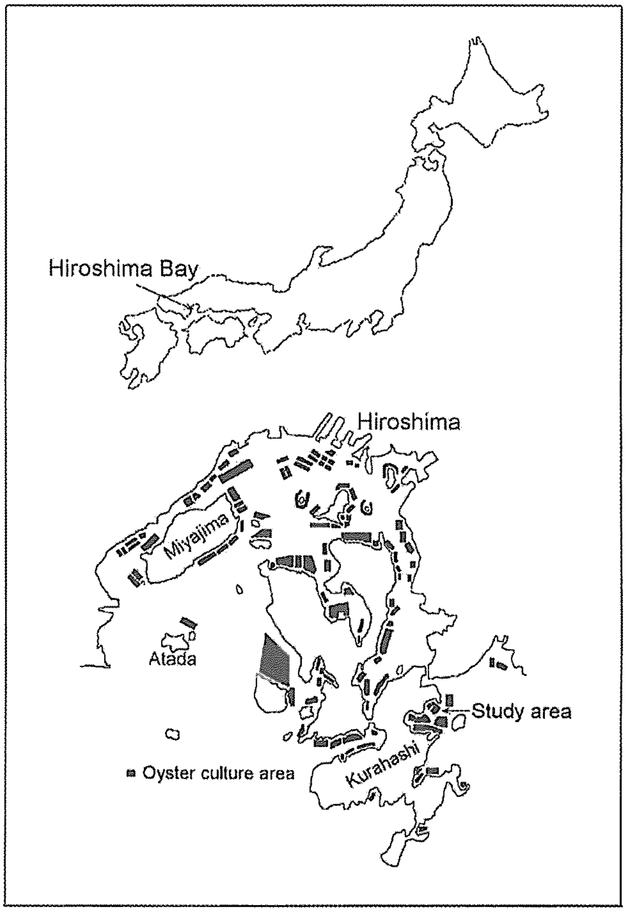


Fig. 1. Map of Hiroshima Bay showing the oyster culture areas and the present study area.

ly (DAME *et al.*, 1984; ASMUS and ASMUS, 1991), as these two methods allow the investigator to accurately measure the movement of water mass. However, BEST and Flume may not be suitable for the present study that carried out at a floating oyster raft, because of a three dimensional large structure and little mobility. Therefore, the movement of water mass was calculated by direct measurement of the water current for 5–10 min at different depths (0.5, 4 and 8 m) in the center of the raft using a current meter (model ACM210-D, Alec electronic). Raft direction was measured against the north during current measurement using a magnetic compass. Since oyster raft is rectangular in shape, current components flowing along X-axis (raft direction) and Y-axis (vertical axis to raft direction) were calculated from the net current for each depth. Based on the dimension of raft, the cross sectional areas along X-and Y-axes were calculated to be about 80 and 160 $m^2$, respectively. The inflowing (IN) and outflowing (OUT) sides were determined according to the net current vector (Fig. 2).

*Sampling and analytical methods*

Water samples were collected from four sides of the raft (outer edge) at the depths of

