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Macrobenthic community at type and age-different artificial reefs located along the Korean coast of the East Sea

Wan Ki Kim[1], Yong Soo Son[1], Ji Hyun Lee[1], Jeung Pyo Hong[1], Young Seop Kim[1], Jeong Woo Lee[2] and Qtae Jo*[2]

[1]Fisheries Resources Management and Enhancement Team, East Sea Fisheries Research Institute, Gangwon - 210-861, Korea
[2]Aquaculture Research Team, National Fisheries Research and Development Institute, Busan - 619-902, Korea

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Abstract: *Two types of artificial reefs, one for simple (S-AR), another for complex artificial reef (C-AR), were installed on a Korean coast of the East Sea (Sea of Japan) where a barren ground was progressive. Compared with macrobenthic organisms at NHB (natural hard bottom) control, AR (artificial reef) enhanced seaweed composition, reducing echinoderm composition, mostly sea urchins, the causative animal of the barren ground. Composition of the two mutually exclusive communities was AR type-specific, the C-AR exerting better function over S-AR by enhancing higher seaweed composition. However, this ecosystem-sound composition at C-AR was maintained only within 10 years. Another negative aspect of the AR was an unexpectedly higher composition of tunicates that can be a sign of nutrient-rich environment in the Korean waters. Overall, C-AR was more agreeable when simply based on its function excluding construction cost.*

Key words*: Artificial reef, Type and age of reefs, Epibenthic macroorganisms, Barren ground, Korean coast*
PDF of full length paper is available with author ***(*qtjo@nfrdi.re.kr)***

Introduction

In recent years there has been a growing awareness that enforced efforts to wild stock enhancement. It is now being recognized that the stock enhancement can only be achieved if strategic approaches are exerted. Two approaches to wild stock enhancement have been practiced in Korean water: stock enhancement through the release of cultured juveniles and installation of artificial reefs for marine lives.

Artificial reefs (ARs) have been strategically established by intentionally placing some structures such as old ships, barges, concrete and steel debris, and dredge rocks on the designated reef sites to provide a hard substrate or shelter for marine lives. With the accumulated evidence of the structures for marine lives, types of artificial reefs have been manufactured and installed in the coastal waters for marine lives endangered or to be enhanced for commercial purpose (Stone *et al.*, 1991; Jensen, 1997).

Since 1983, National Fisheries Research and Development Institute (NFRDI) has developed an intensive program of artificial reef construction and biological monitoring along the Korean coasts of the east sea (Sea of Japan). However, most of the monitoring has been confined in the fisheries resources near the ARs (Lee and Kang, 1994). Because doubts regarding ARs performance and possible effects on the natural environments are still remaining unanswered, an ecological survey covering a wide range of marine organisms are necessary (Bohnsack and Sutherland, 1985; Polovina, 1991; Steimle and Meier, 1997; Perkol-Finkel and Benyahu, 2004).

AR effect on macrobenthos might be different from fish. It might be free from the arguing attraction hypothesis raised by Bohnsack (1989), in which ARs totally attract fishes from other habitats, which otherwise would have dispersed. However, limited information on macrobenthos at ARs is available from Korean waters. Here, we studied community structures of macrobenthos at type and age of ARs located on a Korean coast of the east sea where a sign of barren ground is emerging, particularly focusing on two mutually exclusive benthic communities, the seaweeds and sea urchins.

Materials and Methods

Experimental site: The experimental sites are located in Gangwon coast (200-800 m from coast and depth 15-30 m), Korea, where a barren ground was progressive (Fig. 1).

Artificial reef and installation: Fig. 2. shows a diagrammatic representation of the two types of concrete ARs, named simple Cube-AR (S-AR) and complex M-shaped AR (C-AR). The size and surface area for the two reefs are L2.0 x B2.0 x H2.0 and 14.9 m^2 for S-AR and L2.5 x B2.0 x H1.5 and 23.3 m^2 for C-AR. The construction cost for S-AR was half a cost for C-AR. Six ARs (3 each) were installed in the experimental site during 1990, 1995 and 2000. All the benthic lives were removed from the experimental sites prior to installation of the ARs. All the benthic lives were also removed from a specially designated natural hard bottom (NHA) in year 2000 for a reference site (control).

