THE SETO INLAND SEA, JAPAN - A HIGHLY PRODUCTIVE AND EFFICIENT SEA

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The Seto Inland Sea, Japan, is a highly eutrophic, enclosed sea, but it provides one of the world highest fish catch on a per-unit-area basis (mean annual fish catch during 1989-1993: 16 ton wet weight km^{-2} yr^{-1}). It is our responsibility to preserve the health of this productive ecosystem in order to sustain fishery production in the future. If we fail, fishery production may collapse, as has already been apparent in heavily polluted areas such as Black Sea and Tokyo Bay. The objective of this study is to quantify the present-day status of the biological productivity and the trophic level interactions from primary production to fish production in the Seto Inland Sea, for the proper management of this area as a sustainable fishing ground.

Materials and Methods

A collaborative work was conducted during 4 cruises (in October 1993, January, April and June 1994) to cover the entire Seto Inland Sea. Along with general oceanographic surveys, we measured the phytoplankton primary production rate using the ^{13}C technique and zooplankton secondary and tertiary production rates using the cumulative growth rate method. Production rate of the major planktivorous fish, i.e. anchovies, sand eels and sardines, was also estimated based on their annual catch.

Results and Discussion

Phytoplankton Primary Production Rate

The average primary production over the entire Seto Inland Sea was highest in October (1,300 mg C m^{-2} d^{-1}), followed in order by April, June and January (779, 566 and 394 mg C m^{-2} d^{-1}, respectively). The annual average primary production was 781 mg C m^{-2} d^{-1} (i.e. 285 g C m^{-2} yr^{-1}). The extremely high production rate in October was probably due to large amount of nutrient load associated with high precipitation during the preceding months.

Zooplankton Secondary and Tertiary Production Rates

Secondary production, which is attributed to the production by microzooplankton and herbivorous or suspension-feeding net-zooplankton, was much higher in October (637 mg C m^{-2} d^{-1}) than that in the remaining months (89, 146 and 94 mg C m^{-2} d^{-1} in January, April and June, respectively). The annual average secondary production was 221 mg C m^{-2} d^{-1} (i.e. 81.0 g C m^{-2} yr^{-1}), 64% of which was attributed to net-zooplankton.

Tertiary production, which is assigned to the production by carnivorous net-zooplankton, was also much higher in October (120 mg C m^{-2} d^{-1}) than that in the other months (22.5, 44.0 and 18.3 mg C m^{-2} d^{-1} in January, April and June, respectively), with annual average of 54.5 mg C m^{-2} d^{-1} (i.e. 19.9 g C m^{-2} yr^{-1}).

Planktivorous Fish Production Rate

Annual planktivorous fish production rate was estimated as 4.77 mg C m^{-2} d^{-1} (i.e. 1.74 g C m^{-2} yr^{-1}), 26% of which was attributed to secondary production due to herbivory of sardines and anchovies. Fish tertiary production was 3.53 mg C m^{-2} d^{-1} (i.e. 1.29 g C m^{-2} yr^{-1}).

Trophic Dynamics

Fig. 1 depicts the simplified food chain in the pelagic ecosystem of the Seto Inland Sea. The transfer efficiencies from primary production to secondary one and secondary production to tertiary one were 28 and 26%, respectively, being higher than the efficiency (<20%) commonly accepted by researchers for the marine food chain. The production of planktivorous fish was only a small portion (6%) of the total tertiary production. The transfer efficiency from primary production through secondary production to the fish tertiary production was 0.45%.

Conclusion

At present, the Seto Inland Sea is the sea area with high primary production and high transfer efficiency between the lower trophic levels, and we can not detect any deleterious effect by excessive eutrophication in the pelagic food chains. However, in stagnant areas such as Osaka Bay, Harima-Nada and Hiroshima Bay, where benthic hypoxia or anoxia is prevailed in the summer, the production of benthos may be significantly affected. Proper environmental measures should be undertaken in these areas for the recovery of demersal fish population.

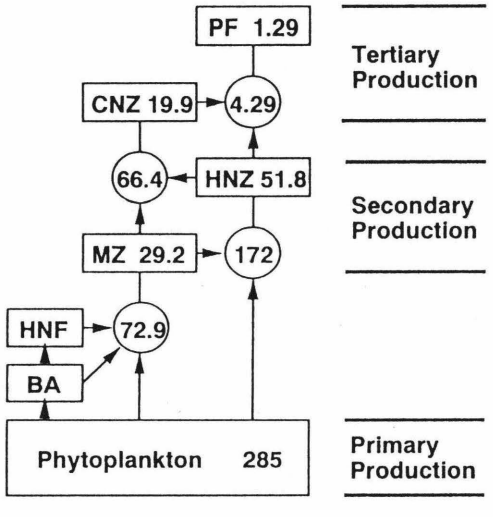

Fig. 1. Annual carbon flow (g C m^{-2} yr^{-1}) through components of the plankton community in the Seto Inland Sea, Japan. Values in boxes denote annual production rate and those in circles are annual requirements of the components above them. BA: bacteria, HNF: heterotrophic nanoflagellates, MZ: microzooplankton, HNZ: herbivorous net-zooplankton, CNZ: carnivorous net-zooplankton, and PF: planktivorous fish.