Artificial Reefs Contribute to Marine Resources Enhancement

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Abstract

When there are things such as sunken vessels in sea bottoms, Japanese ancient people knew by experience that various fishes gather near these sunken vessels. The function of sunken vessels is the same as natural reef. Therefore, artificial reefs had been constructed from ancient times as auxiliary fishing gear that aim to gather fishes. At present, artificial reef fishing ground had been constructed to gather, propagate and protect fishes from larval/juvenile stage to adult stage, because fishery resources are observed to be in extreme decrease in their juvenile stages. Depending on the scale of artificial reef fishing ground, in Japan there are the fishing grounds of around 400 cubic meters called "Namigata-sho", fishing grounds of several thousand cubic meters called "Oogata-sho", and fishing grounds of more than 30,000 cubic meters called "Jinkou-sho". The aim of installing artificial reefs is to expand the natural reefs and create new fishing grounds equal to natural reefs. In addition, there is a new-type of artificial reef which is called "upwelling mound". If this new artificial reef can raise rich nutrient salts near the bottom layer into the euphotic zone, artificial reefs will enhance primary productivity of the surrounding sea area, which in turn will raise fishery production capacity as a result. For discussion in this Symposium, two Japanese artificial reef activities will be introduced. The first is artificial reef fishing ground for marine resources enhancement, and the second is measurement method on fish-gathering effect and fish-propagation effect around artificial reefs.

Keywords: artificial reef, fish-gathering effect, fish-propagation effect

Introduction

Among the many things that linger at the bottom of the sea are sunken vessels. Ancient people in Japan learned through experiential observations that various fishes gather near these sunken vessels and that these sunken vessels function as natural fish reefs. Based on such observations therefore, artificial reefs (ARs) had been constructed from ancient times in the waters of Japan as auxiliary fishing gear for the purpose of gathering fishes.

Moving from the ancient times to the present, fishing grounds with ARs have recently been created to gather, propagate and protect fishes from their larval/juvenile to adult stages, considering that the fishery resources are observed to be extremely decreasing, especially the juvenile stage of many species.

The creation of fishing grounds with ARs is aimed at expanding the natural fish reefs, and establishing suitable habitats similar to that of natural fish reefs. Thus, several types of fishing grounds with ARs had been constructed in Japan, such as the "namigata-sho", "oogata-sho", "jinkou-sho", and others depending on the scale of fishing ground creation.

In order to increase the fishery production from constructed AR fishing grounds, sea farming is practiced to enhance the marine resources, *i.e.* from seed production, releasing and transplantation, in addition to enforcement of fishery restrictions.

Recently, a new type of AR fishing ground known as the "upwelling reef" has been promoted in Japan. This type of AR is capable of raising rich nutrient salts near the sea bottom layer to the euphotic zone, enhancing the primary productivity of the surrounding sea areas, and as a result increasing fishery production.

Therefore, integrating fishing ground creation, sea farming and marine resources management would lead to marine resources enhancement. Recent movements in Japan with respect to development of ARs include determining the amount of fish or other marine resources that gather or aggregate around ARs, and creating AR fishing grounds for marine resources enhancement.

Determining the quantity of fish that aggregate around ARs

The main objective of determining the fish or marine resources that aggregate around ARs is to know the answers for 5W1H on the impacts of ARs, *i.e.* when, where, who, what, why, and how. In Japan, observations of fish schools around ARs are carried out through visual inspections by divers using optical and acoustic devices, among others. Sampling surveys are also being carried out using such fishing gear as pole-and-line, longline, gillnet, and others. In addition, biotelemetry and tagging of fish for releasing experiments have been undertaken. Results of fish gathering surveys, fish market surveys, questionnaire surveys, and interviews have been used to analyze the extent of enhancement or cost-effectiveness of the AR fishing grounds. The characteristics of several measurement methods to determine the fish and marine resources aggregating around ARs are shown in **Table 1**. For example, the characteristics of diver's visual inspection could include: observation area which should be narrow and short; observation inside of ARs should be possible; duration time of observation should be very short, *i.e.* within about 1 hour; observation of the composition and body lengths of fishes near the ARs could be done. If the water depth near the created AR fishing grounds is shallow, observation cost could be cheaper than in deeper waters.

