Eco-technological approach for improving environment in a hypertrophic enclosed bay, Japan

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Abstract

To improve the water quality in a hyper-eutrophic enclosed bay, we have established an interdesiprinay research project from 1995 to 1997. This study was conducted for development of new eco-technology to treat hyper-eutrophicated water. In this research project, we are aiming at promoting material circulation with activities of mussels in the bay ecosystem. The system, which consists of 50cm-long ropes to collect mussels, are settled from surface to 1.5m depth. Two ropes which settled at upper layer(0-0.5m) and lower layer(1.0-1.5m) are collected for each month from February to September, 1997. After retrieval of the rope, mussels were numbered, and their shell length and body weight were measured. Furthermore, we conducted some experiment in the laboratory to determine the clearance rate and the assimilation efficiency of mussel. Total settling mussels biomass are rapidly increased from April to September. The integrated values of settling *Mytilus galloprovincialis* biomass on each 50cm long ropes, increased from 0g in February to ca.7800g in August at upper layer, and 0g to ca.4700g at lower layer. In the experiment, the clearance rate of *M.galloprovincialis* increased with the magnitude of shell length, are expressed in (V) according to the following:

$$V(\mu molC/h)=0.896*SL+0.202$$

where SL is shell length. About the assimilation efficiency, it is expressed with 36% for nitrogen and 20% for phosphorus. Total nitrogen and phosphorus contents in *M.galloprovincialis* was 11.8 mgN/g (d.w.) and 1.1 mgP/g (d.w.), respectiv

ely. However, the role of mussels cultured on rope collector was estimated from biomass and individual activities, the clearance rate(gC/rope/d) of the whole rop e collected in August was as same value as the 18m^2 of primary productivity, w hen the red tide was occurred. Furthermore, assuming one rope collected in Aug ust was submerged into the water mass with the volume of 25m^3 (5x5x1m), the relationship between the values of assimilation rates and loading rates indicate t hat 70.1% of DIN and 163% of DIP loaded to the 25m^3 box were assimilated by them. Therefore, mussels can play good role as a N, P cleaner in hyper-eutr ophic enclosed bay, such as Dokai Bay.

Introduction

From 1901, Dokai bay was suffered from eutrophication caused by factory or domestic drainage, and still now, one of the most eutrophicated bay in Japa n(Fig. 1). From spring to autumn, red tide frequently occurs in Dokai Bay, Kita kyushu City, Japan, sessile animals on a quay including a mussel, *Mytilus gallop rovincialis*, often exhibit potentials to graze the phytoplankton vigorously.The cap asity of bivalves as eutrophication control is suggested for different aquatic ecos ystems(Nichols et al.1985, Alpine and Cloern 1992) and is often seen as a cons equence of sudden increases in exotic suspention-feeding bivalves(Caraco et al.19 97). And it is expected that the effect of bivalves as water depuration will incre ase with increase in closing efficiency of aquatic capacity such as Dokai Bay. H ereout, we conducted to apply these biological activities to decrease the density of phytoplankton in the water column directry, and harvest these recruit or growt h mussels to decrease the loading nutrients with utlization of food chain. In this study, we presented the new eco-technology, which could be applicable to impr ove the environmental conditions in other various enclosed bays that have been suffered from the environmental disturbance due to eutrophication.

Material and method

Field experiments

The system, which consists of 50cm-long ropes to collect mussels, is show n in Fig. 2. This system was moored in the sea to a depth from surface to 1.5 m at Stn.T, from February to September 1997. Monthly samplings were perform ed to remove each rope located at upper layer(0-0.5m) and lower layer(1.0-1.5m).

