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Original article

Creation of fish habitats with thinning timbers in Mitsu Bay - a case study of ICZM

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Introduction

In Japan, fisheries production has been declining during the past 30 years, and the self-sufficiency of marine products in Japan currently is approximately 60%.

Forests, on the other hand, covers more than 60% of the land area in Japan. To maintain adequately healthy forests, cutting timbers is important [1]. Most cut timbers from forest thinning are discarded without effective use, given the change in life style to preferentially use fossil fuels rather than timbers.

The thinning timbers can be used to construct artificial reefs (ARs) which can serve as effective gear to increase fishery production by creating new habitats and enhancing their growth by providing feed [2-5]. Thus, the deployment of artificial reefs composed of timbers (ATRs) may be beneficial to promote integrated coastal zone management (ICZM), a universal concept in which the basin ecosystem and its environmental condition is managed considering all aspects of the total system, encompassing the upper forests to the seas.

ATRs may support the settlement of seaweeds and provide habitats for sessile animals that contribute to the formation of a food web in the sea owing to their textural variety and stable surface area [6]. In this study, 3 different types of ATRs were evaluated for their ability to successfully create a habitat and increase fish production, while confirming to good ICZM principles.

Materials and methods

The ATRs were constructed using discarded timbers from forest thinning activities in Ikoinomori Park, Higashi-Hiroshima, Japan. The ATRs were cube shaped (1.5 × 1.5 × 1.5 m) with three variations in design: simple artificial timber reefs (ATRs), artificial timber reefs with oyster shells (ATRsOS), and artificial timber reefs with leaves and branches (ATRsLB). At two of the sites (Kazahaya and Kidani) in Mitsu Bay, Higashi-Hiroshima, 15 ATRs were deployed in November 2015.

Field observations were conducted from November 2015 to January 2017 by monitoring the water quality and sampling the organisms found on the ATRs, as well as in control locations including sites with artificial concrete reefs (ACRs) settled in 2013. Organisms attached to each type of ATR and ACR were collected. Benthic organisms were also collected using a grab sampler from an area of 25 cm × 25 cm and 5 cm depth. Fish abundance was recorded using 13 cameras (Hero Session 4, GoPro Co. Ltd.) that were placed at all sites for one hour during each sampling. All organisms were identified to species or genus level and numbers recorded.

Results

Attached organisms belonging to 139 taxa were identified in the collections from the test material of ATRs, including bivalves, errant and sedentary worms, arthropod, colonial ascidian, and algae.

The abundance and wet weight of the attached organisms increased gradually in the Kazahaya and Kidani sites until July 2016, and decreased in January

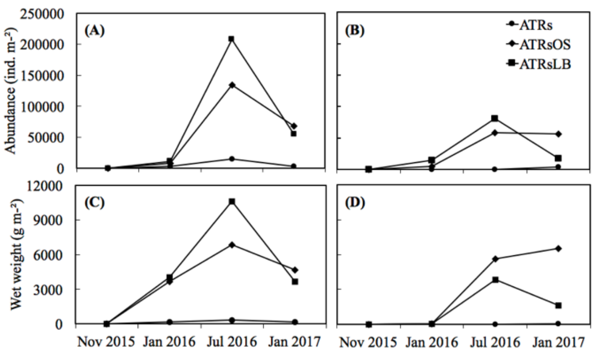

Fig. 1. Temporal changes in the attached organisms in the ATRs: abundance of attached organisms at **(A)** Kazahaya and **(B)** Kidani, and wet weight of attached organisms at **(C)** Kazahaya and **(D)** Kidani.

2017 with the exception of a slight increase for ATRsOS in Kidani in January 2017 (Fig. 1).

The highest abundance of attached organisms was recorded at Kazahaya with 2.07×10^5 ind. m^{-2} in ATRsLB, with a wet weight of 1.06×10^4 g m^{-2}, which was twice that observed in Kidani (8.1×10^4 ind. m^{-2} and 3.8×10^3 g m^{-2}, respectively). The abundance and wet weight of attached organisms were highest ATRsLB, followed by that in ATRsOS and ATRs.