Table 1. Characteristics of several measurement methods to be used around created AR fishing grounds

Method	Observation of Fish School			Observation Area			Duration Time	Cost
	Composition	Mass	Body Size	Distance	Width	Inside		
Visual Inspection by Diver	◎	△	○	Short	Narrow	Available	Hour	Average
Optical Device ROV	○	△	△	Short	Narrow	Unavailable	Day	Average
Acoustic Echo-sounder	×	△	×	Long	Extensive	Unavailable	Day	Expensive
Fish Finder	×	○	△	Long	Extensive	Unavailable	Day	Average
Pole and Line Fishing	△	△	○	Short	Narrow	Unavailable	Day	Cheap
Long Line Fishing	△	△	○	Middle	Middle	Unavailable	Day	Cheap
Gill Net Fishing	○	△	○	Middle	Middle	Unavailable	Day	Cheap

Note: ◎Exact result ○Present conditions recognition is possible △ Conjunction with other investigations ×Unavailable

How the created AR fishing grounds can contribute to marine resources enhancement

The creation of AR fishing grounds could contribute to marine resources enhancement through the promotion of three major attributes, namely: integrating or linking resources enhancement with sea farming and resources management; creation of protected areas; and adoption of new method of AR fishing ground creation such as the establishment of "upwelling reef."

Integrating resources enhancement with sea farming and resources management

Marine resources enhancement has been carried out in Japan through the integration of fishing ground creation, sea farming, marine resources management, and fishery restrictions. The aim of fishing ground creation is to improve or create habitats for marine organisms while that of sea farming is for artificial enhancement of the marine resources. As shown in red broken line in **Fig. 1**, the aim of marine resources management is to control illogical fishing in order that through marine resources enhancement which aims for artificial creation of habitats, the blue broken line could be reached starting from the black solid line which is the natural condition of the resources (**Fig. 1)**.

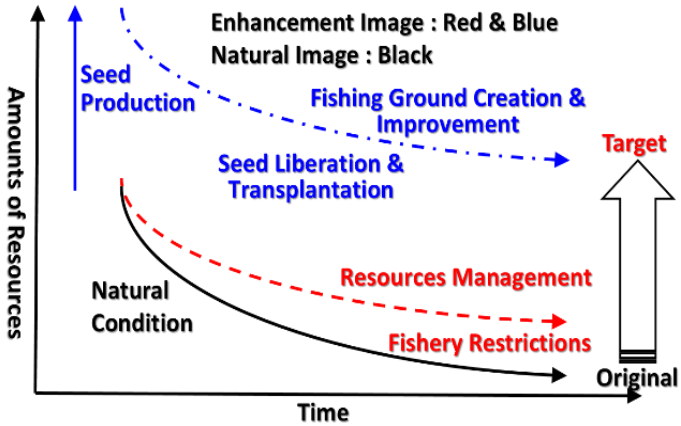

Fig. 1. Concept of marine resources enhancement adopted in Japan

When marine organisms are observed to have extremely decreased until juvenile stage, artificial enhancement of the marine resources is undertaken such as seed production, intermediate breeding, seed releasing, and transplantation (**Fig. 2**). Based on the life stages of target species, the habitats of marine organisms could therefore be improved or created artificially. In addition, fishing restrictions on fishing methods, gear, season, ground, catch-size, among others could be enforced. If necessary, protected areas or fishing prohibitions should also be established.