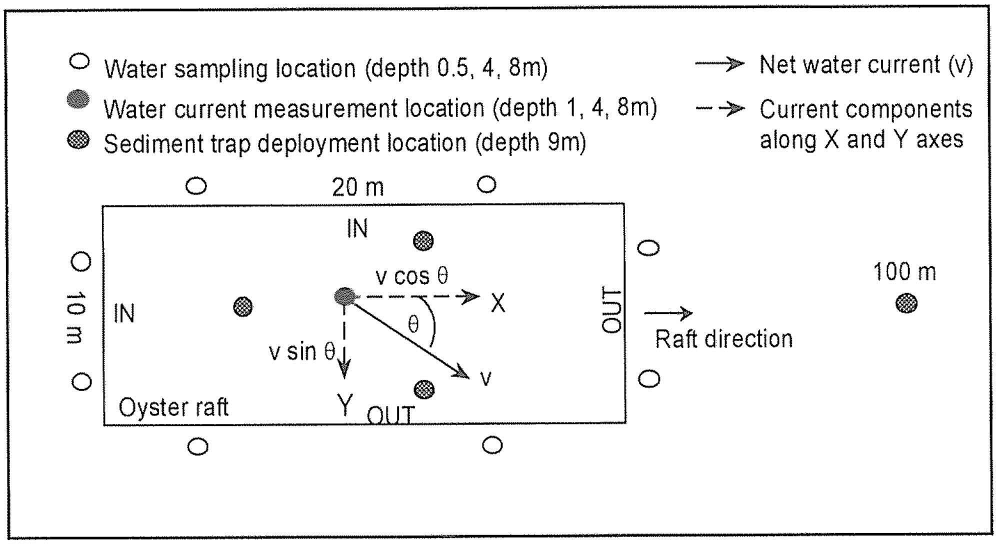


Fig. 2. Top view illustration of oyster raft showing the locations of water sampling, sediment traps deployment and current measurement. Current components along X and Y axes were calculated from net current inside the raft.

0.5, 4 and 8 m, where every side had two sampling locations. One liter of water sample from all three depths of each location was combined to make a composite sample. Water temperature was measured during the sampling. Samples of particulate matter (PM) were prepared on the filter of known weight, removed salt by eluting with 30 ml of ammonium-formate solution (0.9% w/v), and determined as weight after drying at 70°C for 48 h. Chlorophyll *a* (Chl. *a*) was determined from the 90% acetone extracted sample and calculated using the equation of SCOR/UNESCO (STRICKLAND and PARSONS, 1972). For the analysis of POC and PON, particulate matter in water sample was collected on pre-combusted filter (Whatman GF/F). Chloride ion in the sample was removed with 2 ml of $Na_2SO_4$ after the filtration. POC and PON were determined using a CHN corder (YANACO model MT3). PP collected on membrane filter (Millipore HA) was analyzed according to the method of STRICKLAND and PARSONS (1972) after the digestion with perchloric acid in a Teflon bomb at 150°C for 5h (TSUNOGAI and NORIKI, 1989).

Sinking particles were collected by deploying 3 sets of sediment trap at the depth of 9 m under the raft. Another 3 sets of sediment trap were deployed at 100 m away from the raft at the same depth in an ambient area. In order to prevent the entry of large organisms and pieces of oyster shell, a small piece of net (mesh size 0.5 cm) was used to cover the top of the trap before deployment. After removing swimmers and/or obvious contaminant from the samples, supernatant was siphoned out of the trap and all the particles sank in the trap and the remaining seawater were poured into clean polyethylene tanks and transferred to laboratory. Prior to sub-sampling, volume of the collected sample in the tank was measured. The sinking mass (SM) and contents of C, N and P in sinking particles were determined from the sub-samples by following the methods described above.

*Uptake and release of particulate material by suspended oyster culture*

Uptake of the particulate material by the suspended oyster culture from water column was calculated according to the difference in total material flux of IN and OUT of the raft. The velocities of water along X-and Y-axes were used for the calculation of water mass flux along X-and Y-axes ($Wm_X$ and $Wm_Y$; unit $m^3 m^{-2} h^{-1}$). In this study, we assumed that water volume flowing through X and Y cross-section areas at IN were equal to those of same sections at OUT. The net amount of each material taken up ($M_{net}$) for whole raft was calculated as

$$M_{net} = [(Wm \times Mc \times A)_X + (Wm \times Mc \times A)_Y]_{IN} - [(Wm \times Mc \times A)_X + (Wm \times Mc \times A)_Y]_{OUT}.$$

Where $Mc_X$ and $Mc_Y$ are the average material concentration (unit: $\mu$g atom $l^{-1}$) of water flowing through X and Y cross sections. $A_x$ and $A_Y$ are the areas of X and Y cross sections, respectively. The positive value of $M_{net}$ indicates the uptake of particulate material from water column, whereas the negative value of $M_{net}$ indicates the release of particulate material into water column.