Measurement of productivity: In November of 2005 productivities of age-different reefs were surveyed using a modified point-contact quadrat method (Foster *et al.*, 1994). In brief, each site was assessed by establishing quadrats (50 x 50 cm) in the low, middle, and high zones of the reefs. All the samples from the quadrats were collected in separate zipped bags and placed in a container where a low temperature was maintained. Samples transported to laboratory were analyzed in terms of species composition and total biomass in wet weight. Data were statistically analyzed using tow-sample t-test. For

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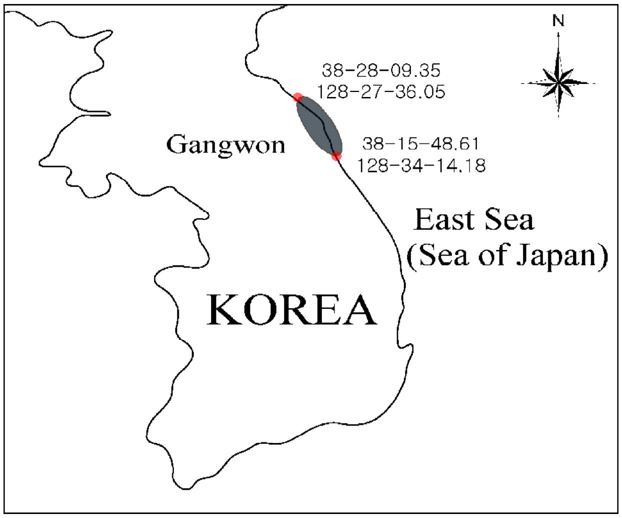

Fig. 1: A map showing study site at East

species identity, a Guide book to marine life of Korea (Park and Choi, 2001), Mollusks in Busan (Son and Hong, 2005), Illustrated encyclopedia of fauna and flora of Korea (Kang, 1968), and The Encyclopaedia of Fish and Seafood IV (KORDI, 2004) were used as a reference.

Results and Discussion

Total species on the reef: All the macrobenthic lives found at the ARs were tabulated (Table 1). The epibenthic macrofaunas were of a species of bryozoan, a species of sponge, a species of Cnidarian, a species of Sipunculidan, 19 species of Molluscan, 7 species of Annelid, 21 species of Crustacean, 9 species of Echinoderm, and 5 species of Tunicate. The seaweed communities were of 4 species of Chlorophyta, 4 species of Phaeophyta, and 20 species of Rhodophyta.

AR type-specific benthic lives: Epibenthic life compositions at 5-year old ARs were studied. The taxonomic groups found in the present study were AR type-specific (Fig. 3). Tunicates dominated all the epibenthic animals on both of the reefs with an abundance of 37% for S-AR and 30% for C-AR. Echinoderms and molluscs followed the tunicates with abundances of 17 and 13% for S-AR and 13 and 15% for C-AR, respectively. The composition of the taxonomic group for NHB was absolutely dominated by echinoderms with 54%.

A dominant species representing each taxonomic group on the two typed artificial reefs was different. Most dominant epibenthic macrofauna on 5-year old S-AR was *Chelyosoma dofleini* (Tunicate, 15%) followed by *Strongylocentrotus nudus* (Echinderms, 9%), an unidentified cnidarian (4%), *Neptunea arthritica* (Molluscan, 3%), and so on. For seaweeds on S-AR, *Agarum cribrosum* (Phaeophyta, 10%) was dominated all the seaweeds. A dominant epibenthic macrofauna for 5-year old C-AR was *Strongylocentrotus nudus* (Echinoderm, 10%) and *Halocythia roretzi* (Tunicate, 10%) followed by *Mytilus galloprovincialis*, a species of Scleractinia (Cnidarian, 2%) and so on. For seaweed for C-AR, *Laminaria japonica* dominated all the species with a dominance of 9%. Species belonging to echinoderms dominated all the epibenthic macrofaunas (54%) with a dominant species of *Strongylocentrotus nudus* (37%) in the NHB control. Dominance of seaweeds was low in the NHB compared with that in the artificial reefs. The most abundant species in NHB was *Odonthalia corymbifera* (6%).

In the comparison of seaweed and echinoderm composition, the proportions of seaweeds were noticeably higher at ARs compared with those at NHB and vice versa, the proportion of echinoderms. This higher seaweed and lower echinoderm composition was more evident at C-AR than at S-AR.

