D-1.1 Study On the Mechanism of Variation in Ocean Element Cycle

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Abstract We have developed a mesocosm (marine enclosure) at Seto-inland sea in order to understand the mechanism of ocean element cycles based on biochemical processes. The mesocosm enclosed cylindrical water column (5m in diameter and 18m in depth), and the upper layer (0-5m) was identified as the euphotic layer. Nutrients were added into the water column, and chemical/biological conditions have been monitored for 19 days.

Carbon tracer experiments were done within the water column. The transformation rates of dissolved inorganic and dissolved organic carbon (DIC and DOC) into biogenic particulate organic carbon (POC) were observed through the experiments.

Variations in the transformation rates, phytoplankton species and concentrations, carbon standing stocks and other oceanographic parameters were analyzed. Followings are the major results obtained through this research.

a) Phytoplankton species succession; the dominant species were categorized into *Centrales*, *Pennales* and *Pyrrophyta*. Succession of these was explained by the variations in nutrient concentrations.

b) Carbon standing stocks; POC was not increased both at the upper layer and the lower layer even after successive phytoplankton bloom, while DOC increasing at both layers.

c) Carbon transformation rates; the transformation rate of DOC into POC (through the bacterial loop) was 20 % of that of DIC into POC (through the photosynthetic loop) at the upper layer in average, but just the same at the lower layer in average.

d) Methods developed; pigments analysis methods to understand the component of POC and continuous P_{CO2} monitoring system were developed.

Key Words Mesocosm, Carbon-cycles, photosynthesis, Grazing, Mineralization, Sediment

1.Introduction

Increasing loads of anthropogenic pollutants such as nutrients, organic matters and toxic chemicals deeply concern the marine elemental cycles. Especially the loads into inland bay and coastal sea zones are large, it is expected to influence the marine environment in the continental shelf zones and thereby affect the global element cycles.

Characterization of carbon cycles based on biochemical processes is essential to understand the cycles of pollutants within marine ecosystems. Especially the characterization of carbon transfer into higher trophic levels is important, because it could be linked with the characterization of pollutants being concentrated within the ecosystems.

Carbon elemental cycles within marine ecosystems have been examined from quite a many aspects. But the quantitative analysis on the carbon flux among marine ecological components is still not enough to explain the variations in the flux together with the variations in the chemical, biological and physical conditions.

In this study, we have used a mesocosm (marine enclosure) in order to analyze the carbon transformation flux through biochemical reactions. Because the mesocosm allows to develop mass-conserved ecosystems and thereby allows to analyze the variations in the carbon biochemical flux, quantitatively.

2.Research Objective

The final goal of this research is to develop a model of element cycles in coastal zones. This could be done through the analysis of the dynamical link of each chemical, biological and physical process forming the elemental cycles.

We have selected a way to simplify the physical conditions and to reproduce the biochemical conditions of coastal zones, using the marine mesocosm. The mesocosm contains the natural ecosystems at the Seto-inland sea, and permits substances transfer only in vertical direction.

Within the mass-conserved water column, we have observed quite a many parameters. Using the parameters, processes performing the biochemical carbon cycles were analyzed.

3.Research Method

(1) N.I.E.S. Mesocosm

Water column was enclosed cylindrically (5m in diameter and 18m in depth, contains 350m^3 sea water), using five rings made of stainless pipes and ethylenevinylacetate reinforced with polyester grids. This material is extremely strong, flexible, translucent and no elution from the surface. The top rim was fixed to flotation module, and the bottom rim was positioned in the sediment with the aid of scuba driver. The stainless rings were fixed using anchors in order to prevent the mesocosm being moved.

Vertical mixing in the upper layer (0-5m) was provided by a circulating system. Water taken from the surface was discharged through a nozzle of vertical jet which was placed within two PVC pipes submerged in the water column (from surface to 3m depth). Vertical jet entrained the surrounding water in the pipes, and thereby brought over this water from the bottom of the pipe. This circulating system created very slow vertical circulation to suspend non-motile phytoplanktons such as diatom. Outside surface water was pumped through Millipore filters into the water column in order to compensate the sample water volume.