The content of materials in sinking particles (Cs; mg atom $g^{-1}$ DW) collected were calculated on the basis of the ratio between the amount of particulate materials and the weight of sinking particles collected on the filter. The SM flux (SMF) was calculated from the mass of particles sank into sediment trap (g DW $m^{-2} h^{-1}$). Total sinking material ($S_{total}$) released from the raft was calculated as the equation shown below

$$S_{total} = Cs \times SMF \times Ar,$$

where Ar is a surface area of raft (200 $m^2$).

*Statistical analysis*

General Linear Model (GLM) procedure was used in order to test the effects of oyster culture (as sampling locations) and season on material concentration in water column and sinking particles. The effects of oyster culture and season on C: N: P atomic ratio were also tested by GLM procedure individually for C: P and N: P atomic ratios. All these tests were performed using Statistical Analysis System (SAS) package (SAS Institute Inc., 1990).

## RESULTS AND DISCUSSION

Depending upon the wind velocity and current direction, the variation of raft direction

Table 1. Variation of net current, flux and retention time of the water flowed through a floating oyster raft.

| | October '95 | January '96 | April | June | August |
|---|---|---|---|---|---|
| Raft direction (degree) | 132 | 145 | 118 | 150 | 132 |
| Net current direction (degree) | 187 | 117 | 143 | 44 | 115 |
| velocity (cm $sec^{-1}$) | 1.09 | 1.33 | 1.40 | 0.84 | 0.75 |
| Water flux along X-axis(1) ($m^3 m^{-2} h^{-1}$) | 22.6 | 42.2 | 45.6 | 8.3 | 35.2 |
| along Y-axis(2) ($m^3 m^{-2} h^{-1}$) | 31.9 | 21.0 | 21.7 | 29.1 | 11.3 |
| Total water flux across oyster raft ($m^3$ $raft^{-1}$ $h^{-1}$)(3) | 6,910 | 7,040 | 7,130 | 5,330 | 4,630 |
| Water retention time under the raft (min) | 13.9 | 13.6 | 13.5 | 18.0 | 20.7 |

(1) X-axis; The longitudinal axis which is equal to raft direction. Cross section area of X-axis = 80 $m^2$

(2) Y-axis; The vertical axis to raft direction. Cross section area of Y-axis = 160 $m^2$

(3) Total raft cross section area = 80 + 160 = 240 $m^2$

ranged from 118° to 150°. During the study period, net current velocity was less than 1.5 cm $sec^{-1}$. Total water mass passing through the raft varied from 4,630 to 7,130 $m^3$ $raft^{-1}$ $h^{-1}$. A retention time of water under the raft was estimated to be in the range of 13–21 min. High retention time was found in summer due to low current velocity (Table 1).

*Particulate materials*

Seasonal variation of particulate materials in seawater in Hiroshima Bay and nearby coastal areas was reported (HASHIMOTO *et al.*, 1996). In the present study, water temperature and the concentration of PM, Chl. *a*, POC, PON and PP around oyster raft varied with the season (Fig. 3). Low PM concentration was found in winter, while high PM concentration was found in autumn and spring. Chl. *a* concentration was found to be high in summer. During the study period, POC, PON and PP varied in the narrow ranges. The average C: N: P atomic ratio of suspended particulate matter over all seasons were about 203: 17: 1 and 192: 17: 1 at IN and OUT of the raft, respectively.

Average concentration of particulate materials sampled at OUT were lower than those found at IN, indicating the removal of particulate materials by oysters associated with the raft. Oyster culture system functions as a biological filter to remove excessive level of