AR age-specific benthic life composition: Total biomass of taxonomic groups differed with types and ages of the ARs (Table 2). S-AR showed an increasing productivity with age, compared with NHB (Fig. 4). NHB productions of seaweeds and epibenthic macrofaunas were 90 g/quadrat and 354 g/quadrat, respectively. S-AR productions of seaweeds and epibenthic macrofaunas were 159 and 412 g, 203 and 510 g, and 182 and 535 g for 5, 10 and 15 year AR, respectively. In statistical analysis, the seaweed increases were significant for 5-year AR ($p<0.01$) and 10-year AR ($p<0.01$). However, significant increases of macrofauna were from ARs older than 10 years ($p<0.05$).

Biomasses of seaweed and epibenthic macrofaunas for C-AR were 259 and 273 g, 167 and 367g, and 111 and 297g for 5, 10 and 15-year AR, respectively (Fig. 5). In statistical sense, significant biomass increases were noticed in 5 year AR ($p<0.01$) and 10-year AR ($p<0.01$).

Establishment of AR has decades of tradition in the global waters for rehabilitation, restoration, or enhancement of habitats (Svane and Petersen, 2001; Seaman, 2002). A number of studies reveal ARs positive function, while disagreements are still existing. One of the arguing points is attraction hypothesis raised by Bohnsack (1989), in which ARs totally attract fishes from other habitats, but do not increase productivity of the habitat. AR effects on macrobenthos might be different from fish. In our study, diverse macrobenthic organisms were found at AR. Compared with macrobenthic organisms at NHB control, AR enhanced seaweed and tunicate composition, while reduced echinoderms, mostly sea urchins.

Communities of seaweed and sea urchin are not necessarily mutually exclusive, but they can be considered as two extremes along a gradient. The enhanced seaweeds and reduced sea urchin at AR have some implication for a restoration of ecologically damaged coastal habitat known as a barren ground. It is well known that sea urchins are economically important species in the global waters, but, at the same time, their heavy foraging pressure can cause serious damage to coastal seaweed communities, causing a barren ground (Lawrance, 1975; Bernstein *et al.*, 1981; Gagnon *et al.*, 2004). Sea urchin-driven barren grounds have expended for decades on the Korean coasts

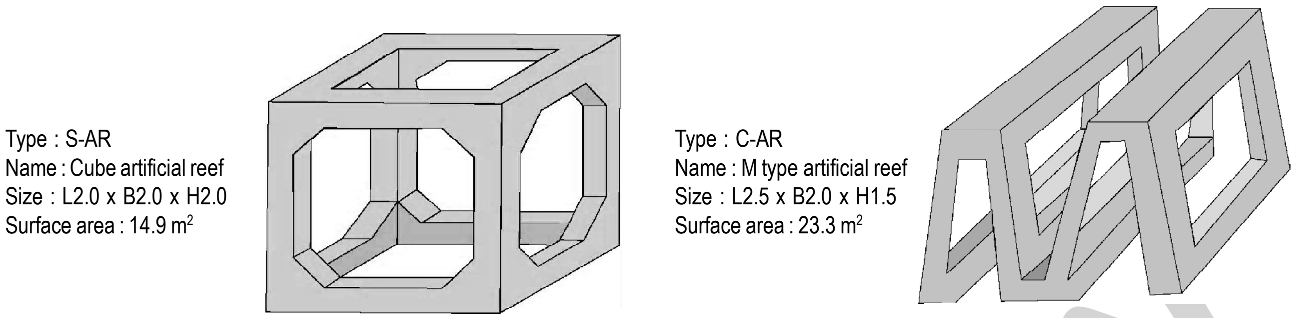

Fig. 2: Structures of the concrete artificial reefs used in the study

Table - 1: Species list of macroepibenthic organisms occurred on the concrete artificial reefs

