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Early Stage of Algal Succession on Artificial Reefs at Muronohana, Ikata, Japan

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Different substrata fixed as the roof (for shadow) on artificial iron reef had been developed as a tool for valuable fishery resources. The experiment was set up on a sandy bottom substratum at 8m depth in Muronohana, Ikata, Japan. Within one month of placement of the plates, diatoms dominated the experimental plates with a coverage of 100% approximately. *Enteromorpha intestinalis* and *Colpomenia sinuosa* dominated within three months after the placement. *E. intestinalis* coverage on substrata was estimated 7% on the plate shaped iron bar, 12~14% on concrete plates, 18% on the plate fixed pebble, 61% on the plate to accumulated wood, and 80~100% on the steel materials plate. Whereas after four months of placement, *C. sinuosa* coverage on plates became 1~36% on different plates, and 100% on the plate to accumulated wood. The differences in *E. intestinalis* and *C. sinuosa* colonization on the different substrata were probably due to variations in their surface roughness influencing the settlement of zoospores, and thus gametophyte development. After five months of placement, the above two species slowly disappeared.

Key words: algal succession, artificial iron reef, coverage, seaweed bed

Introduction

Kelp forest is one of the most important marine resources. It acts as a habitat, shelter, nursery and spawning beds for some fishes, abalone and spiny lobster, which are valuable fishery resources (Hagen, 1983; Ohno et al., 1990; Watanuki and Yamamoto, 1990; Tsutsui et al., 1996). Artificial reefs construction has become an important and popular technique in the coastal area for enhancement of fishery resources. These reefs are thought to improve fishing by concentrating fishes and also increase natural production of biological resources (Bohnsack and Sutherland, 1985; Lee and Kang, 1994). For purpose of recovering the lost seaweed beds, many fishery scientists and phycologists have tried to create new seaweed beds using artificial reefs (Yamada et al., 1992; Ohno, 1993; Jee et al., 1995; Serisawa and Ohno, 1995a).

Recently, devastation on coasts causing barren grounds is increasing in many parts of the world resulting to the loss of natural population of many marine organisms and macrophytes. Many ecological studies have been undertaken with special attention for re-establishment of artificial kelp forest (Chang, 1985; Sonu and Grove, 1985; Terawaki et al., 1995; Tsutsui et al., 1996; Serisawa et al., 1998). Furthermore, fishery resources such as abalone, lobster, fishes and seaweeds became extremely depleted (Ohno, 1993; Serisawa and Ohno, 1995b).

The roof of artificial iron reef gathers more fishes for their shadow. It is more effective to construct seaweeds bed on the roof structure for the fish gathering, because there are plenty of small animal feeds available for fishes on the seaweeds bed.

In this study, we used different substrata on the roof of artificial iron reef for growing various seaweeds. The present paper describes early stage of succession of seaweeds on different substrata fixed

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on artificial iron reef.

Materials and Methods

The experiment was conducted at a depth of 8m at Muronohana, Ikata, Shikoku in the southern part of Japan (Fig. 1). A large number of perennial seaweeds such as *Sargassum horneri*, *S. macrocarpum* and *Ecklonia kurome* grow on natural substrata around the experimental site. Artificial reefs made up of iron frames were placed on the sandy bottom at a depth of 8m on February 16, 1999 (Fig. 2).

The succession and growth of various marine algae on the plates were observed monthly or bimonthly by scuba diving between March to July 1999. Photographs were taken by digital video camera, video camera and 35mm camera. Photographs of various seaweeds growing on the natural substrata around the artificial reefs were also taken.

Twelve different types of plates made up of various materials were fixed on the artificial iron reef. In the following manner 1) steel plate, 2) steel plate with big hole, 3) plate shaped an iron bar, 4) steel plate with irregularity, 5) steel plate with a triangle shaped irregularity, 6) steel plate with a irregularity of A shape, 7) plate fixed pebble, 8) plate to accumulate wood, 9) steel plate with small hole, 10) concrete plate, 11) concrete plate of water permeability and 12) concrete plate of coal fly-ash, respectively (Fig. 3).