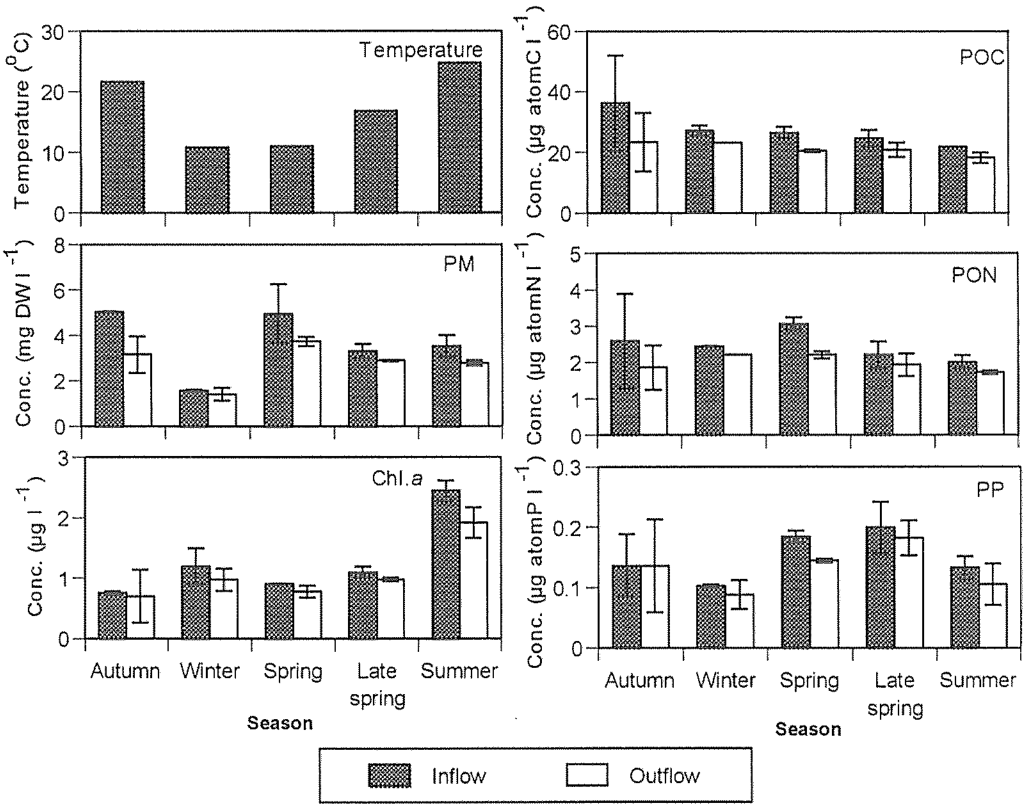


Fig. 3. Seasonal variation of temperature and the average concentration (bar) and SD (vertical line) of particulate matter (PM), chlorophyll *a* (Chl. *a*), particulate organic carbon (POC), particulate organic nitrogen (PON) and particulate phosphorus (PP) in the inflowing and outflowing water of the oyster raft.

Table 2. Results of statistical test for the effect of suspended oyster culture and seasonal variation on materials concentration in particulate matter and sinking particles using General Linear Model. C: N: P atomic ratio was separately tested as C: P and N: P. * indicates the level of significant difference ($p<0.05$).

| Material concentration in suspended particulate matter | | | | Material content in sinking particles | | | |
|---|---|---|---|---|---|---|---|
| | Calculated F value | | | | Calculated F value | | |
| Variable | Total | Suspended oyster culture[1] | Season | Variable | Total | Suspended oyster culture[2] | Season |
| PM | 26.77* | 3.72 | 32.5* | SM | 29.35* | 20.07* | 31.67* |
| POC | 5.53* | 6.08* | 3.34 | C | 41.98* | 1.21 | 52.18* |
| PON | 2.88 | 5.30* | 2.27 | N | 19.58* | 0.08 | 24.46* |
| PP | 4.93* | 1.47 | 5.80* | P | 26.76* | 1.68 | 33.03* |
| Chl. *a* | 26.24* | 4.74* | 31.61* | | | | |
| C: P | 4.12* | 0.14 | 5.12* | C: P | 5.03* | 2.04 | 5.78* |
| N: P | 6.34* | 0.01 | 7.92* | N: P | 1.15 | 2.25 | 0.87 |

[1] Effect of suspended oyster culture was considered as the difference of the variables between inflowing (IN) and outflowing (OUT) side.