The abundance, individual shell length and wet weight of mussels attached to the ropes were measured. The vertical profiles of water temperature, salinity and dissolved oxygen were diterminded by STDDO-meter(ADR-1000) from sea surface to the bottom, and water samples for chemical analysis were taken monthly from the three layers(0,1.5,Bottom-1 m) at Stn.T from March to September 1997. Water samples were filtered onto a Whatmann GF/F filter for determination of particulate organic carbon(POC), nitrogen(PON), phosphorous(PP), Chlorophyll a(Chl a), and filtered seawater for nutrients. Filtered samples for determination of POC, PON were freeze dried (-20C,24h) and analyzed by CHN coder(YANACO MT-Type3). PP was extracted by 4%$K_2S_2O_8$ method and determined by the molybdenum-blue-method (Parsons et al.,1984). Chla was extracted by N,N-dimethylformamide-method (Suzuki and Ishimaru,1990) and determined spectrophotome-trically with the Lorenzens method(1976). Filtered water samples for nutrient were analyzed by using a Technicon Auto-Analyzer II .

Laboratory experiment

To estimate the retention rate and the assimilation efficiency of mussel, we conducted experiment in the laboratory. Diatom *Skeletonema tropicum* which is the predominant species of phytoplankton during summer in Dokai Bay were cultured with ESM medium at 21C as a food particles for mussels. Cells were carefully sieved through a 10μm mesh screen and transferred into the vessel contained sterile filtered seawater. The mussels for this experiment were collected from the rope which sampled on August 1997 at Stn.T. They were distributed into a size class S(15=5mm), M(25=5mm) and L(35=5mm) and kept in tank containing seawater passed through a membrane filter(0.45μm) for 1 day before the experiments. The experimental schema are shown in Fig. 3. Each size of the mussels were previously placed on the funnel connected to Erlemmeyer flask which traps their feaces, and submerged into the vessel filled with 3-litter of filtered seawater including *S. tropicum*.. The aeration in the vessels were adjusted to suspend the food particles constantly. The retention rate of mussels were determined by the reduction of phytoplankton density with using Turner Design Fluorescent Photo Meter(AU-10) and at the same time nutrients variance are traced. This measurement was performed 48h-long from when the mussels start their filteration. Water temperature and light intensity were adjusted constant during experiments with the levels of 20C and 370 lux, respectivery. After 48hours, the total nitorogen and total phosphorous of whole vessel were measured to determine the assimilation efficiency.

Results

Field study

Seneral vertical profiles measured during sampling period at Stn.T, are sho wn in Fig. 4. Vertical distribution of water temperature and dissolved oxygen(D O) concentration were constant during the sampling period, with the maximum v ertical variations always less than 1C or 1.5mg/l. Mean water temperature during the sampling period ranged from 10.7C(SD=0.06) to 28.1C(SD=0.12) which obs erved on February and August, respectively. The highest DO concentration was observed on February with the mean value of 14.2mg/l(SD=0.09) and the lowest that observed on June was 5.9mg/l(SD=0.99). Although the DO concentration d ecreased during summer period, the anoxic water masses were not observed. Sali nity did not change intensively from surface to the bottom (less than 1psu) exce pt in September when the lowest salinity(25.2psu) was observed.In the summer p eriod, the red tide of the *S. tropicum* , reaching abundance ca.2000cells/ml was observed. Due to this red tide, the Chla concentrations increase extremely in this period, and the highest value of 63.2μg /l was observed in August. Except the summer period, Chla concentrations were remained constant less than 10μg/l.

The mussel biomass(w.w.) was calculated by expression of relationship bet ween individual shell length and the wet weight of *M. galloprovincialis* in Doka i Bay (Fig. 5). Total settling mussels biomass are rapidly increased from April t o September. The integrated values of settling *M.galloprovincialis* biomass on ea ch 50cm-long ropes, increased from 0g in February to ca.7800g in August at up per layer, and 0g to ca.4700g at lower layer(Fig. 6). Intensive decrease of musse l biomass was observed from August to September, and finally the biomass dimi nished to 733g/rope at the upper layer and 67g/rope at the lower layer in Septe mber.