Benthic organisms belonging to 131 taxa comprised mostly errant and sedentary worms, bivalves, and amphipods, and small numbers of bryozoans and sea anemones.

The abundance and wet weight of benthic organisms in the sediment of ATRs were found to be slightly higher than that seen in the control site, except for the abundance in Kidani (Fig. 2). However, those were still below those recorded for ACRs.

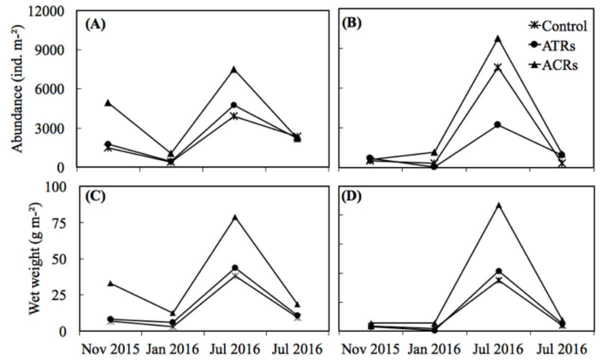

Fig. 2. Temporal changes of benthos in the ATRs: abundance of benthos at **(A)** Kazahaya and **(B)** Kidani, and wet weight of benthos at **(C)** Kazahaya and **(D)** Kidani.

Temporal changes in identified fish based on video recordings at the two sites are shown in Fig. 3. Eighteen fish species were observed during 2016-2017, of which the five predominant species were *Halichoeres poecilopterus, Pagrus major, Acanthopagrus schlegelii, Ditrema temmincki,* and *Sebastes inermis*.

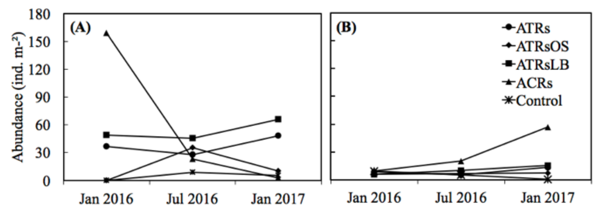

Fig. 3. Temporal changes in fish: abundance at **(A)** Kazahaya and **(B)** Kidani.

Fish abundance in all types of timber reefs increased gradually over time, but was still below the abundance levels seen with ACRs at the Kidani site, while in Kazahaya fish abundance in all timber reefs in January 2017 was higher than that seen with ACRs. Fish abundance was generally higher in sites deployed with ARs than in the control sites at all sampling times.

Various sizes and all developmental stages of *Sebastes inermis* were observed on all kinds of timber reefs, while larger fishes of *Pagrus major* and *Acanthopagrus schlegelii* were commonly found in the ACRs.

Discussion

ATRs revealed their ability to alter the habitats for attached and benthic organisms, and increase their population, probably by providing suitable substrates for establishing and settling. Similar results were reported in other studies in which wooden substrata of discarded barges were more effective in promoting the settlement of organisms, and were also attractive to fish [7,8].

ATRsLB, in particular, had the highest abundance of feed organisms among all the types of ATRs studied, which is consistent with previous reports, in that ARs with a more complexed and diversified structure generally provide additional microhabitats and increase the abundance of organisms [8].

However, the abundance of benthos and fish was still higher in ACRs than in ATRs. This is possibly due to the differences in deployment time, as the ACRs were deployed 2 years prior. This may have established a more stable condition in benthos and fish inhabitancy.

It is concluded that ATRsLB with a complex form, stuffed with leaves and branches, were the most effective in enhancing fish production, by serving as shelters and providing food. Using thinning timbers along with leaves and branches for ARs is a good practice to link forests and seas in terms of ICZM, particularly in Japan with a high proportion of forests and lower fishery production.

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