Water temperature was recorded and salinity was measured with a digital salinometer (Model 3-G, Tsurumi Seiki, Yokohama).

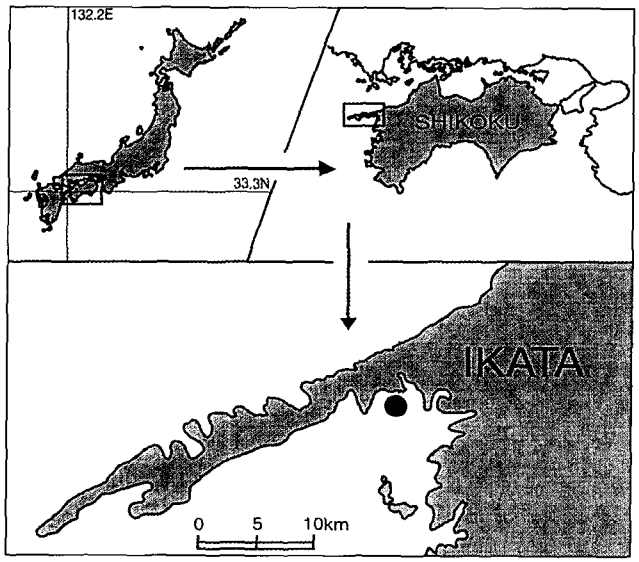

Fig. 1. Map showing the survey site (●) in Muronohana, Ikata, Japan.

Results and Discussion

Seawater temperature and salinity at the study site are shown in Table 1. Water temperature ranged

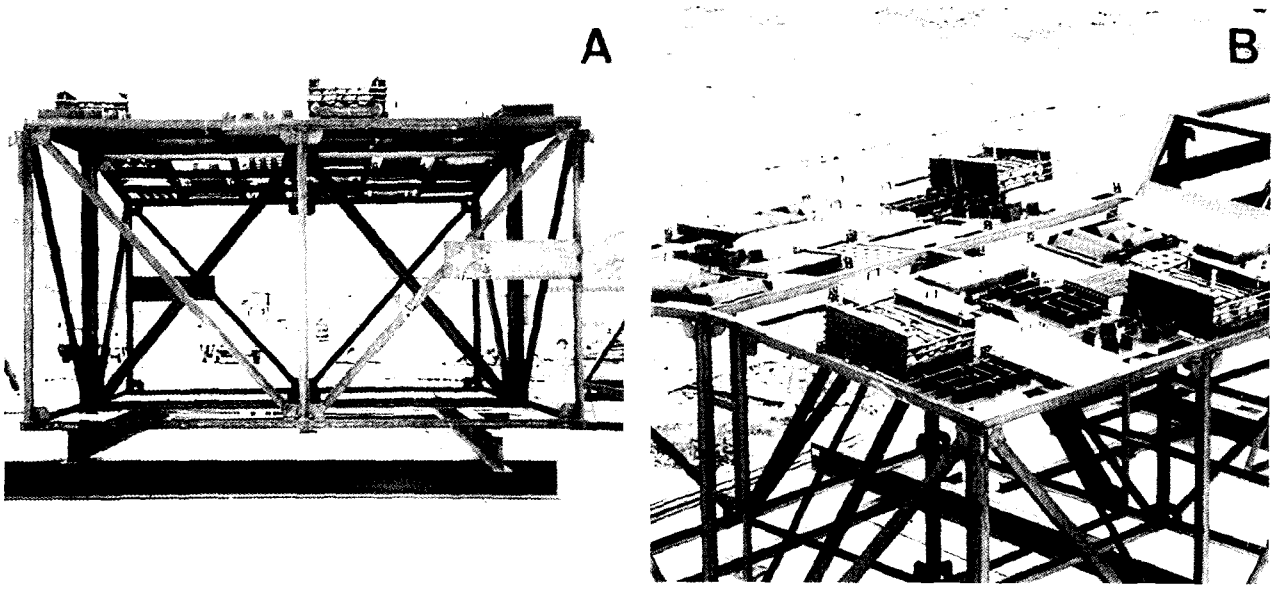

Fig. 2. Different substrata fixed on iron artificial reef.
A: Front, B: The upper layer.

