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Seaweed Succession on Artificial Reefs Placed in Different Depths at Ikata, Japan

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Artificial reefs were set on a sandy bottom substratum at 8 m, 10 m and 13 m depths along the coast in Muronohana, Ikata, Japan. Succession of seaweed communities was observed monthly or bimonthly from February 1999 to August 2000 on artificial reefs. Within one month, the diatom colonized on the reefs with coverage of 100%. After three months, *Enteromorpha intestinalis* and *Colpomenia sinuosa* dominated on the reef in the spring. Seaweed flora decreased during the summer and the dominant species were several species of Melobesioidea. In the winter, the seaweeds grew up again and the dominant species on the each reef were *Sargassum* spp., *Ecklonia kurome* and *Padina arborescens* after one year. The dominant species in the algal succession process changed from diatoms to the perennial seaweeds such as *Sargassum* spp., *E. kurome* and *P. arborescens*. Thus, the pattern of succession of the dominant species and the degree of domination were changed by the season, water depth and the recruitment of spores and eggs from the mature alga around the reefs.

Key words: Artificial reef, Substratum, Coverage, Succession, Recruitment

Introduction

Many studies have been carried out on the succession of seaweeds both in the intertidal and subtidal zones either by placing artificial substrata on the sea bottom or by removing seaweeds from natural substrata (Hirata, 1986; Yamada et al., 1992; Ohno, 1993; Serisawa et al., 1998).

In recent, devastation of coasts worldwide has led to barren grounds resulting in the loss of the natural population of many marine organisms. Furthermore, fishery resources such as abalone, fish and seaweeds have been depleted (Serisawa and Ohno, 1995a; 1995b). Since 1980, many fishery scientists and phycologists have tried to create artificial seaweed beds using artificial reefs in order to recover lost seaweed beds (Choi et al., 2000a; 2000b; Ohno, 1993).

Artificial reefs are commonly used to increase the fishery resources in depauperate areas (Tsuda and Kami, 1973) and, to protect ports, coastal structures have been constructed along the shorelines (Watanuki and Yamamoto, 1990). These structures also act as artificial substrata for seaweeds. Algae colonize on the reefs and serve as the primary food source for herbivores.

Aims of this study are to observe colonizing seaweeds and their succession on artificial reefs. Thus, the present paper describes the succession of seaweeds on the artificial reefs placed in different depths.

Materials and Methods

The experiment was conducted at 8 m, 10 m and 13 m at Muronohana, Ikata, Shikoku in the southern part of Japan (Fig. 1). *Sargassum horneri, S. macrocarpum* and *Ecklonia kurome* were common seaweeds, with *Codium* spp., *Undaria undarioides* and *Gelidium amansii* on natural substrata around the study site. Artificial reefs were placed on the sandy bottom on February 16, 1999.

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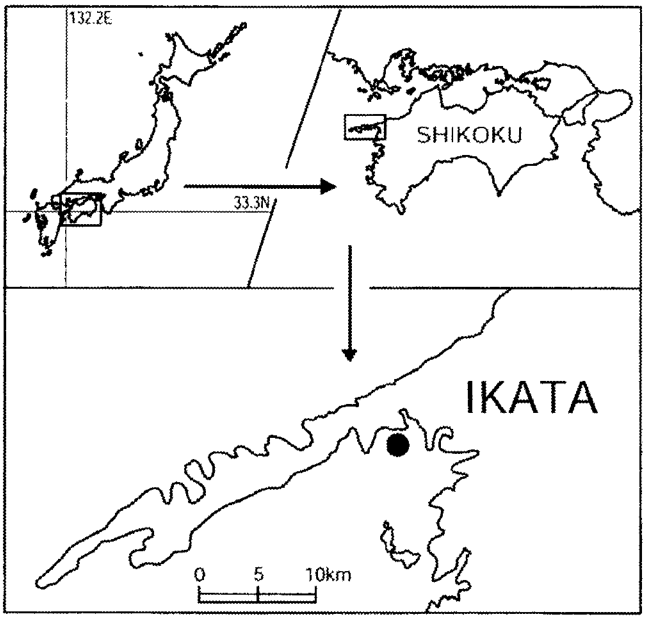

Fig. 1. Study site (●) in Muronohana, Ikata, Japan.

