Change of Oceanic Condition by the Man-made Structure for Upwelling

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The change of oceanic condition by the man-made structure for the upwelling is revealed in the Bungo Channel, the Seto Inland Sea, Japan. The big man-made structure of 10m height and of 20m width was set 50m below the sea surface in order to induce the upwelling at the eastern part of the Bungo Channel in autumn 1987. The intensive field observations were carried out before and after the setting of this structure. The nutrients, concentration of chlorophyll *a* and biomass of zooplankton were increased after the setting of this structure.

The development of coastal fisheries ground has been an urgent program in Japan because the 200 nautical miles declaration is fixed all over the world. Ehime Prefecture and Penta Ocean Construction Company Limited set the man-made structure of 10m height and of 20 width (called MARITEX) 50m below the sea surface at the eastern part of the Bungo Channel, the Seto Inland Sea, Japan (Fig. 1) in October 1987 in order to induce the upwelling phenomenon. The MARITEX was set as shown in Fig. 2. The center point between two L-type structures is located at

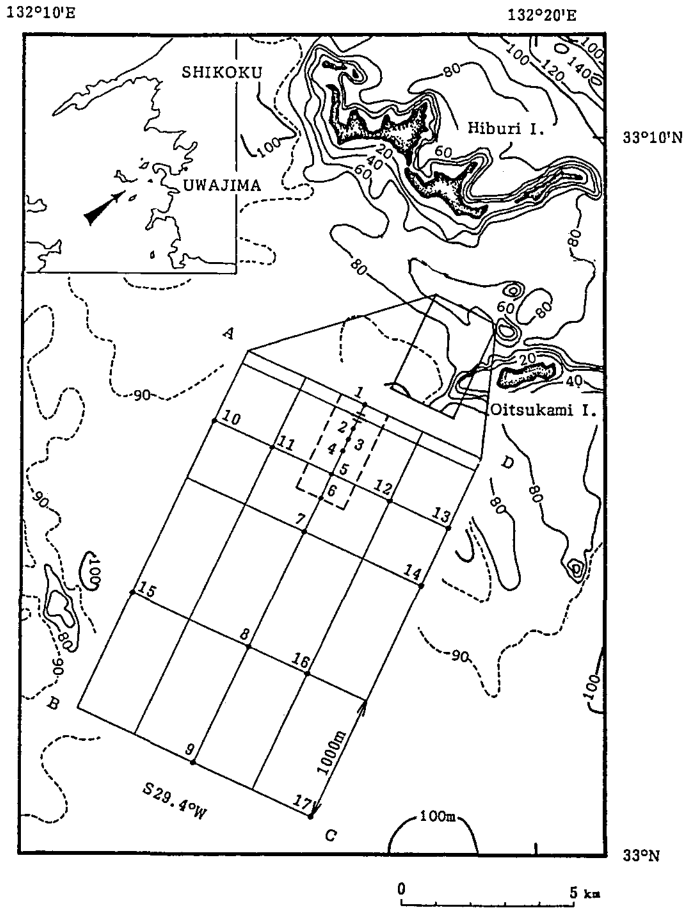

Fig. 1 Observation area.

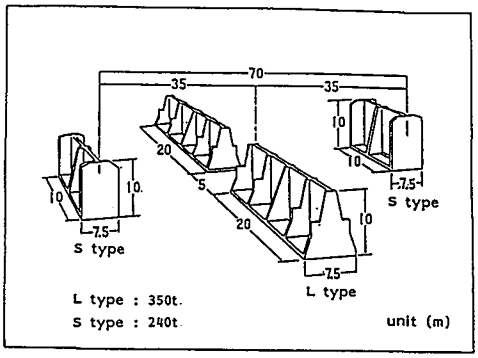

Fig. 2 Man-made structure for upwelling called MARITEX.