Taxon	Name of species (total number)
Sponge	U.K.* (1)
Cnidarian	U.K.* (1)
Bryozoan	U.K.* (1)
Sipunculidan	*Phascolosoma scolops* (1)
Mollusc	*Agriodesma navicula, Arca boucardi, Chlamys farreri nipponensis, C. farreri farreri, C. swiftii, Hiatella orientalis, Modiolus kurilensis, Musculus corrugatus, Mytilus galloprovincialis, Calliostoma multiliratum, Ceratostoma inornatum, Mitrella bicincta, Neptunea arthritica, Ocinebra lumaria, Omphalius pfeifferi pfeifferi, Pleurobranchaea japonica, Primovula triticea, Cryptochiton stelleri, Lepidozona coreanica* (19)
Annelid	*Arabella iricola, Eunice indica, Halosydna brevisetosa, Nereis pelagica, Serpula vermicularis*, a species of Harmothoinae, a species of Syllidae (7)
Arthropod	7 amphipods, 8 isopods, *Paguristes ortmanni, Paguristes* sp, *Pagurus brachiomastus, P. middendorff, P. pectinatus, Pilumnus minutus* (21)
Echinoderm	*Hemicentrotus pulcherrimus, Strongylocentrotus intermedius, S. nudus, Cucumaria chronhjelmi, Ophiopholis aculeata, Aphelasterias japonica, Asterias amurensis, Asterina pectinifera, Lethasterias fusca* (9)
Tunicate	*Boltenia echinata, Chelyosoma dofleini, Halocynthia aurantium, H. roretzi, Styela clava* (5)
Chlorophyt	*Ulva japonica, U. pertusa, Ulva* sp, *Cladophora sakaii* (4)
Phaeophyt	*Undaria pinnatifida, Agarum cribrosum, Laminaria japonica, Sargassum* sp (4)
Rhodophyt	*Palmaria palmata, Gelidium amansii, Hyalosiphonia caepitosa, Amphiroa ephedraea, Tichocarpus crinitus, Plocamium telfairiae, Gracilaria textorii, Chondrus ocellatus, Rhodoglossum japonicum*, 3 *Rhodymenia* sp, *Champia* sp, 4 *Acrosorium* sp, *Delesseria serrulata, Polyneura japonica, Odonthalia corymbifera* (20)

*Unknown species

of the East Sea (NFRDI, 2006). Therefore, the increased seaweeds, together with reduction in echinoderm (sea urchin) at AR are suggesting some positive aspect for the local ecosystem.

Composition of the macrobenthic organisms was AR type-specific; the complex AR (C-AR) exerted better function over the simple AR (S-AR). The higher seaweed and lower sea urchin composition at C-AR were more ecologically sound. This, however, is based on a simple concept excluding higher construction cost for C-AR. In reality, the economic concept should be taken into consideration in the AR establishing project.

One of the outstanding community features at our ARs was ascidian tunicate domination by two major species, *Chelyosoma dofleini* and *Halocythia roretzi*. Generally, benthic organisms, mainly filter feeders like bryozoans, bivalves, sponges and tunicates are abundant at ARs. Tunicate domination at the ARs is location-specific: the species remain as a minor community in some locations (Perkol Finkel and Benayahu, 2007), while they occupy most locations as a major species. For instance, newly introduced ascidian tunicates are characterized by rapid population explosion, becoming a dominant member of their new communities (Agius, 2007; Bullard *et al.*, 2007). Ascidians are opportunistic for space, raising a problem in aquaculture facilities particularly located on nutrient-rich coasts. This might be considered as a negative aspect of AR establishment.

One of the key issues of AR projects is how to keep the reefs in inert condition for at least 20 years. Limited options are available for maintenance of underwater structures like ARs because anything beyond the most preliminary management is impractical and limited by expense. When designing ARs several factors should be taken into consideration, including type of materials (Baine, 2001) and complexity and durability (Connell and Jones, 1991). Most AR studies have examined the early colonization stages of benthic communities, while only a few have monitored the development of AR communities beyond the initial successional phases and evaluated the time scale needed for such development. In our study, total biomass of taxonomic groups differed with ages as well as types of AR. Overall, C-AR provided better substrates for

Table - 2: Total biomass (g, wet wt.) of benthic lives on artificial reefs by type and age

Type	Age (Year)					
	5		10		15	
	Seaweed	Epibenthic macrofauna	Seaweed	Epibenthic macrofauna	Seaweed	Epibenthic macrofauna
S-AR	159±24(3)*	412±42(19)	203±14(11)	510±52(27)	182±55(11)	535±54(23)-
C-AR	259±89(11)	273±95(21)	167±16(14)	367±96(18)	111±43(14)	297±15(17)
NHB	90±9(11)	354±42(13)	-	-	-	-