The succession and growth of various marine algae on the reefs were observed monthly or bimonthly by scuba diving from March 1999 to August 2000. Photographs of various seaweeds growing on the natural substrata were also taken with digital video camera, video camera and 35 mm camera.

Three artificial iron reefs made up of different sizes were placed on the sandy bottom at a depth of 8 m (station A), 10 m (station B) and 13 m (station C) at the study site (Fig. 2).

The artificial iron reef placed on station A weighed 3.2 tonnes, has a volume of 45.38 m^3 (4.5×4.1×2.5 m). The reef placed on station B measured 157 m^3 (9×9×3 m) and weighed 20 tonnes. The station C was a 155 m^3 (9×9×3 m) artificial iron reef, weighing 7.6 tonnes.

Water temperature, salinity, DIN (nitrate, nitrite and ammonium nitrogen) and PO_4-P were measured at the study site. Salinity was measured with a digital salinometer (Model 3-G, Tsurumi Seiki, Yokohama). Concentrations of DIN and PO_4-P were determined by colorimetric methods (Japan

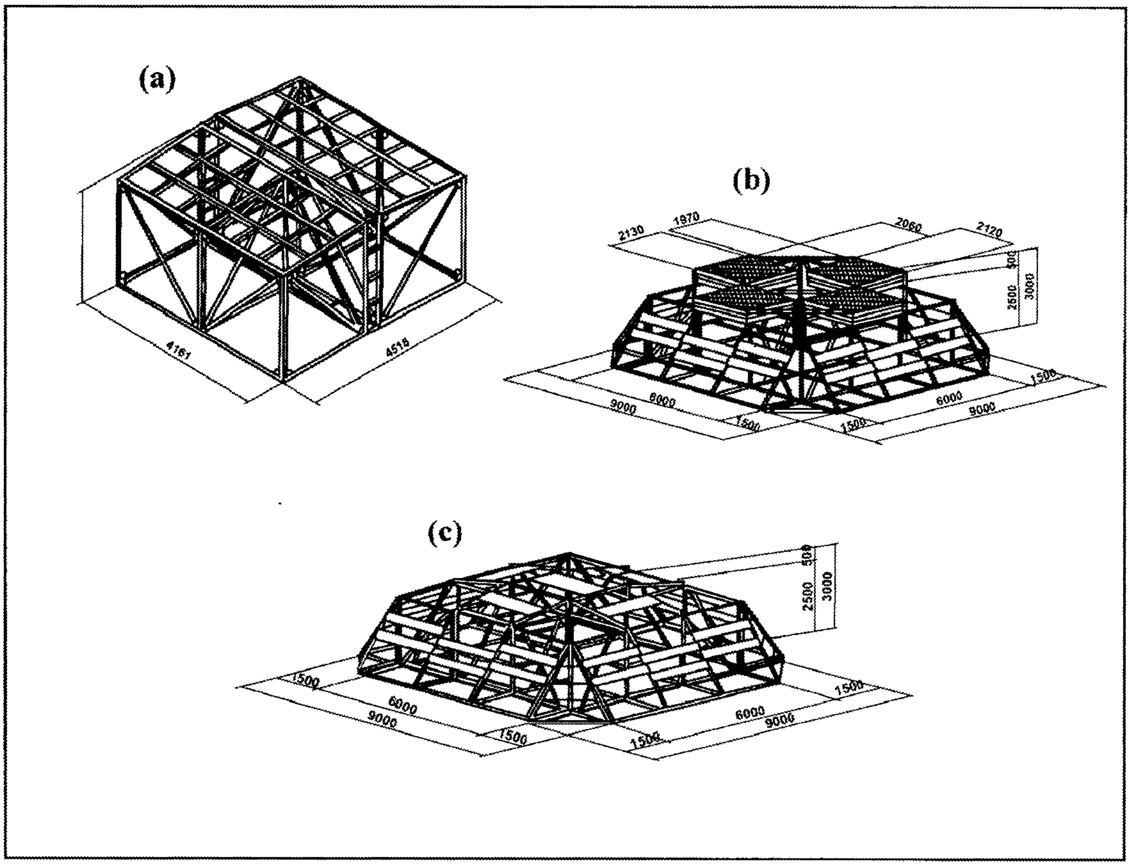

Fig. 2. Schematic designs of the three types of the artificial iron reefs placed at the station A (a), station B (b) and station C (c).