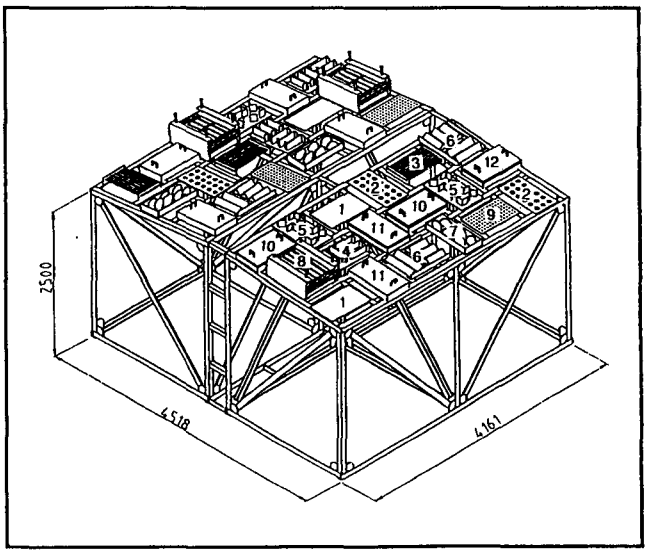

Fig. 3. Illustration of different substrata fixed iron artificial reef.
1: steel plate, 2: steel plate with big hole, 3: plate shaped an iron bar, 4: steel plate with irregularity, 5: steel plate with a triangle shaped irregularity, 6: steel plate with a irregularity of A shaped, 7: plate fixed pebble, 8: plate to accumulated wood, 9: steel plate with small hole, 10: concrete plate, 11: concrete plate of water permeability, 12: concrete plate of coal fry-ash. Unit=mm.

Table 1. Environmental factors in Muronohana, Ikata, Japan

Factor	Station	Date			
		Mar. 23	May 10	Jun. 12	Jul. 10
Water temperature (℃)	Surface	10.0	19.68	22.5	25.3
	Bottom	−	19.12	21.8	23.0
Salinity (‰)	Surface	34.35	34.37	33.84	34.90
	Bottom	−	34.38	34.15	34.95

between 10℃ to 25.3℃, whereas salinity ranged between 33.84‰ to 34.95‰. Salinity was shown to be low at surface but high at the bottom.

The surface of each experimental plate turned brown within one month after placement. Diatoms colonization was observed in the brown parts of different substrata (Fig. 4). Diatoms on all experimental plates showed approximately 100% coverage. Ohno et al., (1990) and Watanuki and Yamamoto (1990) reported the similar colonization on the artificial concrete reefs.

Enteromorpha intestinalis and *Colpomenia sinuosa* appeared remarkably on the experimental