[2] Effect of suspended oyster culture was considered as the difference of the variables between oyster raft and the ambient area (100 m away from the oyster raft).

phytoplankton (SHPIGEL and BLAYLOCK, 1991). The concentrations of Chl. *a*, POC and PON in water sampled at IN were significantly higher ($P<0.05$) than those at OUT (Table 2). Although the average concentrations of PM at OUT and IN showed differences, they were insignificant due to some amounts of particulate matter that were retained on the clusters of oysters, and then flowed downstream with the current (MARIOJOULS and KUSUKI, 1992). In such cases, only the concentration of Chl. *a* can indicate the effect of suspended oyster culture on the variation of particulate matter particularly phytoplankton. Our results indicated that suspended oyster culture play a role on the uptake of materials from water flowing through the raft and one of the suitable parameters for the monitoring the oyster role is probably Chl. *a*. Although C: N: P atomic ratio of particulate matter at IN was slightly higher than that at OUT, the statistical test did not show significant difference (Table 2), suggesting that suspended oyster culture did not affect C: N: P atomic ratio in particulate matter.

The variation of temperature and particulate matter have large influences on the filtration of *C. gigas* (BERNARD, 1974; SORNIN *et al.*, 1988). Our results showed that the $M_{net}$ values of PM, Chl. *a*, POC, PON and PP were positive in all seasons (Fig. 4), indicating the uptake of particulate matter from water column. The high uptake rate of PM was found in autumn, while the low uptake rates were found in spring, late spring, summer and especially the lowest in winter, revealing seasonal variation in oyster filtration. However, the uptake rate of individual particulate material was not in good agreement with the rate of PM uptake, as concentration of all these materials did not show similar seasonal variation. The uptake rate of PM, Chl. *a*, POC, PON and PP were found in the range of 1.1–8.5 kg DW $raft^{-1}\ h^{-1}$, 0.8–2.8 g $raft^{-1}\ h^{-1}$, 6.7–43, 1.3–7.0 and 0.09–0.30 g atom $raft^{-1}\ h^{-1}$, respectively. When compared to the amounts of inflowing particulate materials with the outflowing

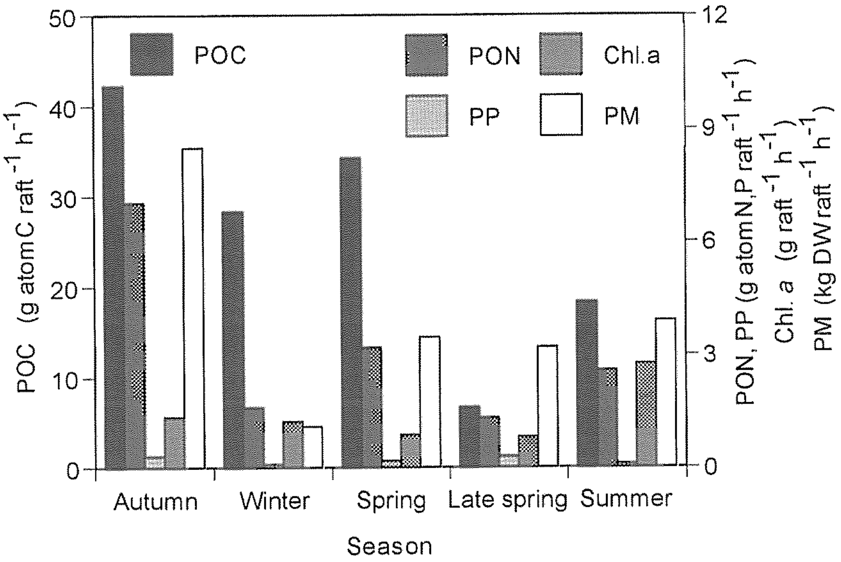


Fig. 4. Seasonal variation of particulate matter (PM), particulate organic carbon (POC), particulate organic nitrogen (PON) and particulate phosphorus (PP), and chlorophyll *a* (Chl. *a*) taken up from water column by oyster culture.