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between Stas 1 and 2 in Fig. 1 The main axis of setting S29. 4° W is along the major axis of M_2 tidal current ellipse at this point. The flood and ebb tidal currents come across S-type structure and vertical eddies are generated at both sides of S-type structure. Induced vertical eddies flow down, come across L-type structure, change into horizontal eddies and ascend to the surface layer. The intensive field observations were carried out three times, once before the setting of man-made structure and twice after the setting. The change of oceanic conditions due to the setting of MARITEX is documented in this paper.

Observations

Field observations were carried out from 8 to 24 August 1987 before the setting of MARITEX, from 12 to 27 August 1988 and from 10 to 24 August 1989 after the setting. The field observations were carried out only in late August when the density stratification is most developed because the change of oceanic condition due to MARITEX is expected to be dominant at this time. The observations in 1987 and 1988 were carried out in a narrow region which is enclosed by dotted line in Fig. 1 and those in 1989 in a wide region shown by full line in Fig. 1. Current measurements were carried out 15m, 25m and 35m below the sea surface at Sta. 2 and 30m below the sea surface at Sta. 3 with use of electromagnetic current meters (ALEC ACM16M-6). Current direction and speed were recorded every 5 minutes in 15 days. Horizontal and vertical distributions of water temperature, salinity, nutrients, chlorophyll *a* were observed three times at stations shown in Fig. 1 at ebb tide in spring and neap tides. Water temperature and salinity were observed with use of a CTD (ALEC Model AST-1000). Water samples for nutrients and chlorophyll *a* were obtained every 5m below the sea surface with use of a pair of Van Dorn bottles. Zooplankton sample was obtained by vertical towing from the bottom to the surface with use of Marutoku net and benthos sample with use of Smith-maxintire sampler.

Results

Residual flow which is average in 15 days is directed to southeast with the speed of about 15 cm/s and it was not changed by the setting of MARITEX. The major axis of M_2 tidal current, 35cm/s, increased by about 1. 2 times (Fig. 3) and that of K_1 tidal current, 10cm/s, by about 1. 7 times after the setting of MARITEX. However, the major axes of S_2 and O_1 tidal currents, 11cm/s and 4cm/s, respectively, were not changed by the setting of MARITEX. The increase of major axis of M_2 tidal current by 1. 2 times may be due to the decrease of cross-area by 0.8 times because of

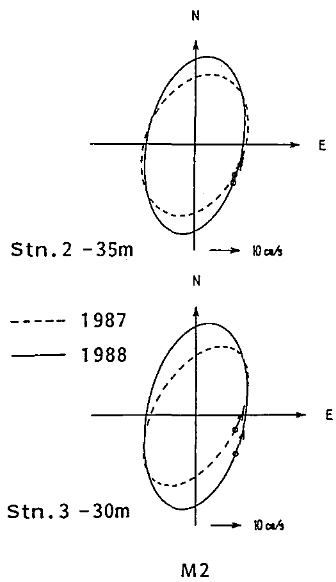

Fig. 3 Change of M_2 tidal current ellipse.

the setting of MARITEX. The standard deviation of vertical turbulent velocity whose period is shorter than 2 hours 35m below the sea surface at Sta. 2 was 1. 7cm/s in 1987 and that 2. 6cm/s in 1988. It increased by about 1. 8 times after the setting of MARITEX.

The change of vertical distribution of water temperature, PO_4-P and chlorophyll *a* at spring tide are shown in Fig. 4. The temperature stratification was the largest in 1988 and this may be considered to be due to the year-to-year variation of oceanic condition in the Bungo Channel. The disturbance of stratification was dominant in the middle layer at the lee side of MARITEX in 1988 and 1989. Such disturbance may be induced by the internal wave at the lee side of MARITEX. The concentration of PO_4-P was increased by about 2 times after the setting of MARITEX. The changes of concentration of DIN and SiO_2 show the similar trend. The concentration of chlorophyll *a* was also increased by about 2 or 3 times after the setting of MARITEX.