(2) Experiments and Observation

Just after enclosing the water column on July 24th, DIN, DIP and DISi were added into the whole water column. Also these were added into the lower water column on Jury 30th and August 4th. On August 9th, only DIN and DIP were added into the lower water column. On August 6th, the circulation system was stopped in order to prevent nutrients being re-suspended from the bottom sediment.

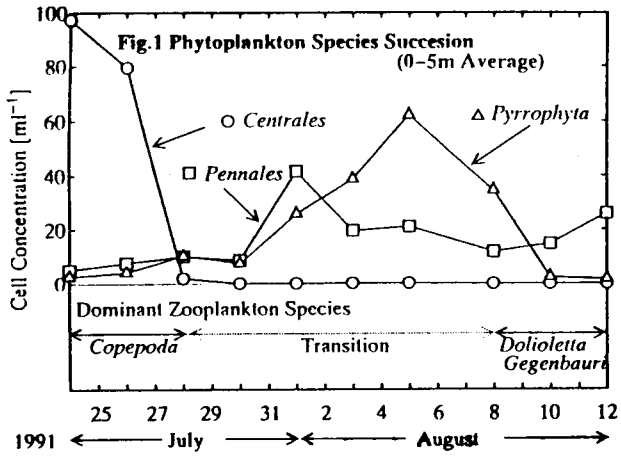
The vertical profiles of water temperature, pH, DO, POC, PON, DOC, DIC, nutrient concentrations, pigment concentrations, phytoplankton species and cell concentrations, zooplankton species and concentrations, metal concentrations were observed by one or two days intervals. Also sediment traps were settled at 5m, 10m and 15m depth, and POC, PON and pigment concentrations within sedimenting particles were observed every day.

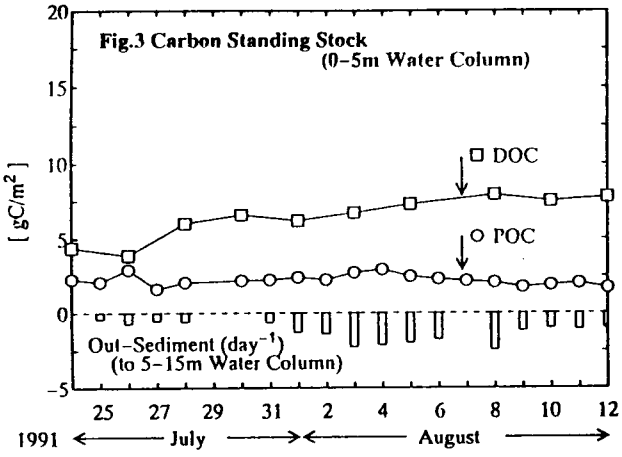
Stable carbon isotope tracer experiments were done, using the bottle incubation technique. Every morning, sea water was sampled at 0.5m and 10m depth, and enclosed within 4.5 litter PC bottles. ^{13}C-DIC or ^{13}C-DOC was added into the bottles in order to examine the transformation rates of DIC to POC and DOC to POC, in turn. After 4 hours incubation (at the sampling depth), POC was fractioned by its size in order to know the transformation rate into bacterial POC, phytoplanktonic POC, micro-zooplanktonic POC, zooplanktonic POC.

