

## Analysis of Primary Production in the Seto Inland Sea, Japan, Using a Simple Ecosystem Model

TOSHIYA HASHIMOTO<sup>1</sup> and HIDETAKA TAKEOKA<sup>2</sup>

<sup>1</sup>Faculty of Applied Biological Science, Hiroshima University, Higashi-Hiroshima 739-8528, Japan

<sup>2</sup>Faculty of Engineering, Ehime University, Matsuyama 790-8577, Japan

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A simple model of lower trophic level ecosystem has been created to analyze possible environmental control of primary production in eight sub-areas of the Seto Inland Sea. The primary production rates observed by Hashimoto *et al.* (1997a) in these sub-areas are well reproduced by the model, including horizontal processes such as horizontal transport of nutrients and vertical processes such as vertical mixing, light intensity and sinking of particulate matter. Without taking account of horizontal processes, the model also successfully reproduces the observed primary production rates in some areas, but it fails to reproduce those in the others. This shows that the relative importance of the horizontal transport on the primary production differs area by area. Two time scales,  $T_Z$  and  $T_H$ , are introduced to explain this difference.  $T_Z$  is a vertical cycling time of material, which is defined as the time during which the stock of the material in the water column is utilized for primary production;  $T_H$  is the horizontal transit time of the material. The relative importance of the horizontal process is well explained by the  $T_H/T_Z$  ratio; that is, the horizontal transport process is important in the areas where this ratio is small. Further the possible mechanisms of nutrient supply for the primary production in each sub-area are investigated using this model.

Keywords:

- Primary production,
- ecosystem model,
- Seto Inland Sea,
- horizontal transport,
- nutrients.

### 1. Introduction

The Seto Inland Sea is a semi-enclosed coastal sea in Japan and is well known as a treasury of fishery resources due to the variety of fish stocks and their abundance (Fig. 1). It is thus important for the management of fishery resources to understand environmental control of primary production since primary production is the first step in the marine food chain.

Several field measurements of the primary production have been made in local areas of the Seto Inland Sea (e.g. Endo, 1970; Endo and Okaichi, 1977; Yamaguchi and Anraku, 1984; Uye *et al.*, 1987). However, each measurement is limited, both seasonally and spatially. Therefore, Hashimoto *et al.* (1997a, b) investigated seasonal and geographic variations of water quality and primary production in the Seto Inland Sea during four cruises in October (autumn), 1993, January (winter), April (spring) and June (summer), 1994. Secchi disk depth and vertical profiles of temperature, salinity and *in vivo* chlorophyll fluorescence were measured at all 39 stations (Hashimoto *et al.*, 1997a). Seawater samples were collected from depths of 0, 5, 10, 20 m, and also from 2 m above the sea-bottom at 21 main stations and the nutrient concentrations of the samples were determined. Diel primary production was estimated at all stations by using the results of the <sup>13</sup>C tank method obtained at about 10

stations for each cruise (Hashimoto *et al.*, 1997b). Figure 2 shows the observed results for the annual average total nitrogen (TN) and the annual average primary production rate in eight sub-areas in the Seto Inland Sea (Hashimoto *et al.*, 1997a, b).

Our aim is to understand how the distribution of the primary production rates shown in Fig. 2 is controlled. In the open ocean, the horizontal gradients of oceanographic conditions and concentrations of nutrients are usually small. Hence, primary production in the open ocean has been explained in terms of a vertical one-dimensional scheme which is mainly controlled by the vertical stability of the water column, euphotic layer depth, sinking of phytoplankton, and so on (Sverdrup, 1955; Pingree *et al.*, 1975; Parsons *et al.*, 1984; Mitchell and Holm-Hansen, 1991; Radach and Moll, 1993; Kawamiya *et al.*, 1995; Yoshimori *et al.*, 1995). In coastal seas like the Seto Inland Sea, however, horizontal gradients of the oceanographic conditions are often much greater than those in the open ocean due to complicated coastal geometries and supply of materials from the land. Therefore, the application of a vertical one-dimensional scheme may fail to explain the distribution of the primary production rates shown in Fig. 2. For example, in Bisan-Seto, where the water column is vertically well mixed due to strong tidal currents (Yanagi and Okada, 1993;