Diversity of attached marine life in different types of artificial timber reefs

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Abstract. Artificial reefs (ARs) have been implemented as a tool to increase fish catch by gathering fish and creating new habitat. In Japan, fisheries production has been decreasing in the last several decades. Research on ARs to date has mainly focused on fish biomass and community structure. The present study describes the community structure of marine organisms attached to the ARs deployed in Mitsu Bay, Hiroshima, Japan. We compare those communities on three types of ARs, which are made of timbers (ATRs), ATRs with oyster shells (ATRsOS) and ATRs with leaves and branches (ATRsLB). Attached organisms were collected seasonally from 2016 to 2018. Overall, 272 taxa were identified from two deployment sites. Arthropods were the dominant group identified, followed by molluscs and annelids. Seasonal variation of individuals collected was observed, with numbers being high in summer and low in winter. The number of individuals was high in the first year after deployment of ATRs, decreasing in the second year and beyond, suggesting the animal community may have matured by balancing the growth and feeding by fish. All three types of ATRs were commonly large in individual number and small in species number, characterized by a low diversity index. The highest individual number and highest species number were observed in ATRsLB and ATRsOS, respectively. More specifically, the diversity index for simple ATRs was lower than those for ATRsOS and ATRsLB. This result suggests that ATRs with additional materials can provide a wide range of feed animals which may attract more fish. The deployment of ATRs made of materials like timbers and oyster shells is also good practice for promoting a recycling-oriented society.

1. Introduction

Artificial reefs (ARs) are submerged structures placed on the sea bottom for a variety of purposes [1]. ARs modify both the physical and biological environment in the deployment area and have the potential to boost production through two functions: providing habitats for fish [2–4] and increasing attached marine organisms on the ARs’ surface, the growth of which, in turn, provides food for fish [5–7].

In Japan, fisheries production has been declining over the past 30 years and the self-sufficiency of marine products in Japan is currently approximately 60% [8]. Given the prospect of ARs that may help to increase fish production, deployment of ARs is widely used as a countermeasure in many prefectures in Japan. We have been conducting a project with the support of Higashi-Hiroshima city, Japan, where the ARs were made of timbers (ATRs); and created three types of ATRs: simple ATRs, ATRs with additional material comprising oyster shells (ATRsOS) and ATRs with additional
materials comprising leaves and branches (ATRsLB). Hiroshima city habitats widely range from mountain areas to the coastal sea of Mitsu Bay, where oyster culture is intensively conducted. In this city, we have two major issues. One is how we can effectively use the discarded timbers produced by forest thinning activity. Another is the effective use of the oyster shells produced through oyster meat processing. Consequently, our project focuses on the simultaneous use of these materials and the formation of a recycling-oriented society.

Although the use of ATRs is not new in Japan, research to date has mainly focused on the fish community as the main reason for AR deployment, with limited information available about the epifaunal community, which may be important to attract fish. The present study describes the attached marine life communities observed on the timber-based AR structures, as these communities are food organisms that make ATRs more attractive to fish, thereby influencing the eventual biodiversity of the system as a whole. In particular, we study the differences in community structures and their diversity on three types of ATRs.

2. Methods
The ATRs were constructed using discarded timbers of Japanese cypress (Chamaecyparis obtusa) from forest thinning activities in Ikoinomori Park, Higashi-Hiroshima, Japan. The ATRs were constructed with timbers in a cube-shaped parallel cross with a size of 1.5 x 1.5 x 1.5 m. Thirty-centimetre logs were also installed on the ATRs as test pieces to observe the growth of attached organisms. The other two types of ATRs were also constructed using the same dimensions. Additional materials of leaves and branches and oyster shells were packed in a 40 cm x 45 cm foldable lantern-shaped basket and installed in the space of the parallel cross of ATRs. Fifteen ATRs (3 ATRs, 6 ATRsOS and 6 ATRsLB) in total were deployed at 10 m depth in two sites in November 2015: Kazahaya and Kidani (34°17’39.8”N - 132°50’21.8”E) in Mitsu Bay, Higashi Hiroshima.

Field observations were conducted from January 2015 to August 2018. Animals from the test pieces and net baskets placed in each ATR were collected and preserved in 10% formalin. These animals were then identified to species or lowest possible taxa level and counted.

The type of diversity used here is α-diversity, which is the diversity of species within a community or habitat. To examine patterns in ecological diversity on the ATRs, Shannon-Weiner diversity ($H'$), Margalef richness ($D$) and evenness ($J'$) indices were calculated as per [9]:

\[
H' = -\Sigma pi \ln pi
\]

\[
D = (S-1)/\ln N
\]

\[
J' = H'/\ln S
\]

Where $pi$ is the proportion of individual number $i$ to the total individual number in the sample ($N_i/N$), and $S$ is the total number of species [10].