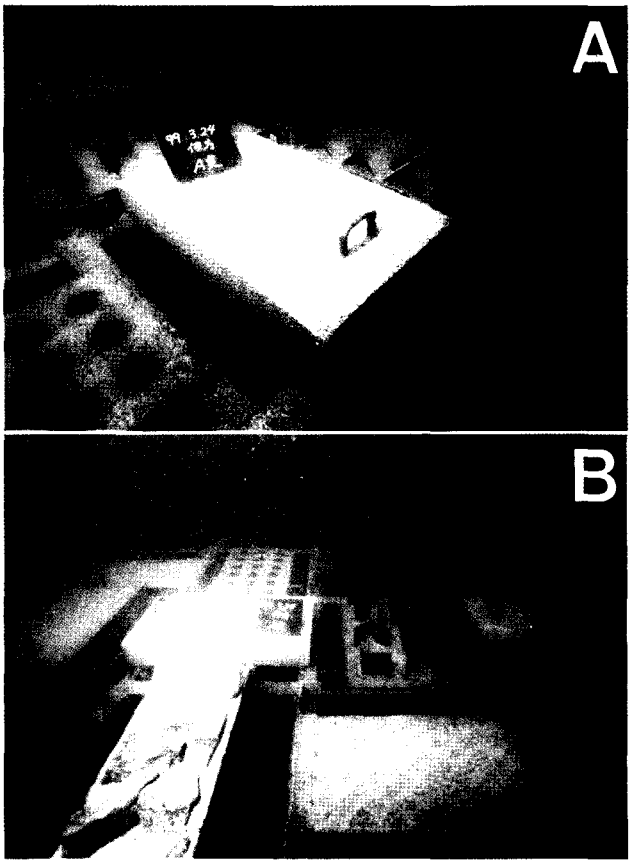

Fig. 4. Colonization of Diatoms species on different substrata fixed on iron artificial reef after 1 month.
A, B: Diatom on the different plates.

plates within three months after the placement (Fig. 5, 6). A total of 23 species of green, brown and red algae: such as *Ulva pertusa, C. sinuosa, Hydroclathrus clathratus, Ecklonia kurome, Dictyota dichotoma, Pachydictyon coriaceum, Padina arborescens, Spatoglossum pacificum, Sargassum giganteifolium, S. horneri, S. macrocarpum, S. patens, S. piluliferum, Undaria undarioides, Scinaia latifrons, S. moniliformis, Gelidium amansii, Amphiroa dilatata, Jania arborescens, Gracilaria incurvata, Lomentaria catenata, Prionitis angusta* and *Plocamium leptophyllum* were found growing on the natural substrata adjacent to the artificial reefs, although *E. intestinalis* which grew luxuriously on the experimental plates did not occur on the rocks in the area. Settlement of zoospores of *E. intestinalis* and *C. sinuosa* were abundant on the surface of plates having rough structures with grooves. There were also a few growth on the smooth top.