Meteorological Agency, 1970).

Results

Monthly changes in water temperatures ranged between 10.0~28.3℃ at the surface, and between 12.3~26.9℃ at the bottom; salinities ranged between 32.96~35.49‰ at the surface and 32.99~35.50‰ at the bottom. Dissolved inorganic nitrogen concentrations ranged from 0.31~5.93 μg/L at the surface and 0.35~5.96 μg/L at the bottom. Phosphate concentrations ranged from 0.10~2.75 μg/L at the surface and 0.16~2.80 μg/L at the bottom.

Fig. 3 showed the relative coverage of algae on the artificial reefs over the study period. Artificial reefs turned brown colour within one month after the placement. Diatoms were observed in the brown parts of different reefs and their relative coverage was 100%

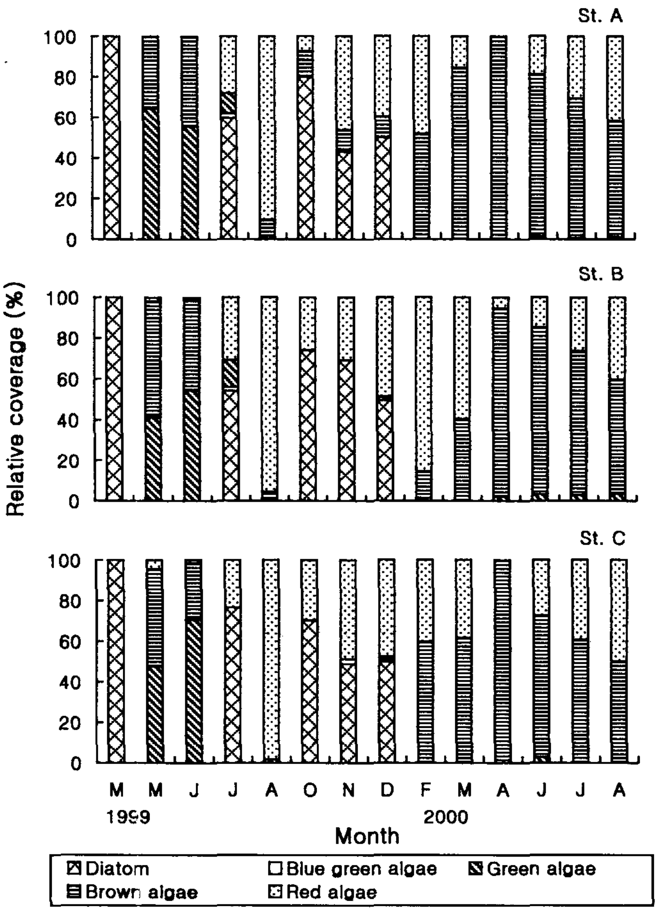

Fig. 3. Relative coverage of marine algae division on surface part of each artificial reef at different depths.

Remarkably *Enteromorpha intestinalis* and *Colpomenia sinuosa* appeared on the artificial reefs within three months after the placement. A total of 23 species of algae were found on the natural substrata adjacent to the artificial reefs, although *E. intestinalis,* which grew luxuriously on the artificial iron reefs, did not grow on the rocks in the area. The relative coverage of *C. sinuosa* was less than that of *E. intestinalis* on most reefs on June 1999. The thalli of *E. intestinalis* and *C. sinuosa* decayed in July (summer season), i.e. after five months, whereas coralline algae started to grow on the artificial iron reefs.

Within 6 months, coralline algae covered approximately above 80% of the artificial reefs at the study site. The relative coverage of coralline algae on the reefs placed on the station C was high, about 98%. The other study sites had 90 to 95% coverage. From October to December 1999, diatoms and coralline algae had greatly colonized the surface on the reefs.

In winter relative coverage of brown algae, such as *Sargassum* spp. and *E. kurome,* was recorded above 50% of the reefs. The relative coverage of brown algae on the reefs placed on station A and station C covered approximately 100%. The number of species tended to be comparatively greater on the reefs during the winter and spring months (February 2000 to June 2000); 14~16 species appeared during this period.