3. Results
The immediate growth of marine animals was found in the first year of ATR deployment. A total of 155,541 specimens belonging to 272 species/taxa were observed in the three types of ATRs in two deployment sites (Fig. 1). The results showed that arthropods dominated the community, contributing the highest percentage in species composition in all types of ATRs throughout the observation period. Molluscs and annelids also gave significant contributions to the species composition, especially in ATRsOS and ATRsLB.
In general, the number of individuals was higher in ATRs with additional settlement materials, with numbers peaking in the warmer season and decreasing in the colder season, and a similar pattern in seasonality occurring in both sites (Fig. 2). The number of species was also higher in ATRsOS and ATRsLB compared to the simple ATRs. In Kazahaya, the highest species number was found in July 2017, when 44, 85 and 76 taxa were observed in ATRs, ATRsOS and ATRsLB, respectively. In Kidani, the highest species number was 44 in ATRs found in January 2017, while in July 2017 it was 91 and 71 in ATRsOS and ATRsLB, respectively.

The Shannon-Weiner diversity index ($H'$) did not vary between the two sites (Fig. 3). The highest index value was obtained in ATRsLB in January 2017 in Kidani. In detail, the index value obtained in ATRsLB ranged from 1.48-3.44 with an average of 2.52 in Kazahaya and from 1.35-3.52 with an average of 2.49 in Kidani. In the ATRsOS, the value ranged from 2.47-3.48 with an average of 2.93 in Kazahaya and from 1.78-3.35 with an average of 2.83 in Kidani. These two more complex ATRs had comparably higher values than those in simple ATRs where the value was from 1.13-3.03 in Kazahaya and from 0.96-3.36 in Kidani.
Evenness index \( J' \) ranged from 0.28-0.85 and was usually low in two sites, except for ATRsOS. Although richness index \( D \) was observed to be high over a certain period especially for ATRsOS and ATRsLB (Fig. 4), which related to a high number of species diversity index and evenness remained relatively low due to the presence of a large number of Caprellidae.

Figure 3. Seasonal changes on Shannon-Weiner index \( (H') \) and Pielou’s index \( (J') \) in different types of ATRs in (a) Kazahaya and (b) Kidani. January 2016-August 2018.

Figure 2. Seasonal changes in richness index \( (D) \) in all ATRs in (a) Kazahaya and (b) Kidani. January 2016-August 2018.

4. Discussion
The increase in numbers of animals observed shortly after the deployment of ARs in our two study sites was also commonly observed in other studies [11,12]. After the deployment of ATRs, arthropods dominated in all types of ATRs but became less dominant as time elapsed after the deployment, as molluscs and annelids took over from them; this was observed particularly in ATRsOS and ATRsLB. However, there was no clear difference in the animal compositions in the two study sites, suggesting the source for colonization of the animals may be the same in this bay.

The result of this study showed that the number of individuals and species were higher in ATRsOS and ATRsLB, implying that oyster shells and leaves and branches may provide extra space for animals to attach and grow. The seasonal change in individual numbers (i.e. high in summer and low in winter)
was obvious during the first year, but became unclear in the second year and beyond. This indicates that the community may have matured in balance between their growth and feeding by fish. This seasonal change is consistent with the findings in other AR structures [13,14]. On the other hand, the species number increased over time after deployment and was at its highest in July 2017 for all ATRs. Such heavy colonization was observed during summer, when the larval abundance in the water column was also high [14]. However, the decrease in individual and species numbers was observed 2-3 years after the deployment. This can be attributed to the weathering of the timbers, which was evidenced by underwater video records and visual observation on SCUBA. As timbers and additional materials such as leaves and branches broke down, animals attached to them may also have been lost to the water column.

The seasonal pattern in change of the biodiversity index did not much differ between the two deployment sites. High numbers of individuals and small numbers of species were common across all types of ATRs. The values of the indices in ATRsOS and ATRsLB were higher than those in simple ATRs, as their species numbers were higher and distribution was more even in the former two ATRs.

The higher spatial heterogeneity in ATRs with additional settlement materials could be a key factor in explaining the comparatively richer and higher index value compared to simple ATRs, because of their higher complexities in habitat structures. Finally, this result suggests that ATRs with additional materials can provide a wide range of food animals, which may attract more fish. Deployment of ATRs made of materials like timbers and oyster shells is also a good practice for promoting a recycling-oriented society.

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