The coverage (%) of algae on the each substra-

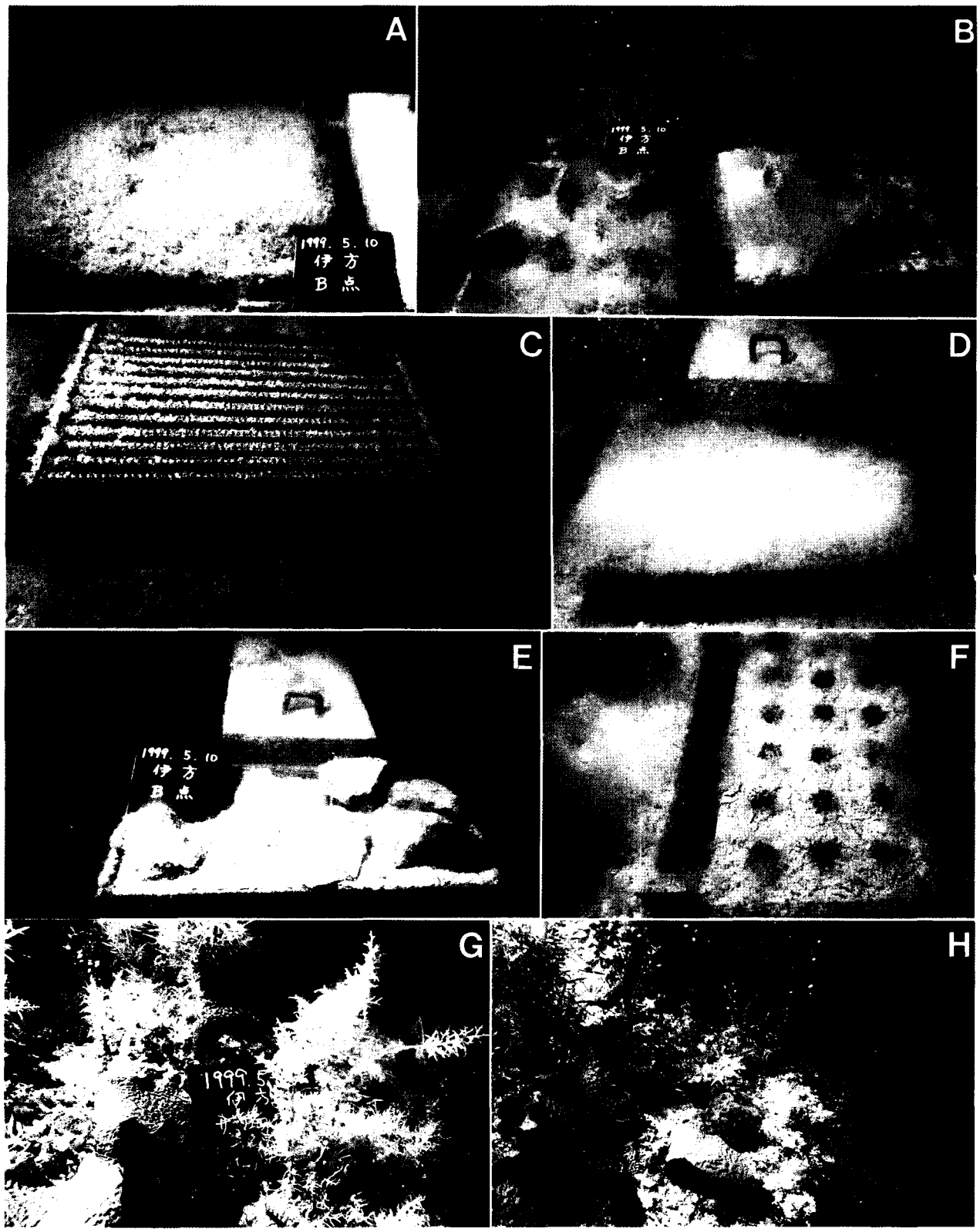

Fig. 5. Growth of *Enteromorpha intestinalis* and *Colpomenia sinuosa* on the different substrata after 3 months.
A: Plate No. 6. B: No. 4, 5, 8 and 10. C: No. 3. D: No. 1. E: No. 7. F: No. 2. G, H: *Ecklonia kurome* and *Sargassum* community dominated around the reef.