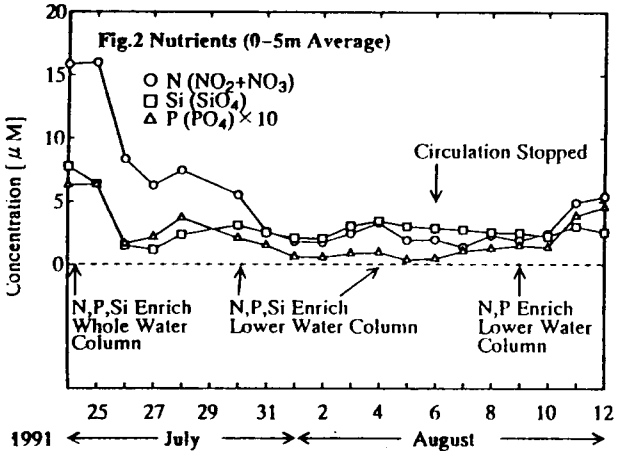
4.Results and Discussion

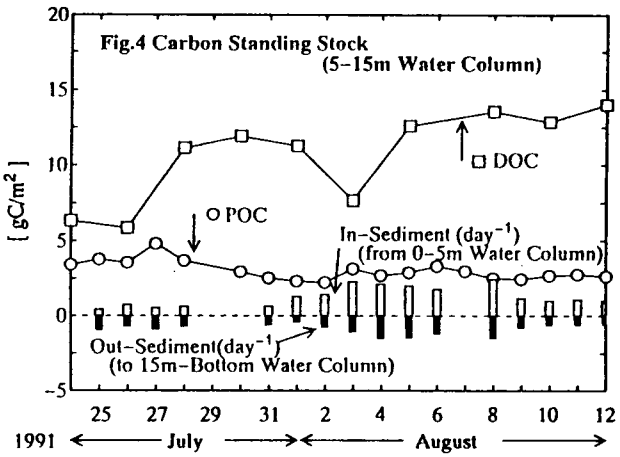
(1) Phytoplankton species succession

Through the experiments, about 80 phytoplankton species emerged. These were categorized into *Centrales*, *Pennales* and *Pyrrophyta*. Fig.1 shows the variations in cell concentrations of these category as average in 0-5m layer, and Fig.2 shows that of nutrients. Just after the mesocosm being installed, *Centrales* were the dominant species. But these decayed in accordance with the decrese of Si concentration. *Pennales* survived Si limiting condition. *Pyrrophyta* were dominant at the P limiting stage (Aug.1 to 6). This is because of the species belong to this category being able to migrate, and thereby used enriched P within the lower water column. At the ending stage of the experiment, *Pyrrophyta* decayed and *Pennales*









survived again. This is assumed to be because of the *Pyrrophyta* grazed by *Dolioletta gegenbauri*.

(2) Variations in carbon standing stocks

Figs.3 and 4 show the carbon standing stock within 0–5m water column and 5–15m water column, respectively. These figures show POC was not incresed at both layer, even after the successive phytoplankton bloom. On the other hand, DOC was increasing, and it is clear that DOC could be the big carbon pool through phytoplankton bloom. The value of the sediment-ing POC flux at the 5m depth is as large as that of the standing POC stock within 0–5m water column. It is clear that the sedimenting POC deeply affects the carbon cycles within coastal sea zones.