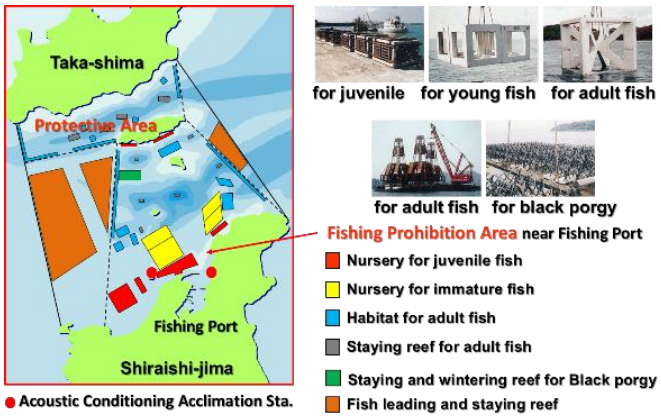

Fig. 2. Methods of marine resources enhancement adopted in Japan

A marine ranching project around Shiraishi Island in the Inland Sea of Japan shown in **Fig. 3**, was carried out from 1993 to 2001, targeting such species as the red sea bream, black sea bream, gopher, scorpion fish, Japanese sea bass, red-spotted grouper, and others. Sea farming that involves seed production, seed releasing and intermediate breeding with acoustic acclimation was carried out, while protected area and fishing prohibition had been established. Taking into consideration the life stages of the target fishes, existing fishing grounds had been improved into suitable habitats, especially when new juvenile nurseries with ARs were constructed.

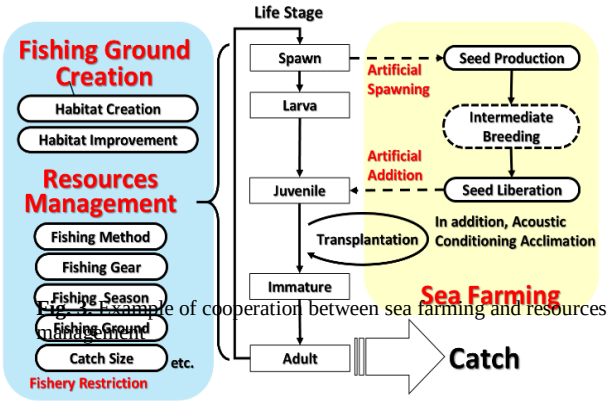

Fig. 3. Example of cooperation between sea farming and resources management

Furthermore, as shown at the left side of **Fig. 4**, fish catch from set net fishery had increased immediately based on the progress of this project.

At the right side of **Fig. 4**, fish catch of gill net fishery had also gradually increased after the effects of the cooperation that had taken place. However, there was a time-lag in the emergence of such effect.

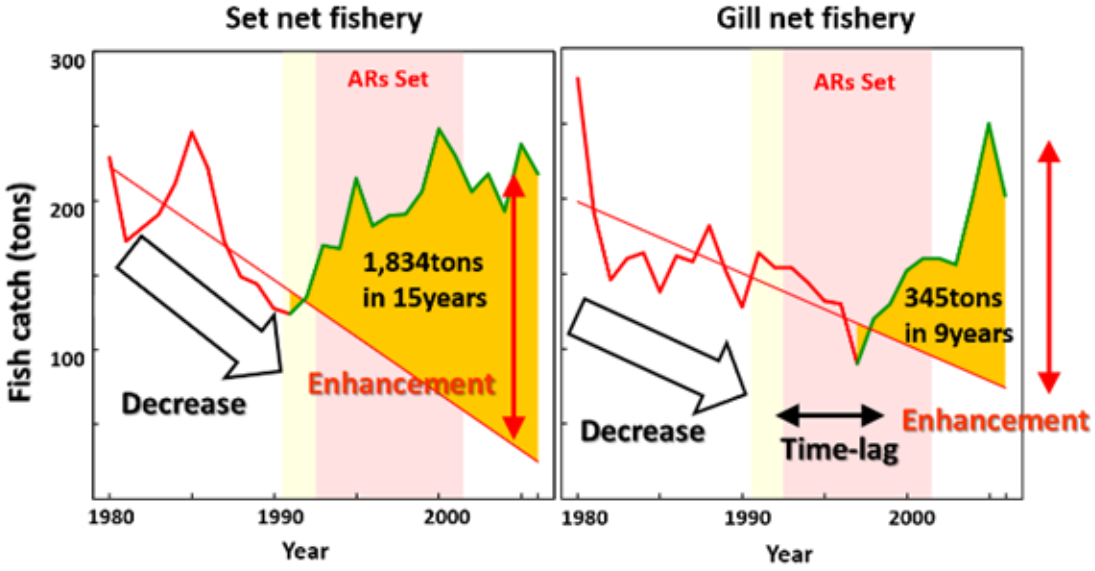

Fig. 4. Effects of cooperation with sea farming and resources management

Creation of protected areas

In the case of female snow crabs which should be protected during their spawning season from trawl fishery or basket net fishery, a fishing ground was created by local governments in the western part of the Sea of Japan since the 1980s (**Fig. 5**). In addition, fishing ground creation was undertaken by the national government starting in 2007. The red circles in **Fig. 5** are the sites of fishing grounds created by the national government, which also specified certain conditions for constructing AR fishing grounds under their direct control, *i.e.* (1) inside the EEZ, (2) target species for TAC or TAE, and (3) development of marine resources recovery plan.