*Number in parenthesis stands for species number observed

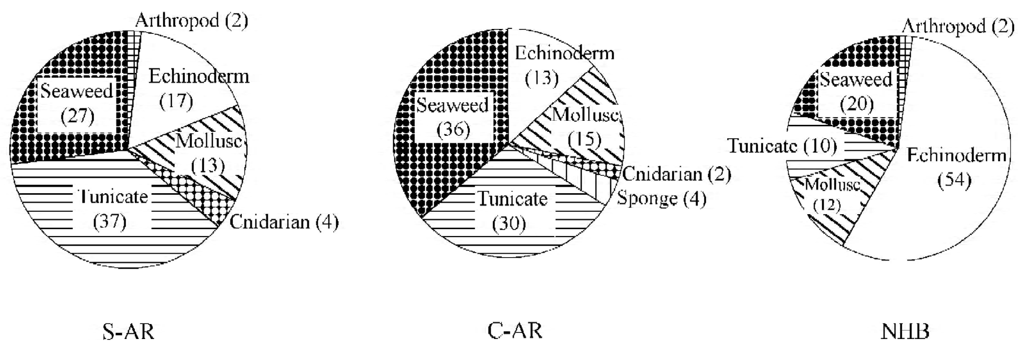

Fig. 3: Percent abundance of marine macroorganisms by taxonomic group attached on the types of artificial reefs

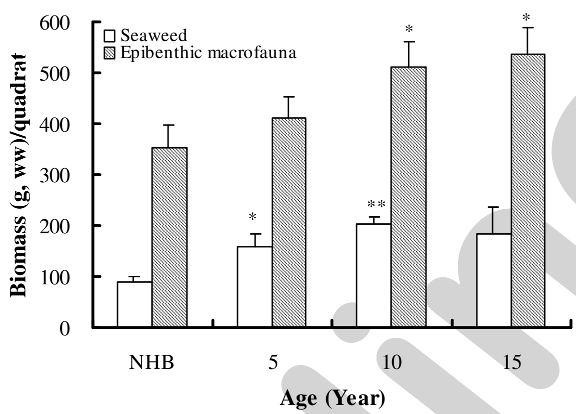

Fig. 4: The biomass compositions of seaweed and epibenthic macrofauna on the age-different AR (S-AR). A quadrat is 50 x 50 cm². Error bar is mean ± SE. Yields with no letter in common are significantly different on one-way ANOVA (*p<0.05, **p<0.01)

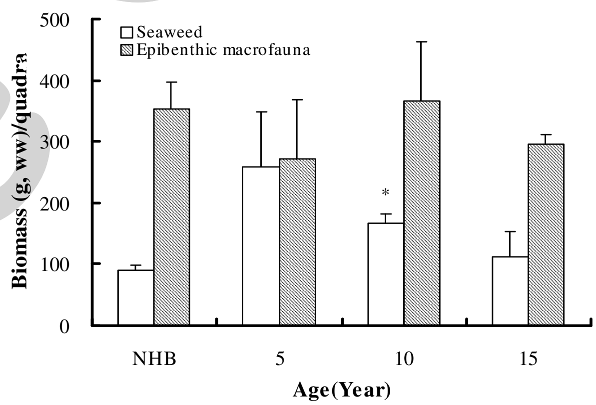

Fig. 5: The biomass compositions of seaweed and epibenthic macrofauna on the age-different AR (C-AR). Size of quadrat, error bar, and statistics are as in Fig. 4

seaweeds, but it did only within 10 years, thereafter providing itself for epifaunas. This raises a problem because our ARs were designed to be durable for at least 30 years.

Epibenthic life composition at the reefs is changing in relatively short period of time anong the age of the reefs (Connell and Jones, 1991; Perkol-Finkel and Benayahu, 2005). In this regard, our 5-year-based survey might be too long to give precise information. Therefore, short term-based studies are additionally needed.

Destruction of seaweeds or occurrence of barren grounds is recently progressive in recent coastal areas. Establishing ARs on the coasts is a rehabilitation strategy to the progressive barren grounds. Overall, the two types of ARs brought a positive result at least in 10 years. In spite of its positive result, a concept behind the establishment of ARs should be based on its ecological performance. In other words, the assessment of physical, chemical, biological, and socio-economic parameters is necessary in documenting the degree of success and impacts of a given AR. Furthermore, the present findings are in accordance with detection of unexpected negative consequences, evaluation of alternative management strategies, improvement of AR construction techniques and identification of additional research priorities as outlined by Rousseau (2006).

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