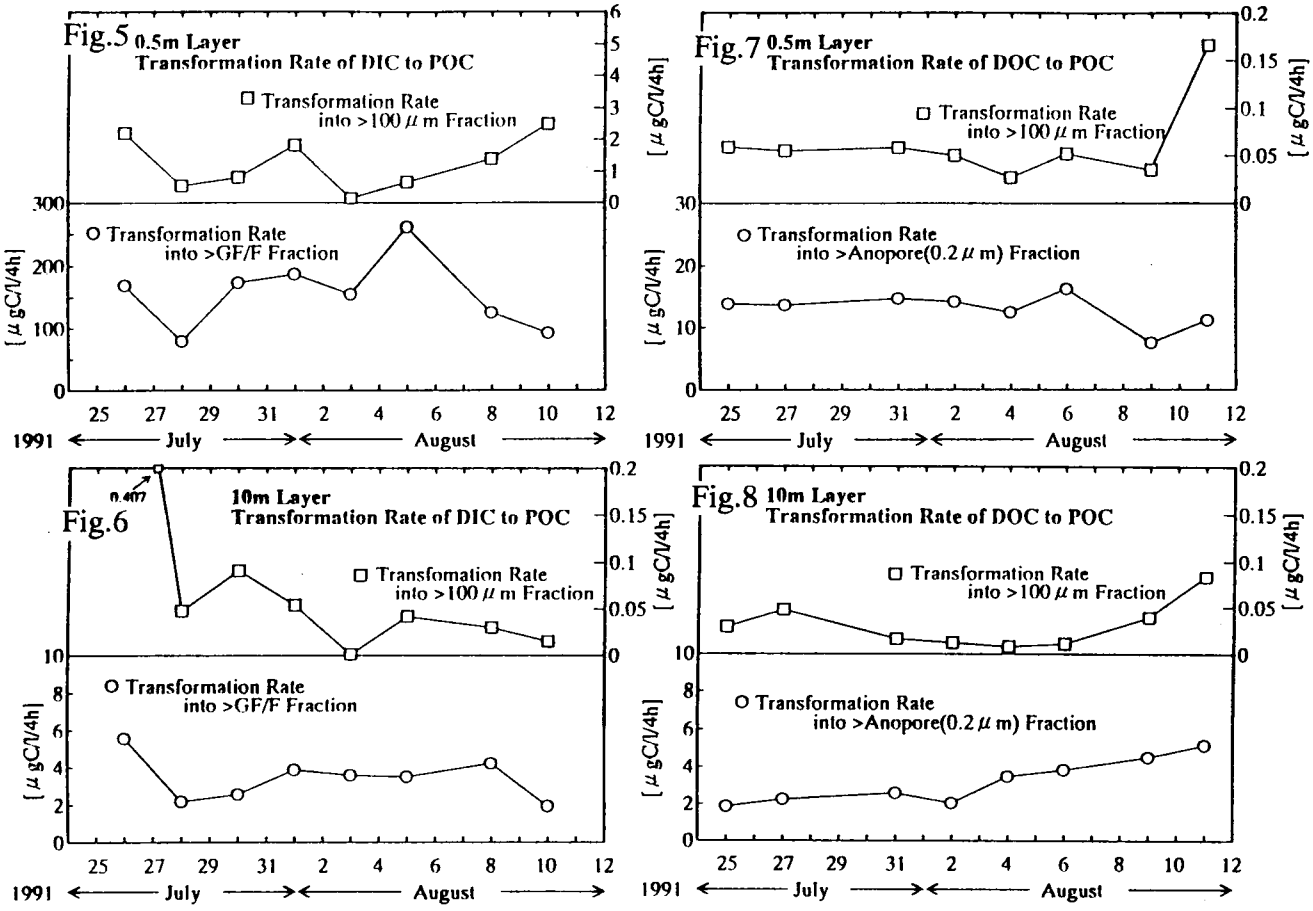
(3) Variations in carbon transformation rates

Figs.5–8 show the carbon transformation rates observed through the stable carbon isotope tracer experiments. The transformation rates into >GF/F fraction in Figs.5 and 6 mean the net photosythesis rates (/l/4hrs), and the transformantion rates into >Anopore fraction in Figs.7 and 8 mean the bacterial mineralization rates (/l/4hrs). These values were obtained by adding the transformation rates into all size fraction. The transformation rates into >100um fraction in Figs.5–8 mean the grazing rates of the POC produced within the 4 hours incubation period. These values are not exactly the grazing rates, but the variations in the transformation rates show the variations in zooplankton activities.

Figs.5 and 6 show that the photosynthesis rates had big variations. These variations were made throuh the phytoplankton species succession. While *Pyyrophyta* were dominant (August 3rd to 5th), the phtosynthesis rates were large. This shows the abitily of *Pyrrophyta* being able to transform DIC to POC even in the stage N and P are limiting within the euphotic layer.

Figs.7 and 8 show that the bacterial mineralization rates had small variations. Also the differences between the rates of upper water column and lower water column were smaller than that of photosynthesis rates. This means bacterial mineralization rates could be large even at the deeper water column.

Figs.5–8 show that the grazing rate of the POC produced through phtosynthetic loop was so much bigger than that through the bacterial loop at the upper water column, but almost same at the lower water coulmn.



The total amount of POC production through photosynthetic loop and bacterial loop within 0–5m water column and 5–15m water column was estimated for 19 days, using the results shown in Figs.5–8. In both loops, the vertical profiles of the POC production rates were approximated to the exponential curves. The POC production through bacterial loop was 20% of that through photosynthesis loop within 0–5m water column, but just the same within the 5–15m water column. This result underlines the importance of bacterial loop below the euphotic layer.

(4) Other results

Pigments analysis method was developed, and the component of POC was analyzed. The importance of zooplankton pellets was clearly explained. Also the continuous P_{CO2} monitoring system was developed, and applied to the observation of the CO_2 concentration in air and surface sea water.