Figs. 4~6 showed the seasonal changes of the dominant algae on the reefs during the study period. Within 3 months, *E. intestinalis* covered approximately 60~75% of the artificial reefs. In June, the coverage of *E. intestinalis* placed on the station C was nearly 100% (Fig. 6).

From summer to autumn (August to December), coralline algae were dominant at all stations. Within 6 months of the placement of the reefs, *Sargassum* spp. appeared on the reefs placed on the station A (Fig. 4), while on the reefs placed on the station B and station C it appeared after 10 months. *Sargassum* spp. became dominant at station A within 12 months following immersion. The station B and station C became dominant after 16 months (Figs. 5, 6).

In February 2000, 12 months after the placement, *C. sinuosa* reappeared, and coverage was increasing

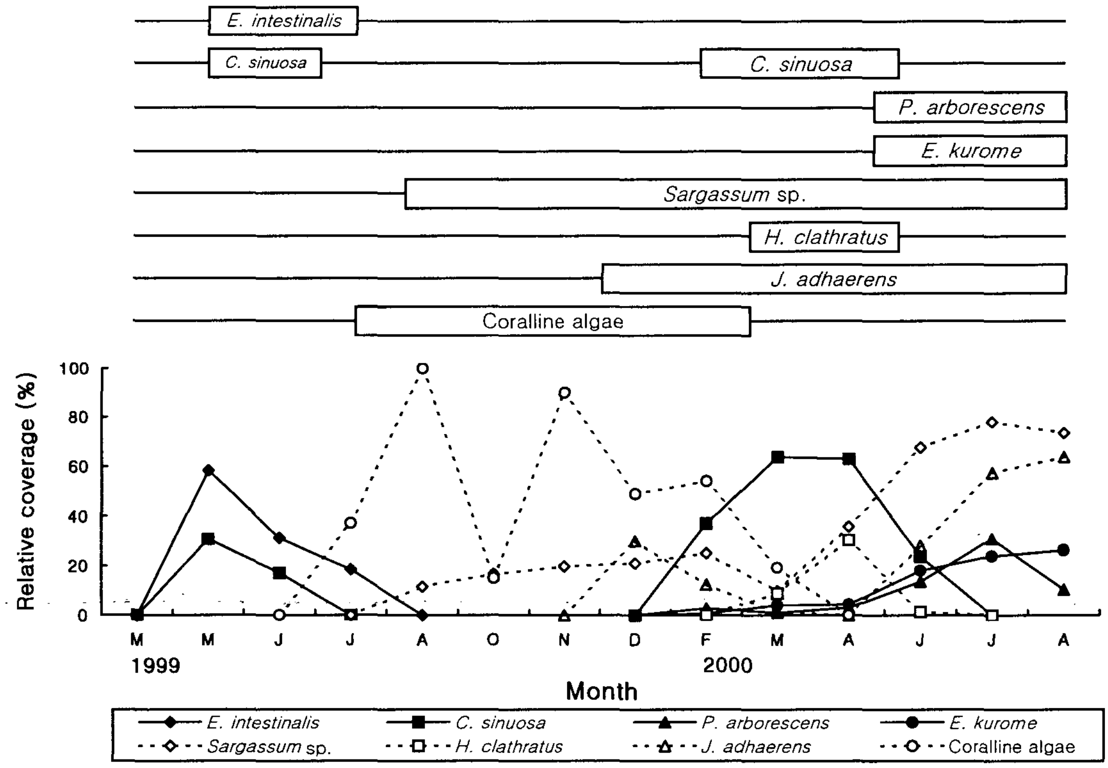

Fig. 4. Monthly changes of dominant algal species and relative coverage of them attached on the artificial reefs at the station A.