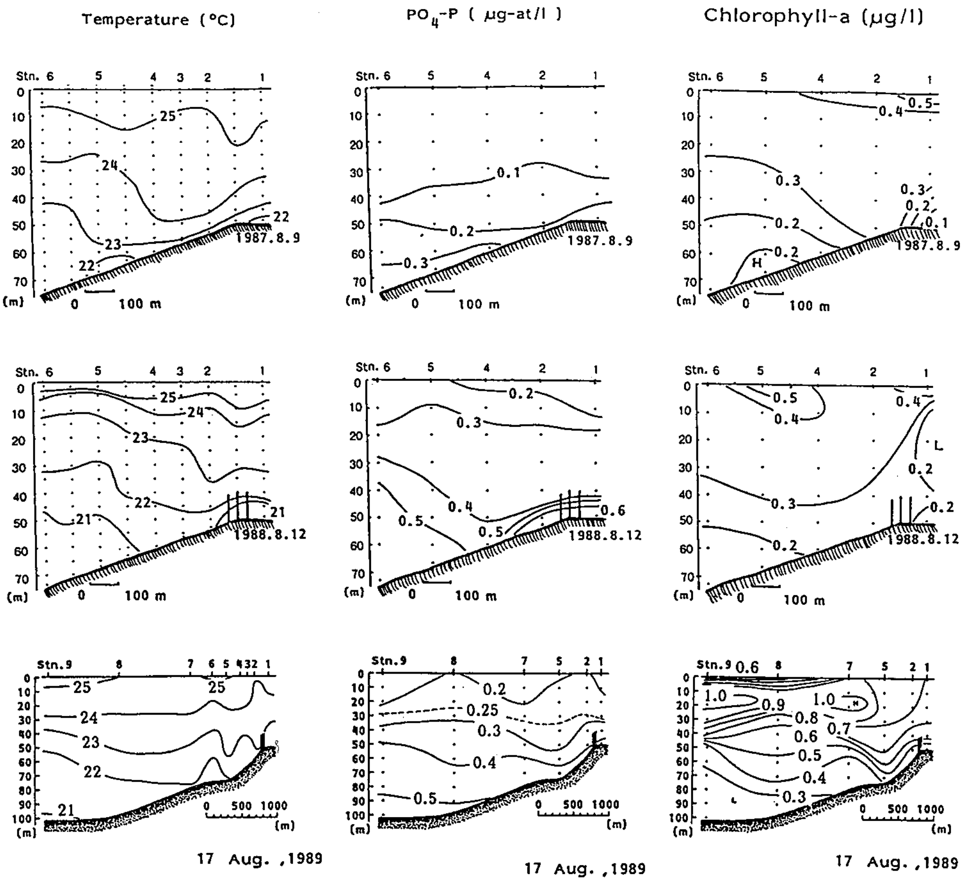

Fig. 4 Change of vertical distributions of water temperature, PO_4-P and chlorophyll *a*.

The temporal variations of water temperature and salinity 30m below the sea surface at Sta. 3 are shown in Fig. 5. The tidal variations of water temperature and salinity are large in spring tide and small in neap tide. The water with low water temperature and high salinity upwells four times a day. The horizontal distributions of density and secchi disk depth are shown in Fig. 6. The water with high density spreads in 2km length and 1km width in the lee side of MARITEX. The tidal excursion was about 4km on 11 August because it was neap tide. The region where the MARITEX affect is considered to be within the tidal excursion. The change of average individual number and settling volume of zooplankton in a narrow region is shown in Table 1. Both

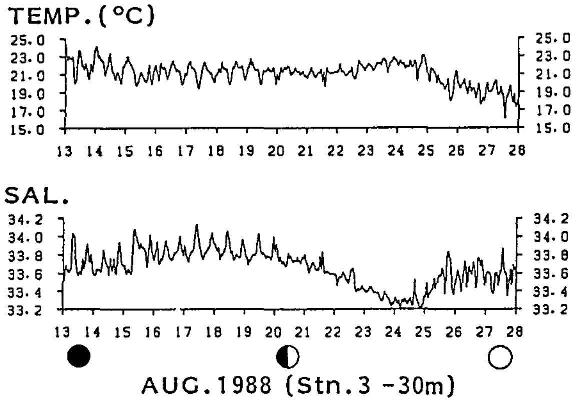

Fig. 5 Temporal variations of water temperature and salinity 30m below the sea surface at Sta. 3.