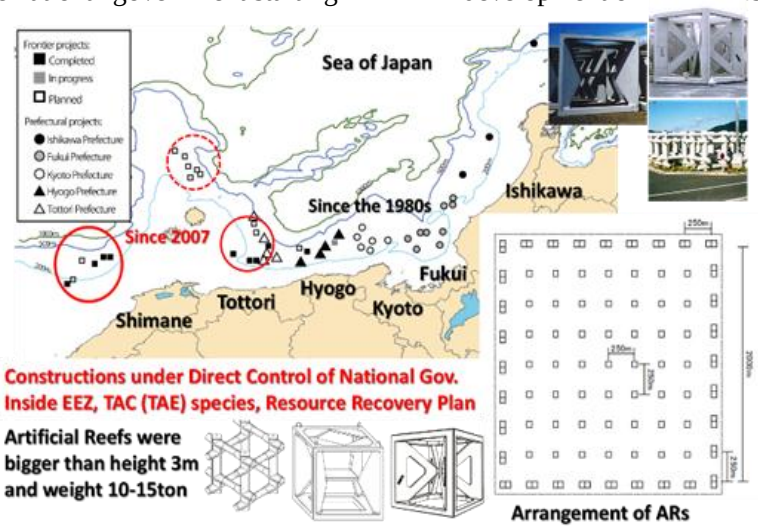

Fig. 5. Creation of protected area for snow crabs

The water depth of the spawning grounds of snow crabs was about 200 m to 300 m in the western part of the Sea of Japan. Several AR fishing grounds within the 2.0 km^2 area had been constructed with sizes bigger than 3 m high and weighing 10 tons. The progress after construction indicated gradual increase of attached organisms and benthic organisms in and around the ARs. Gravid female snow crabs which were about to spawn and various fishes had aggregated in the AR fishing ground. At the left side of **Fig. 6**, the catch of snow crab from the western part of the Sea of Japan was about 15,000 tons/year in the 1960s. Later, the catch of snow crab suddenly decreased to only about 2,000 tons/year in the 1980s. Thus, fishing prohibition area had been established and declared within 2 km of the created fishing ground. In the right side of **Fig. 6**, gravid female snow crabs or spawners had been protected in the created fishing ground. As a result, the catch of snow crab had gradually recovered since the 1990s.