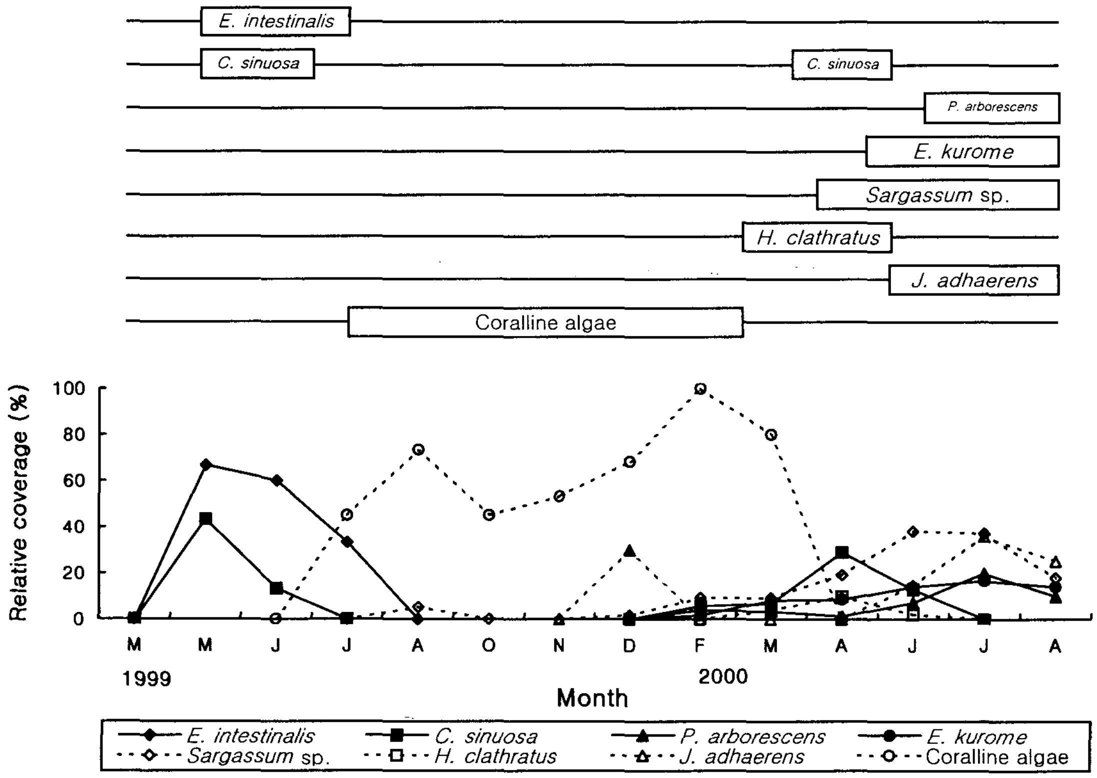

Fig. 5. Monthly changes of dominant algal species and relative coverage of them attached on the artificial reefs at the station B.

