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Colonization of Fouling Invertebrate Community on Suspended Man-made Structures of Varying Slope Angles

Sutheewat SOMSUEB[1], Masao OHNO[2] and Danilo B. LARGO[3]

[1] *The United Graduate School of Agricultural Sciences, Ehime University, Ehime Prefecture, Japan (Email: stwtha@ee. kochi-u. ac. jp)*
[2] *Usa Marine Biological Institute, Kochi University, Usa-cho, Tosa, Kochi 781-1164, Japan*
[3] *Department of Biology, University of San Carlos, Cebu City 6000, Philippines*

Abstract: The effect of substratum slope on fouling invertebrates was examined on suspended man-made structures over a period of one year at the Uranouchi inlet of Tosa Bay, southern Japan. The experimental structures, made of concrete material, have three different slope angles, namely: 0° (horizontal), 45° (incline) and 90° (vertical). A total of 9 independent observations was performed from August 1996 - October 1997.

At different periods of submersion, there was an observed succession of fouling invertebrates on the panels showing variations of dominant taxa among the three substratum slope angles. The common barnacles, tube-dwelling amphipods and serpulid polychaetes appeared seasonally on the structures. As for the influence of substratum slope, the presence of fouling organisms on sloped substratum (45° and 90°) varied in the dominant taxa as well. Barnacles were markedly abundant on substratum with vertical slope, while the other organisms did not show any preference among the different slopes. A greater number of free-living worms were observed on substratum with small slope gradient.

Key words: artificial reef, fouling invertebrates, man-made structure, substratum slope

Introduction

The purpose of artificial reef installation in many areas is to improve the marine environment and to promote and enhance fishery resources. Many reef designs have been developed in Japan for a long time now. However, it is only recently that the interrelationship between the design of the reef structure and biological colonization is being looked into. Several works in the past decade attempted to verify the relationship between the behavior of marine organisms and the physical condition of habitat such as substratum, scour, water motion and so on (as reviewed by Vadas et al., 1992).

In order to understand the natural mechanisms for a community succession, several investigations have been made corresponding to the initial development of fouling community, the intermediate period and its final stable community (after Mook, 1981). The resulting stable fouling community is characterized by high species diversity accompanied by a complex interaction among the members of the community.

With the massive use of artificial structures in all of Japanese coastal areas, it is worth taking into consideration the benthic succession in these structures. This study intends to examine the structure of the benthic invertebrate community in relation to the differences in substratum slope provided by these man-made structures.

Study Site

The water motion in the study site is relatively influenced by the daily tidal current with its fluctuation of about 2 m high. Changes of mean water temperature at 1 m deep vary from a maximum in August of 30°C (summer) to a minimum of 15° in February (winter). Salinity was about 28 to 32 unit (the lowest value observed at 20 unit after rainfall). Nearby the study site the ephemeral green algae such as *Ulva*, *Enteromorpha* and *Cladophora* were dominant flora found throughout the course of study.

Materials and Methods

The study was carried out in a floating platform (3 x 5 m area) located at Uranouchi Inlet of Tosa Bay, southern Japan (Fig. 1) wherein concrete artificial reefs (AR) of different designs (see below) were suspended. Each AR has a pair of bilaterally symmetrical panels slopes varying in angles from 0° (horizontal), 45° (incline) to 90° (vertical). Sheets (each of 6 cm x 9 cm) of roughened acrylic plates were affixed to these panels (with water resistant glue) to serve as detachable substratum on which fouling organisms would attach. The structures were suspended from the floating platform at a depth of one meter. Fig. 2 shows a diagrammatic sketch of the experimental set up.

A total of nine (9) independent observations was conducted from August 1996 to October 1997 each for a period of 6-7 weeks. In each field incubation period, observations of the panels were made twice - one in the initial stage (the first 3-4 weeks) and another at the final stage (the last 6-7 weeks). Two acrylic sheets were retrieved from each panel every sampling. The fouling community was scraped from the plates and sorted according to major taxa. The relative percentage cover of the dominant taxa was also determined from each plate.

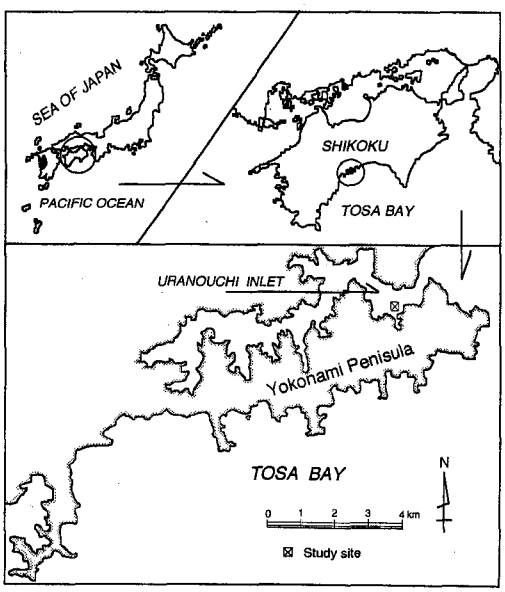

Fig. 1. Location of study site at Uranouchi Inlet, Tosa Bay, southern Japan.