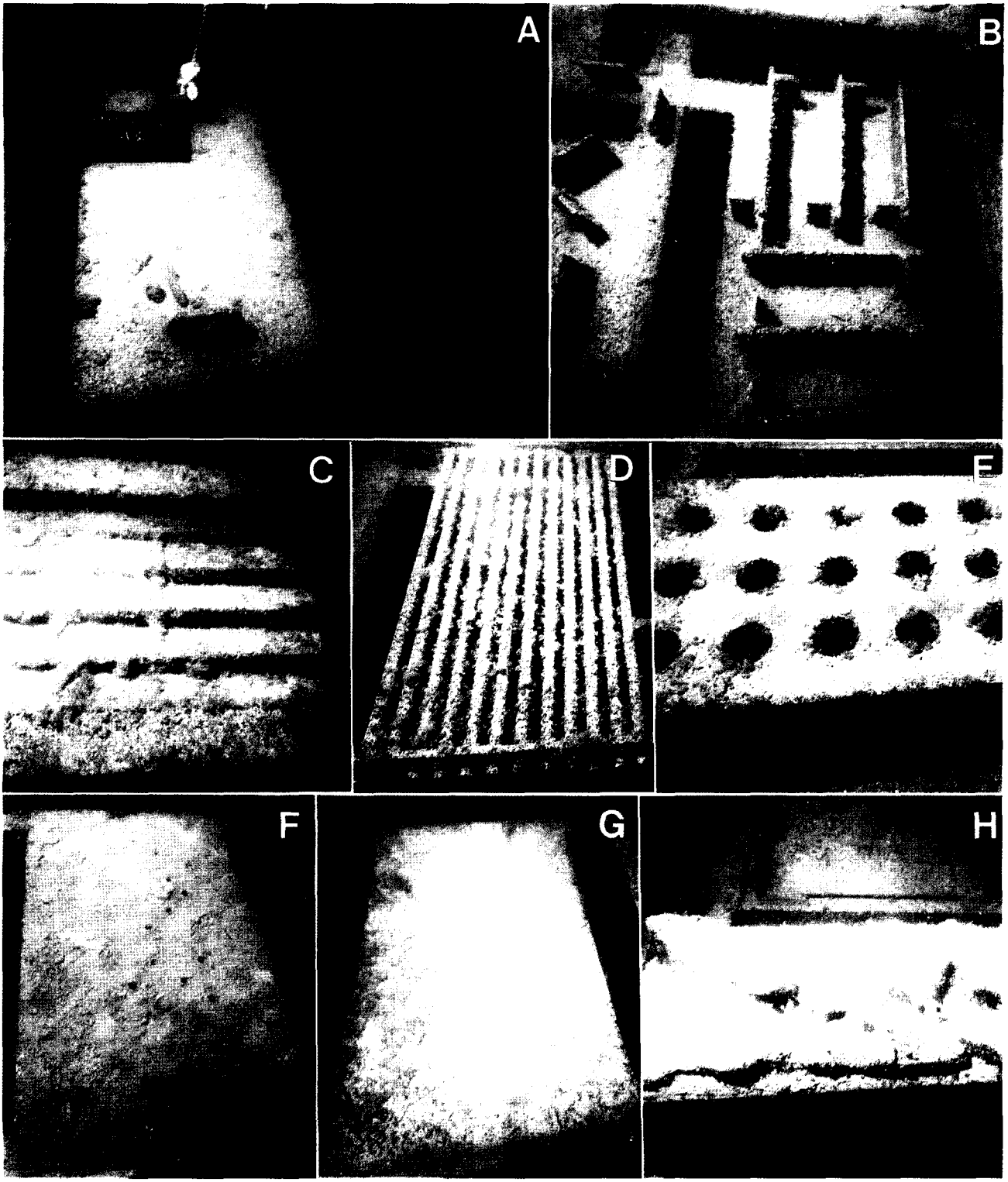

Fig. 6. Growth of *Enteromorpha intestinalis* and *Colpomenia sinuosa* on the different substrata after 4 months.
A: Plate No. 3, 5, 6, and 12. B: No. 4. C: No. 8. D: No. 3. E: No. 2. F: No. 9. G: No. 1. H: No. 7.