Table 3. The average overall season (mean±S. D) of particulate materials taken up and particulate materials released by suspended oyster culture.

| Material | Particulate material taken up from water column by suspended oyster culture | | Material | Particulate material released to benthic environment by suspended oyster culture | |
|---|---|---|---|---|---|
| | Unit area ($g$ atom $m^{-2}$ $h^{-1}$) | Whole raft[(2)] ($g$ atom raft$^{-1}$ $h^{-1}$) | | Unit area ($g$ atom $m^{-2}$ $h^{-1}$) | Whole raft[(2)] ($g$ atom raft$^{-1}$ $h^{-1}$) |
| PM[(1)] | 20.2±13.6 | 4.0±2.7 ($\times 10^3$) | SMF[(1)] | 4.1±2.4 | 815±486 |
| POC | 130.5±70.4 ($\times 10^{-3}$) | 26.1±14.1 | SC | 23.7±21.6 ($\times 10^{-3}$) | 4.7±4.3 |
| PON | 15.7±11.5 ($\times 10^{-3}$) | 3.2±2.3 | SN | 1.6±1.1 ($\times 10^{-3}$) | 0.3±0.2 |
| PP | 1.0±0.5 ($\times 10^{-3}$) | 0.2±0.1 | SP | 0.15±0.10 ($\times 10^{-3}$) | 30.3±19.9 ($\times 10^{-3}$) |
| Chl. *a*[(1)] | 7.0±3.9 ($\times 10^{-3}$) | 1.4±0.8 | | | |

(1) Unit is g DW $m^{-2}$ $h^{-1}$ or g DW raft$^{-1}$ $h^{-1}$
(2) Raft area is 200 $m^2$

particulate materials, oyster and the other organisms associated with the raft could take up about 5–38% of particulate materials from water column.

The uptakes of POC and Chl. *a* by an oyster reef at the estuary and inlets of the southeastern United States where *C. virginica* was predominant, were calculated to be 1,400–4,400 mg $m^{-2}$ $h^{-1}$ (or 100–314 mg atom $m^{-2}$ $h^{-1}$) and 3.2–17.6 mg $m^{-2}$ $h^{-1}$, respectively (DAME *et al.*, 1984). The Chl. *a* uptake in mussel beds of Kerteminde Fjord, Denmark, estimated using flume study was reported to be in the range of 1.84–6.65 mg $m^{-2}$ $h^{-1}$ (JOSEFSEN and SCHLUTER, 1994). The results of particulate material uptake by suspended oyster culture estimated in the present study were shown in Table 3 and these values are

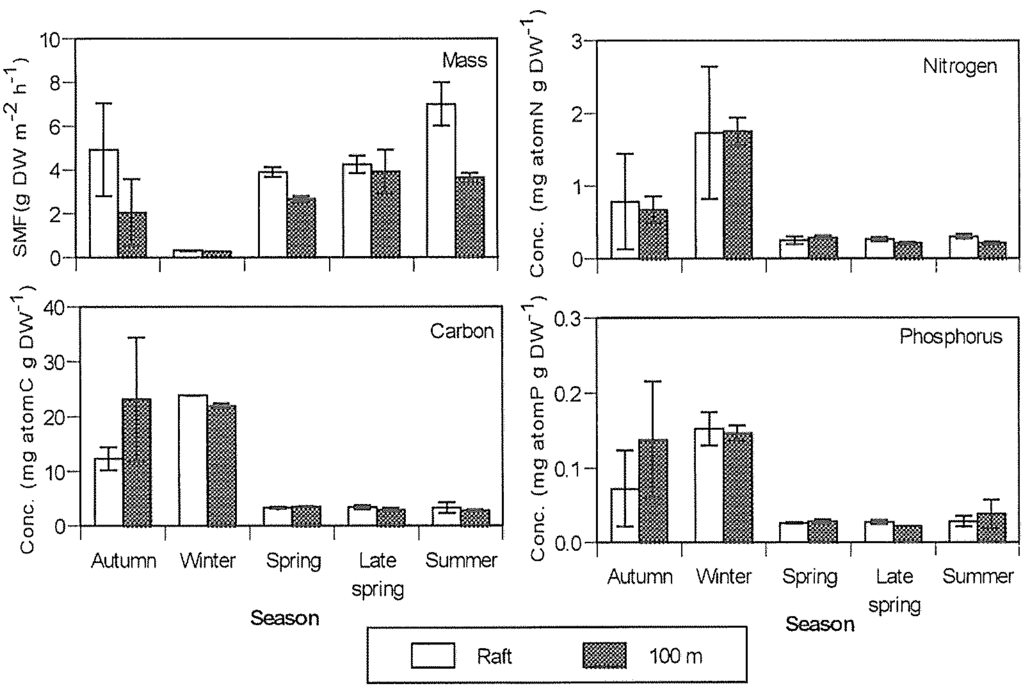


Fig. 5. Seasonal variation of sinking mass flux (SMF) and the contents of carbon, nitrogen and phosphorus in sinking particles collected under oyster raft and at ambient area (100 m).