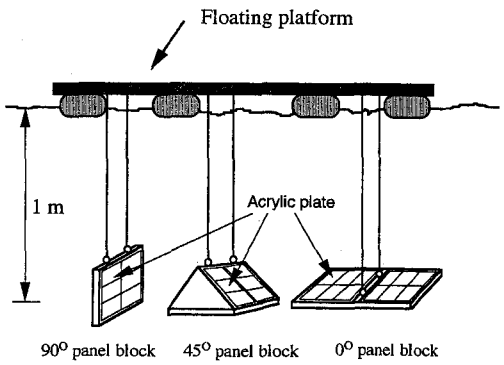

Fig. 2. Diagrammatic presentation of the three artificial reef designs with sloped panels. Acrylic sheets were affixed on the panels to serve as a removable substrate to facilitate examination.

Table 1. Percent cover of fouling organisms observed at different periods from August 1996 to October 1997 on the sloped panels. Shown here are the results of nine (9) independent observations made during initial stage (after the 3-4 weeks of suspension).

Organisms	AUG-SEP 96 3 weeks			OCT-NOV 96 4 weeks			NOV-DEC 96 4 weeks			DEC-JAN 97 4 weeks			FEB-MAR 97 4 weeks			APR-MAY 97 4 weeks			JUN-JUL 97 4 weeks			AUG-SEP 97 3 weeks			SEP-OCT 97 3 weeks		
	0°	45°	90°	0°	45°	90°	0°	45°	90°	0°	45°	90°	0°	45°	90°	0°	45°	90°	0°	45°	90°	0°	45°	90°	0°	45°	90°
Barnacles	○	⊙	●																⊙	●	●	⊙	●	●	⊙	⊙	●
Tube-dwelling amphipods	⊙	⊙	⊙	⊙	⊙	○	○	○	○	●	●	●	⊙	⊙	⊙	○	○	○	○	○	○	○	⊙	○	●	●	⊙
Serpulid polychaetes	*	*	*	●	●	●	○	○	○							○	○	○	○	○	○	○	○	○			

Remark: ● dominant, over 40 % ⊙ sub dominant, >10-40 % ○ less than 10 % * rare, less than 1 %

Table 2. Percent cover of fouling organisms observed at different periods from August 1996 to October 1997 on the sloped panels. Shown here are the results of nine (9) independent observations made during final stage (after the 6-7 weeks of suspension).

Organisms	AUG-SEP 96			OCT-NOV 96			NOV-DEC 96			DEC-JAN 97			FEB-MAR 97			APR-MAY 97			JUN-JUL 97			AUG-SEP 97			SEP-OCT 97		
	0°	45°	90°	0°	45°	90°	0°	45°	90°	0°	45°	90°	0°	45°	90°	0°	45°	90°	0°	45°	90°	0°	45°	90°	0°	45°	90°
Barnacles	○	⊙	●																⊙	●	●	⊙	●	●	⊙	⊙	●
Tube-dwelling amphipods	●	●	●	⊙	⊙	⊙	⊙	○	○	●	●	●	⊙	⊙	⊙	○	○	⊙	○	○	○	○	⊙	○	●	●	⊙
Serpulid polychaetes	○	○	○	●	●	●	⊙	⊙	⊙							○	○	○	○	○	○	○	○	○	*	*	*
Bryozoan																			*	*		*	*	*	*	*	*
Oysters																						⊙	⊙	○			
Mussels																						⊙	⊙	○			

Remark: ● dominant, over 40 % ⊙ sub dominant, >10-40 % ○ less than 10 % * rare, less than 1 %

Results and Discussion

The study site in Uranouchi Inlet was influenced by the fluctuation of tidal current. The variation in coverage of dominant fouling organisms is shown in Tables 1 and 2 for the initial stage and final stages of colonization, respectively. It can be seen that fouling organisms readily colonize the acrylic sheets within 3-4 weeks after suspension and persisted towards the end of submersion period, in this case, 6-7 weeks. However, the community structure changes over time with a succession of different plant and animal population. A large number of fouling invertebrates was observed in summer (July to September), whereas that of seaweed in winter (November to February).