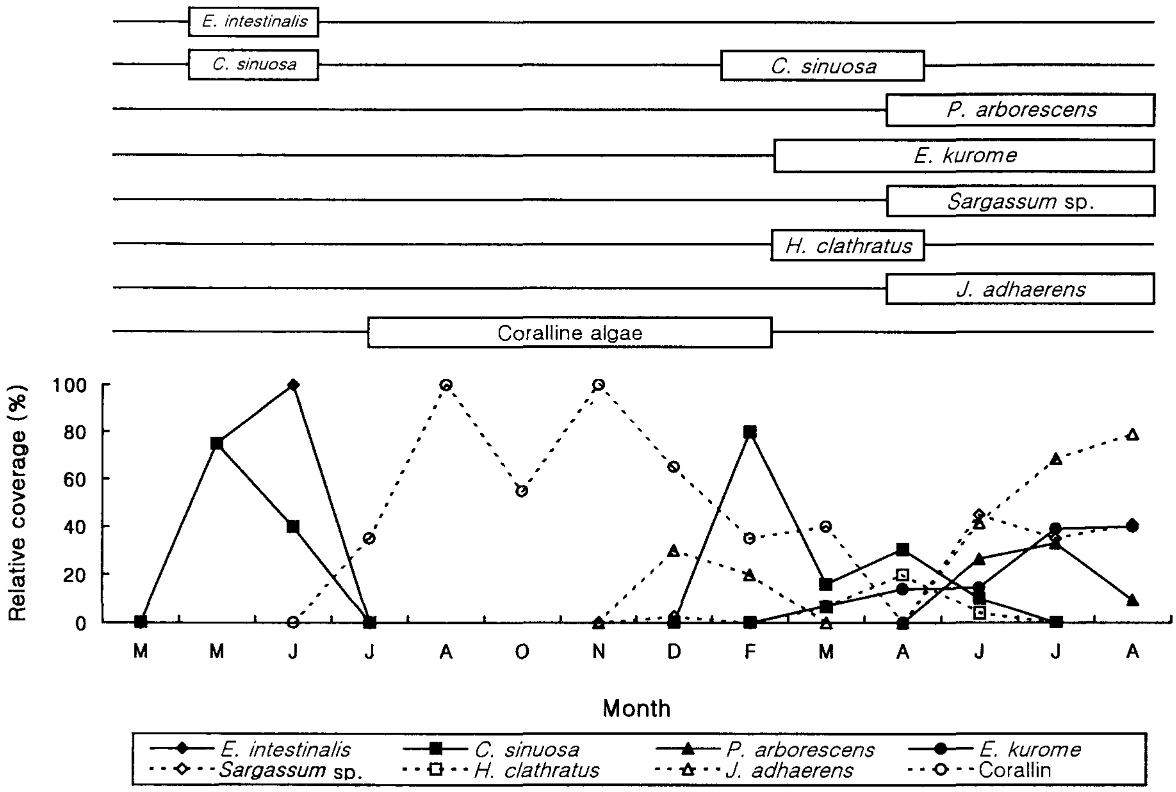

Fig. 6. Monthly changes of dominant algal species and relative coverage of them attached on the artificial reefs at the station C.

on almost all reefs in different depths, about 10~80 % coverage. *C. sinuosa* had decreased considerably on the reefs in June 2000 but *Padina arborescens, E. kurome* and *Jania adhaerens* gradually covered approximately 7~42%. The coverage of *J. adhaerens* tended to be comparatively greater, about 79% on the reefs from June to August 2000 at station C (Fig. 6).

The dominant species in algal succession on the reefs changed from diatoms to *Sargassum* spp., *E. kurome* and *P. arborescens* during the survey period as follows: diatoms, *E. intestinalis* and *C. sinuosa*, coralline algae, *C. sinuosa, Sargassum* spp., *E. kurome* and *P. arborescens*. The pattern of succession of the dominant species and the degree of domination were affected by the season, water depth and the recruitment of spores and eggs from the mature alga around the reefs.

Discussion

Many successional patterns have been noted in the marine benthos. Ohno et al. (1990), Watanuki and Yamamoto (1990) described similar colonization on the artificial concrete reefs within one month after placement. Kim (1987) reported that coccoid blue-green algae and diatoms were observed as pioneer algae settled on newly placed substrata, then filamentous green and crustose coralline algae were dominant.

Yamada et al. (1992) reported colonization of small annuals and crustaceous algae on the artificial concrete reefs. 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 the annual release of their reproductive cells. In our studies, *E. intestinalis* and *C. sinuosa* were found to be a typical early colonizer, whereas *Sargassum* spp., *E. kurome* and *P. arborescens* appeared in late successional stages. Our study suggests that the appearance of diatoms and some annual seaweeds are the early stage of algal succession on the artificial reefs under the shallow waters.

In this experiment, replacement of the dominant species varied according to the depth of the placement of the artificial reefs. Coralline algae dominated the reefs when water temperatures were higher. The algal coverage at the station C was different from that at the station B. At station C, coverage of *J. adhaerens* was recorded above 70% in summer, but station B coverage measured below 36%. During autumn and winter, when water temperatures were lower, the coverage of brown algae was comparatively high while that of the coralline algae was low. In our experiment, the coverage of green algae was higher at station A than at station B and station C. Coverage of brown and red algae the artificial reefs placed at station C was high compared with that of station A and station B.

Succession studies have obviously become central to the study of community structure (Foster and Sousa, 1985). A variety of research approaches, such as those on interspecific competition, the impact of grazing and the tolerance of species to physical stress, have been employed for the investigation of macroalgal succession on hard substrata (Kim et al., 1992). These approaches have provided useful information on community dynamics, but were only slightly considered in the present study.

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