Retention and assimilation rate of mussel

This experiment were conducted to clarify the clearance rate and assimi lation efficiency of *M.galloprovincialis*. The clearance increased with the magnitu de of shell length(Fig.7), and the assimilation efficiency is expressed with 36% f or nitrogen and 19.5% for phosphorus. Total nitrogen and phosphorus contents in *M.galloprovincialis* was 11.8 mgN/g (d.w.) and 1.1 mgP/g (d.w.), respectively.

Discussion

The eutrophic area is well-known for that raises some serious ploblems, such as red tide, development of anoxic water masses, or mortality of marine organisms. During observation period, the red tide caused by the diatom was occured in summer. Because of high imputs of inorganic nutrients, it is likely that light intensity or water temperature will act as a limiting factor of phytoplankton activities. Tada et al.(submitted) suggest that the growth rates of phytoplankton community is correlated by water temperature in Dokai Bay. Sessile animal community, in the most of these enriched places, is dominated by exotic filter-feeders such as mussels *M. galloprovincialis.* Kajiwara and Yamada(1997) suggested that more than half of total biomass of sessile animals observed in Dokai Bay, were occupied with exotic spesies, par excellence, *M. galloprovincialis.* was the most predominant species. In view of mussel larvae, new settlement to the rope collector was observed from March to July, and the total abundance settle to the rope increase expeditious to 4000ind/rope. With a view to harvest efficiency, we adjusted the depth and period of settling trap system, furthermore the rope material was contrived to urge the settlement of mussels, selectively. As a consequence, mussels biomass exceeded to ca.90% of sessile animals attached to a rope collector, which the values with more than 4-times compared to 1995 or 1996(Fig.8). From August to September, intensive decrease of mussel biomass due to mortality was observed, and probably caused by high water temperuture refered to Yamochi et al.(1995) and/or Kajiwara et al.(1978). Furtermore, Yamochi et al.(1995) estimated that the role of mussels in the cycling of nitrogen in Osaka Bay, and suggested that the values of loading effect coused by mortality of mussels are higher than its depollute effects of water with their retention or filteration. It could be expected that applying removal trap system to avoid high temperature, such as used in this study, can prevent from suffering mortality. Thus, the reasons why we choose this species to examine for improve water qualities are expressed: 1.The high ability of physiological tolerance to the eutrophication, 2.High productivity, 3.Simply harvest, 4.Possibility of utilization of edible mussels as a useful sorces.

To estimate the contribution of mussels cultured on the ropes, we made up the box model of biophile elements cycle in summer period of Dokai Bay(Fig.

9). Takeda et al.(1994) conducted to determine whether plankton occurring at a high density, such as that found in red tide water masses, can be removed effectively from water layers by mussels. For the purpose to assure this attempt, the role of mussels cultured on rope collector was estimated respecting the period of red tide(August) in Dokai bay. According to the clearance rate of mussels determined from particle density and individual size in this study, the crearance rate of whole mussels attached to the rope which sampled in August was estimated with the value of 25.8gC/m^2/day. As concerns primary productivity in Dokai Bay, in August 1997, Tada et al.(submitted) reported that with the value of 1.42gC/m^2/day, and most of primary production (ca.72%) arose at the surface layer(0 to 1m depth). Assuming one rope collected in August was submerged into the water mass with the volume of 25m^3 (5x5x1m), the value of clearance rate of the mussels attached to the rope being equal to the value of primary productivity in this water mass, when the red tide was occurred. Furthermore, the relationship between the values of assimilation rates and loading rates indicate that 70.1% of DIN and 163% of DIP loaded to the 25m^3 box were assimilated by them, where the roading rates were calculated from ratios between this presumptive boxs volume and whole water volume of Dokai Bay. Therefore, mussels can play good role as a N, P cleaner in hyper-eutrophic enclosed bay, such as Dokai Bay. We are trying to harvest these recruit and growth mussels to decrease the density of red tide phytoplankton, directly. In this study, we presented the new eco-technology, which could be applicable to improve the environmental conditions in other various enclosed bays that have been suffered from the environmental disturbance due to eutrophication.

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