comparable to the results of DAME *et al.* (1984) and JOSEFSEN and SCHLUTER (1994). From these results, it can be stated that suspended oyster culture in Hiroshima Bay probably provides as much efficiency on the uptake rates of POC and Chl. *a*, as those reported for the densely populated oyster reef or mussel bed in natural environments.

*Sinking materials*

SMF and contents of C, N and P in sinking particles also varied with season (Fig. 5). SMF under raft and at ambient area were lowest in winter. Water pumping and biodeposition rates of oyster were minimized in winter because of low temperature. The biodeposition and water pumping rates of oyster increased together with the increasing of ambient water temperature (BERNARD, 1974). Biodeposition varied with seston consumption by oyster, which was affected by temperature and concentration of seston (RAILLARD *et al.*, 1993). TSUCHIYA (1980) observed positive correlation between suspended particles and the biodeposit production in mussel *Mytilus edulis*. This result is consistent with the result of present study. SMF under oyster raft increased gradually from winter to summer, when the temperature and PM concentration in water column also increased. SMF at ambient area also increased in the similar pattern, which is probably due to high PM concentrations. However, SMF under raft was much higher than that at the ambient area except in winter, when biodepositing activity of oyster was greatly affected by low ambient temperature.

Contents of C, N and P in sinking particles of both under the raft and ambient area

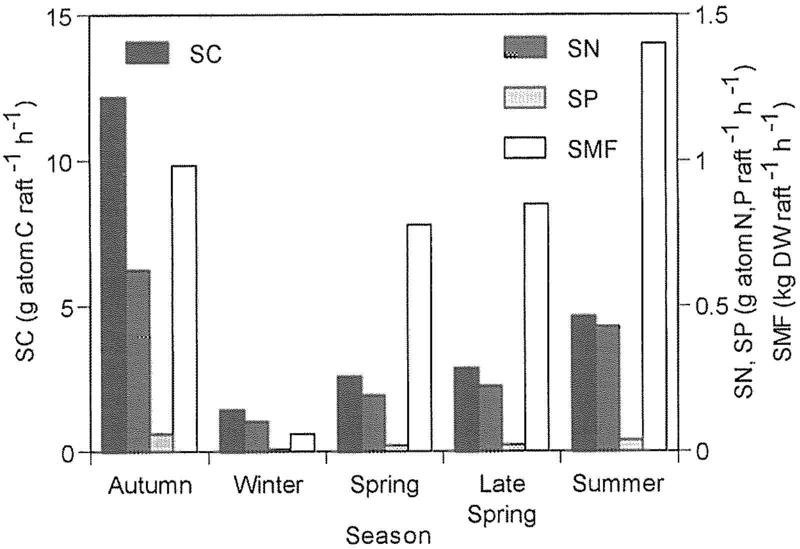


Fig. 6. Seasonal variation of sinking particulate mass flux (SMF), sinking fluxes of carbon (SC), organic nitrogen (SN) and phosphorus (SP) from oyster raft to the benthic environment.

were found to be high in autumn and winter, but found to be low in other seasons. The average C: N: P atomic ratios of sinking particles under the raft and ambient area over all seasons were about 149: 11: 1 and 134: 9: 1, respectively. The statistical tests showed a non-significant difference in contents of C, N, and P between under the raft and ambient area (Table 2). The statistical test for the difference of C: N: P atomic ratio in sinking particles collected under oyster raft and ambient area was similar to the result tested for particulate matter. These may suggest that suspended oyster culture does not significantly affect the variation of neither C: N: P ratio of particulate matter nor that of sinking particles. However, SMF significantly varied with oyster culture and season. Therefore, the results from the present study reveal that suspended oyster culture probably affects the benthic environment through the biodeposited mass rather than their composition. In addition, this result also indicates that SMF is suitable to use as the parameter to monitor release of particulate matter under oyster raft.