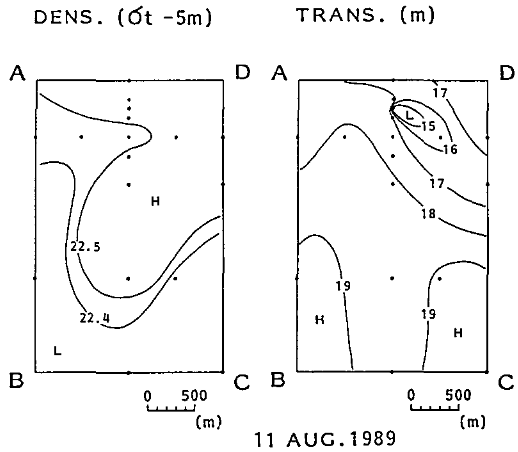

Fig. 6 Horizontal distributions of density and secchi disk depth.

Table 1 Change of zooplankton

	population (ind. /m³)	settling volume (ml/m³)
1987	498.4	0.60
1988	728.1	0.71
1989	871.9	1.36

Table 2 Change of benthos

	species (/0.1m²)	population (ind. /0.1m²)	wet weight (g/0.1m²)
1987	23.3	214.7	0.6
1988	12.0	21.3	1.2
1989	5.0	6.0	1.8

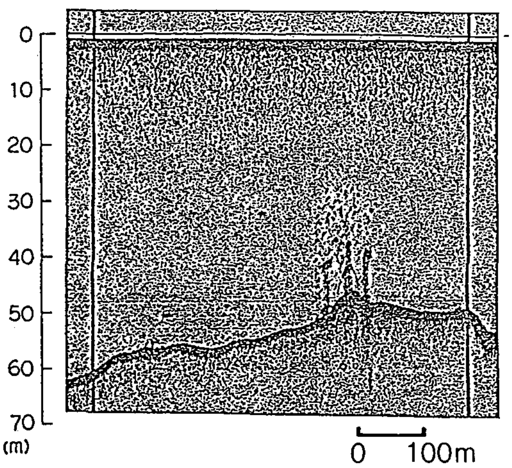

Fig. 7 Result of echo-sounder observation along the central observation line.

figures in Table 1 gradually increase after the setting of MARITEX. Change of benthos in the same region is shown in Table 2. Numbers of species and individuals of benthos gradually decrease but the weight of benthos increases after the setting of MARITEX. This is considered to be due to that the current condition becomes to be severe for small benthos after the setting of MARITEX and only a little and large benthos can survive at the sea bed near the MARITEX. The result of echo-sounder observation which was carried out at 11:00 on 17 May 1988 along the central observation line is shown in Fig. 7. Much fish gather just above the MARITEX.

Discussion

The major axis of M_2 tidal current and vertical turbulent component increase after the setting of MARITEX. The increase of horizontal velocity and vertical turbulence is resulted in the upwelling of bottom water with rich nutrients into the euphotic zone and the increase of chlorophyll *a* concentration, that is, biomass of phytoplankton. The increase of biomass of zooplankton is found but the change of ecosystem in this region seems not to be stable. Therefore the longer investigation is desirable.

Anyway, the man-made structure for upwelling is very promising as the method of development of coastal fisheries ground because the maintenance fee is free. The detailed results of observations may be referred to Yanagi and Nakajima (1990 a, b).

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Yanagi, T. & M. Nakajima (1990 a). Change of oceanic condition due to the man-made structure for upwelling. *Bull. Japanese Soc. of Fisheries Oceanogr.* **54,** 1–8.

Yanagi, T. & M. Nakajima (1990 b). On the effect of man-made structure for upwelling as an artificial reef. *Bull. Japanese Soc. of Fisheries Oceanogr.* **54,** (in press).