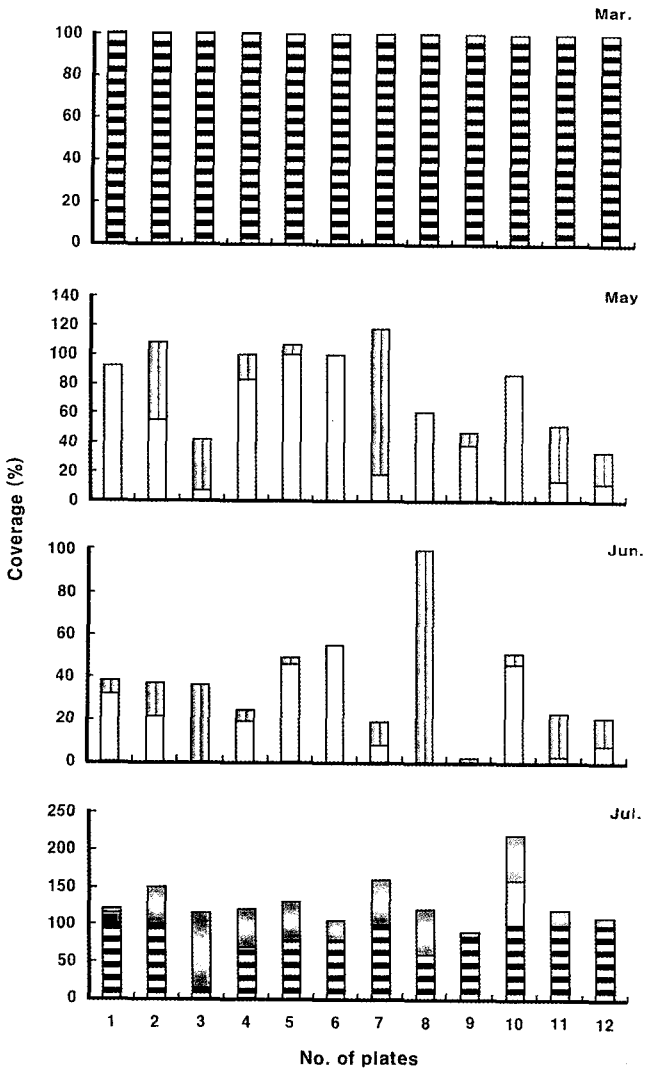

Fig. 7. Average coverage of marine algal species on surface parts of each substance measured from different substrate fixed iron artificial reef.
Diatom Blue green algae
E. intestinalis *C. sinuosa*
Coralline algae

tum is shown in Fig. 7. The seaweeds coverage was shown to be comparatively different on various plates made up of different materials.

After three months of placement, about 80~100% of *E. intestinalis* fronds were found on the upper surface of the steel plates. Whereas the coverage on the plate shaped iron bar is about 7%, 12~14% on concrete plates, 18% on the plate fixed pebble, and 61% on the plate to accumulated wood, respectively. The coverage of *C. sinuosa* was less than that of *E. intestinalis* on almost substrata during this period. *Enteromorpha* fronds were longer and in length like fleecy clouds, whereas *Colpomenia* fronds were growing like speckle carpet. After four months of placement i.e. in the month of June, *C. sinuosa* coverage on plates No. 8 reached 100%, and 1~36% on various other plates. The thalli of *E. intestinalis* and *C. sinuosa* found to be decayed in the month of July (summer season) i.e. after five months, whereas representative coralline red algal species started growing on the substrata.

It is interesting to note that *Enteromorpha* and *Colpomenia* species colonized on the artificial substrata, although they were not found in the natural population surrounding the artificial reef. Ohno et al. (1990) reported colonization of *Enteromorpha* sp. on the surface of the concrete reefs during the first two months after placement of artificial reef at Tosa, Bay. Yamada et al. (1992) also reported colonization of small annuals and crustaceous algae on the artificial concrete reefs. It has been reported that many spores of such short annual algae might be drifting with suspension in the coastal waters during growing season. We think that the colonization of these species is due to annual release of their reproductive cells.

In the present study, *E. intestinalis* and *C. sinuosa* dominated after three and four months of its placement, but they disappeared from two months later. This result was coincided with the observations made in the artificial reefs by Ohno et al. (1990), Watanuki and Yamamoto (1990) and Serisawa and Ohno (1995a, b).

Generally, stability of substratum is very important for maintaining seaweed beds (Watanuki and Yamamoto, 1990). During our investigation, we found that seaweeds bed on the artificial iron reef was stable against waves, and grazers such as sea urchins.

The difference in *E. intestinalis* and *C. sinuosa* colonization on the different substrata was probably due to variations in their surface roughness influencing the settlement of zoospores, thus gametophyte development (Serisawa et al., 1998). This is one of the examples suggesting that roughness of the surface of substrata strongly influences the succession of seaweeds.

The above results suggested that artificial iron reef offered good attachment surface for seaweed

communities. The substrata on the iron reef of the coastal bottom were not covered by sandy mud on their surfaces. For such reason, the early stage of the seaweed succession on each substrata was appeared clearly on each substrata. Our study suggests that diatoms and some annual seaweeds are the early stage of algal succession on the artificial reefs under the shallow waters.

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