The amounts of SMF under the raft were about 60–1,400 g DW raft$^{-1}$ h$^{-1}$, while $S_{total}$ of C (SC), N (SN) and P (SP) under the raft were about 1.4–12, 0.1–0.6, and 0.01–0.06 g atom raft$^{-1}$ h$^{-1}$, respectively (Fig. 6). The average values of SMF, SC, SN and SP for over all the seasons were shown in Table 3. However, these valves may be underestimated because dense clusters of oysters, which are suspended from the raft, may provide small captivities to retain the biodeposit produced by oysters. ARAKAWA *et al.* (1971) conducted the study on biodeposit production in the same study area and concluded that only 20–30% of sinking particles could be collected by the trap under oyster raft. At the level of 30% of the collected sinking particles, the average value of biodeposit production by suspended oyster at the raft of the present study could be estimated to be about 2,716 g DW raft$^{-1}$ h$^{-1}$. This amount accounted for about 68% of the suspended particulate matter taken up from water column by the suspended oyster culture.

## CONCLUSION

The results from the present study revealed that suspended oyster culture plays a significant role on the uptake of suspended particulate materials from water column and the release of particulate materials to the benthic environment of Hiroshima Bay. The suspended oyster culture showed less effect to alter C: N: P atomic ratio in particulate matter and sinking particles. However the suspended oyster culture showed significant effect on concentration of material flowing through the raft, and also on the sinking mass under the raft. In addition, the rates of uptake and release of particulate materials at the raft were found to vary with season. Based on the results, chlorophyll *a* is a suitable parameter to monitor the uptake of particulate matter, and sinking mass is suitable to use as a parameter for monitoring the release of particulate matter under oyster raft.

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# 広島湾の垂下式カキ養殖による粒状物質の取り込みと排出：現場養殖筏における研究

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沿岸域で行われている垂下式カキ養殖による粒状物の取り込みと排出の季節変動を定量的に明らかにするため，1995年10月～1996年8月に広島湾の養殖筏を対象に研究を行った。筏 (200 m$^2$) の上流と下流の粒状物質 (PM), クロロフィル a (Chl. *a*) および粒状態有機炭素 (POC)・窒素 (PON)・リン (PP) を測定した. 筏下および対照海域（筏から 100 m）における沈降物の質量 (SM), 炭素 (SC)・窒素 (SN)・リン (SP) 量を測定した。筏に流入する海水の上流側と下流側での粒状物質の C: N: P 比に違いはなかったが，それらの濃度には有意な違いが見られた。筏下と対照海域での SM フラックスは大きく異なっていた。これらのことは，垂下式カキ養殖が物質の取り込みと排出という面で大きな役割を果たしていることを示している。さらに，筏での粒状物質の取り込みと排出の季節変動は大きいことがわかった。すなわち，PM, Chl. *a*, POC, PON, PP の取り込みは，それぞれ 1.1-8.5 kg DW raft$^{-1}$ h$^{-1}$, 0.8-2.8 g raft$^{-1}$ h$^{-1}$, 6.7-43, 1.3-7.0, 0.09-0.30 g atom raft$^{-1}$ h$^{-1}$ であった。広島湾の垂下式カキ養殖による POC と Chl. *a* の取り込み速度は他の海域の高密度天然カキ礁やイガイ床で報告されている値と同程度である。筏下における SM, SC, SP の沈降フラックスは約 60-1,400 g DW raft$^{-1}$ h$^{-1}$, 1.4-12, 0.1-0.6, 0.01-0.06 g atom raft$^{-1}$ h$^{-1}$ であった。この研究の結果は，広島湾において粒状物質の水柱からの取り込みと海底に対する負荷という点で，垂下式カキ養殖が果たしている役割が大きいことを示している。

**キーワード**：カキ養殖，沈降粒子，広島湾，マガキ