Three most abundant organisms attached to the structures were barnacles, tube-dwelling amphipods and serpulid polychaetes. Oysters and mussels were dominant in August 1997, while other groups, such as oligochaetes, plathyhelminths and polychaetes were also recorded (Table 3). Barnacles dominated the community seasonally particularly in the months of June and October, while tube-dwelling amphipods and serpulid polychaetes were found all year round. The various taxonomic groups varied with the slope of the panels. Greater number of barnacles was frequently observed on substratum having 90°-slope angle while the tube-dwelling amphipods and serpulid polychaetes did not show any preference among the different panel slopes.

Discrete number of fouling organisms were observed three times (series of Aug 96, Oct 96 and Aug 97) at the end of suspension period (Table 3). A greater number of bottom dwelling worms (oligochaetes and polychaetes) was observed on the 0° and 45° slopes which can be attributed to the high accumulation of sediment materials on the horizontal panels, including organic detritus which could serve as their food. Unfortunately, we were not able to quantify the sediment deposit on the panels.

On the other hand, few bryozoans and tunicates were observed on the exposed upper side of the sloped panels. Rather they were greater in the unexposed, lower side of the suspended panels. Some green ephemeral seaweed such as *Ulva*, *Enteromorpha* and *Cladophora* existed in association with the fouling invertebrate communities.

The effect of substratum slope could be species-specific, thus, barnacles preferred to occupy the substratum with vertical slope, while the tube-dwelling amphipods and serpulid polychaetes show no preference at all. These findings were quite different from those reported by Whorff et al. (1995) wherein species of barnacles observed on the natural bed was not significantly different with respect to substratum slope, while species of polychaetes and amphipods were

Table 3. Individual of invertebrate taxa observed on the sloped substratum at three different periods.

Organisms	August-September 96			October-November 96			August-September 97		
	0°	45°	90°	0°	45°	90°	0°	45°	90°
Barnacles	228	168	1,908	15	48	75	75	105	672
Tube-dwelling amphipods	1,758	1,512	3,372	106	1,170	1,986	ND	ND	ND
Caprellid amphipod	96	90	48	197	36	2	0	0	0
Plathyhelminthes	54	42	47	6	15	0	10	19	32
Oligochaetes	810	546	126	91	72	18	0	0	0
Free living polychaetes	72	42	6	37	20	0	21	32	8
Brittle star	12	18	12	2	2	0	0	0	0
Oysters	0	0	0	0	0	0	260	361	15
Mussel	0	0	0	0	0	0	1,050	805	24

ND: means no data

common on horizontal slope. A report by Arai and Watanuki (1992) noted that the presence of benthic organisms inhabiting the bottom-placed concrete structure was slightly different among the gradient of substratum in terms of species composition and abundance. Greater number of barnacles was observed on 45° and 60° sloped panels, while oysters and serpulid polychaetes do not have detectable preference to any of the slope angles.

Results of the field trials also indicated that the structure of fouling communities varies relatively with the season and duration of suspension. This could be due to the differences in the recruitment period of each fouling species. Mook (1981) indicated that, at longer duration, the observed fouling community at a particular period could well develop into a stable community. Furthermore, Mook (1981) also explained that the composition of the fouling community is especially determined at the initial time of submersion. It is also pointed out in his study that the initial community is not always the most significant one in preparing the way for a latter population or community to develop. However, it should be noted that the number of species and diversity in the local area became nearly stable. Similarly, Anderson and Underwood (1994) reported a succession of different fouling organisms on different types of substrata at initial period of submersion but this became more similar after longer periods. It is therefore concluded that the study of fouling assemblage done at different seasons and/or period of time could not be comparable.

Corroborating this observation are several findings reviewed by Amsler et al. (1992) which shows that many of physical characteristics of microenvironment, such as change of flow over boundary layer, light quality etc., may affect development of germlings and settlement of many invertebrate larvae. Furthermore attachment behavior of a particular genus in a fouling community is difficult to determine due to the complex interaction among organisms as well as with their interaction with the different environmental factors (Amsler et al., 1992). However, with the observations made at different times of the year, it was sufficient enough to denote the occurrence of some fouling organisms on the suspended structure to be influenced by the slope of substratum.

Conclusion

In conclusion, the results of this study showed that the structure of fouling community was influenced by the substratum slope. Barnacles tended to dominate on substratum with more vertical orientation, while oysters and mussels community dominated in more horizontal orientation. As for free-living organisms inhabiting the bottom of the structure (such as oligochaetes and polychaetes), they are likely to be abundant also in a more horizontally oriented surface. The large number of the amphipod caprella in the natural bottom surface in the study area was closely associated with the presence of algal community. The attachment behaviors of many marine organisms on these man-made structures remain to be elucidated with more attention given on their recruitment as well as the interaction among themselves. While this study can be considered a preliminary one the results of more long-term observations on fouling organisms could be an essential requirement before administering a program of artificial reef installation in a specific location.

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