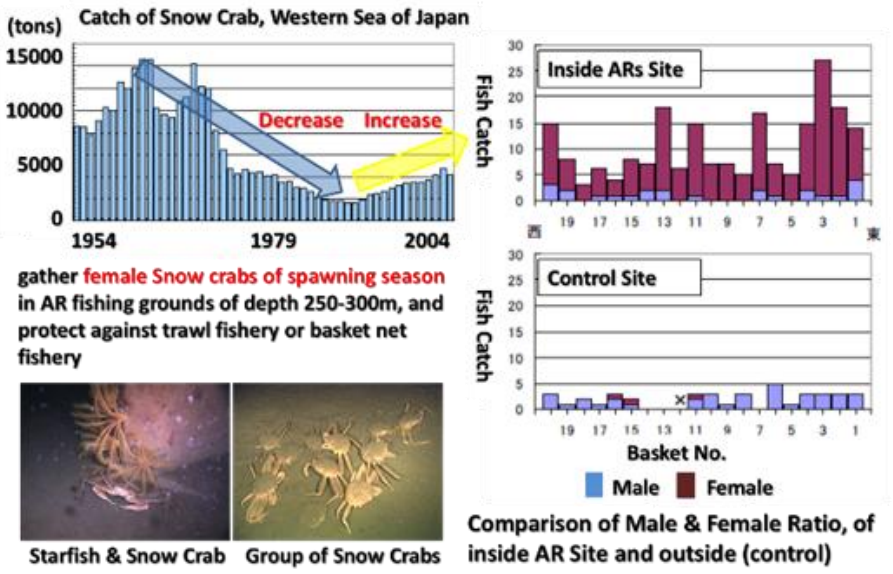

Fig. 6. Effects of creation of protected area for snow crabs

Adoption of a new method to establish upwelling reef

If upwelling reef can raise rich nutrient salts from the bottom layer into the euphotic zone, then upwelling reef would enhance the primary productivity of the surrounding sea areas, and eventually, the fishery production would be increased (**Fig. 7**). An upwelling reef 5 km off the Ikitsuki Island in Nagasaki Prefecture was constructed for the first time in Japan from 1997 to 2000. This upwelling reef 16 m high, 120 m long and 60 m wide, was constructed using concrete blocks set at sea bottom with depth of about 82 m. Since the construction at Ikitsuki, more upwelling reefs had been constructed at 7 sites in Nagasaki, 1 site in Kagoshima, 2 sites in Miyazaki, and 1 site in Shizuoka.

An analysis of the chlorophyll distribution in the sea surface was carried out to confirm that the primary productivity near the upwelling reef had been enhanced. Results of the progress after the construction indicated that chlorophyll distributions around the upwelling reef had increased as shown in blue line in **Fig. 8**. In the control sea area, which was away from the upwelling reef, chlorophyll distributions were not increased as shown in the red line of **Fig. 8**. Fish catch around the upwelling reef was also increased from 250 tons/year before construction to 1,500 tons/year after the construction. Specifically, the catch of anchovy, a plankton-eating fish had increased.

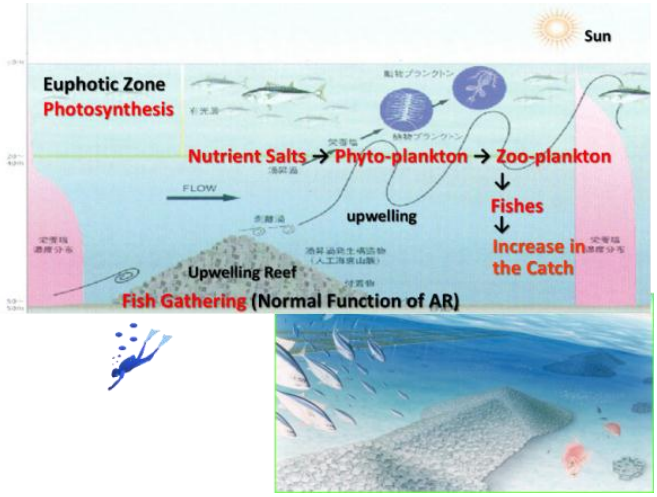

Fig. 7. Concept of establishing an upwelling reef

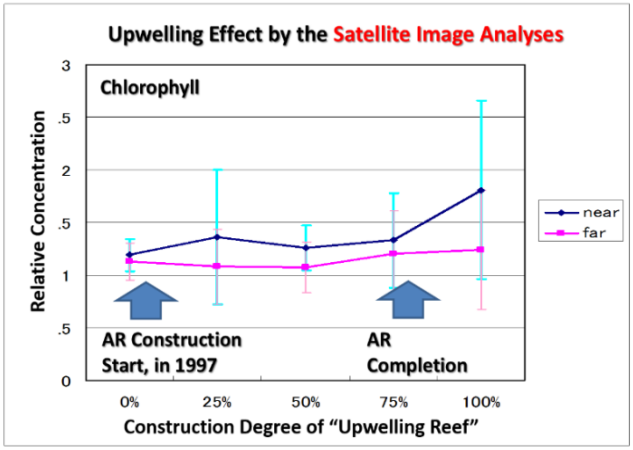

Fig. 8. Effects of creating an upwelling reef

References

Yasuhisa Kayano: http://doi.org/10.11233/aquaculturesci1953.49.15 (in Japanese)

Motobumi Manabe *et al.*: http://doi.org/10.2208/jscejoe.70.I_1056 (in Japanese)

Koji Watanabe et al.: http://doi.org/10.2208/prooe.24.31 (in Japanese)

Fisheries Agency: http://www.jfa.maff.go.jp/j/gyoko_gyozyo/g_thema/sub52.html (in Japanese)