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人工魚礁에 附着하는 底棲生物相에 관한 硏究(Ⅰ)

-人工魚礁의 技術 現況-

A Study on the Succession of Benthic Organisms on the Atificial Reefs

Ⅰ. Present status of the Artificial Reef Technics

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韓國海洋研究所長 貴下

本 報告書를 "人工魚礁에 附着하는 底棲生物相에 관한 研究(Ⅰ)－人工魚礁의 技術現況－" 事業의 最終報告書로 提出합니다.

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共同研究責任者 : 許 亨 澤 · 異 舜 吉

研 究 員 : 諸 綜 吉

要 約 文

1. 題 目

人工魚礁에 附着하는 底棲生物相에 관한 硏究 .I. 人工魚礁 의 技術 現況

2. 硏究開發의 目的 및 重要性

政府는 점차 枯渴되어 가고 있는 沿岸漁場의 魚族資源을 획기적으로 增大시키기 위하여 1971 年 부터 지금 까지 약 600 억원을 投入하여 55 만여 ha의 沿岸漁場에 40 만개 이상의 人工魚礁를 投入하였으며, 앞으로도 人工魚礁 事業을 계속 추진할 계획이다. 한편, 人工魚礁의 集魚 또는 資源增大 效果判定에 관한 硏究는 1975 年 부터 國立水産進興院에서 꾸준하게 실시하였지만, 새로운 棲息環境인 人工魚礁 자체에 遷移되는 生物相에 관한 硏究는 아직까지 體系的으로 실시되지 못하고 있다.

새로이 投入되는 魚礁에 附着하는 生物相 硏究는 해당지역의 生産潛在力을 體系的으로 硏究할 수 있는 가장 적합한 方法의 하나이다. 또한 이들 魚礁에 遷移되는 生物들은 魚礁에 모여드는 魚類의 좋은 먹이가 되어 주위 어류들을 모여들게 하는 역할을 하므로, 魚礁의 정확한 效果判定을 위하여서는 魚礁 위에 遷移되는 生物相 硏究가 先行되어야 한다.

따라서 本 硏究는 지금까지의 國內, 外의 人工魚礁 投入에 대한 現況를 調査하고, 魚礁 投入과 동시에 附着板을 설치하여 附着板 위에 着生하는 底棲生物群集 特性을 파악하고 遷移過程을 究明하므로서 沿岸漁場 造成을 위한 效果的 魚礁投入을 위한 基礎資料를 얻는데 있다.

III. 研究開發의 內容 및 範圍

本 研究는 3 個年에 걸친 研究 中 第 1 次 年度에 해당하는 研究로서 國內, 外의 魚礁 投入 現況調査에 主眼點을 두고 遂行되었으며, 魚礁 上의 底棲生物群集의 遷移研究는 최소한 3 年 이상이 所要되기 때문에 당 연도에는 附着板설치 및 群集分析 方法을 결정하는데 중점을 두었다.

IV. 研究開發 結果 및 活用에 대한 建議

研究開發結果

人工魚礁는 1971 年 國內에 처음 紹介되었으며 1987 年 沿岸漁場造成事業이 실시되면서 劃期的으로 增加하였다. 1990 年 까지 약 40 만개의 魚礁가 投入되었는데, 現在 까지 投入된 魚礁는 사각형, 원통형 및 점보형이었으며, 1991 年 부터 누운 삼각기둥형의 魚礁가 새로 開發되었다. 投入된 魚礁는 비교적 안정된 상태이었고, 投入 後 3, 4 年이 지나야 주변의 硬性底質과 類似한 底棲生物相을 나타내었다. 따라서 魚礁上의 底棲生物 遷移過程을 밝혀내기 위하여서는 최소한 3 年間의 研究가 필요하리라 보여진다.

投入된 魚礁의 形態別 漁獲效果의 增加는 뚜렷하지 않았지만, 魚礁投入 漁場에의 單位勞力當 收穫量이 非投入 漁場 보다 약 2.5 배 정도 높아 魚礁投入 效果가 증명되었다.

日本은 일찌기 19 世期初 아와지현에서 나무로 만든 構造物에 모래주머니를 달아 만든 魚礁를 投入한 記錄이 있다. 20 世期初 漁村契 단위로 魚礁投入이 활발해졌고, 1952 年 政府 주도의 5 個年 計劃에 힘입어 급속히 발전하기 시작하였다. 1966 年 까지 약 1 백만개 이상의 魚礁가 投入되었다. 1973 年 부터 엔세이 計劃이 시작 되어 1, 2 段階事業 (1973 - 1987)에 6 천억엔이 投資되었고, 3 段階事業 (1988 - 1993)에는 약 4.8천억엔이 投資될 예정이다. 漁場造成은 단순한 魚礁投入形에서 複合的인 新技術이 요구되는 社會 및 經濟 集約的인 形態로 변화하고 있다.

美國의 魚礁 投入目的은 商業的 漁業의 活性化 보다는 餘假善用 특히, 레저 낚시(sport fishing)를 위한 것이다. 따라서, 現在까지의 魚礁投入은 實驗的인 것이 많았으며, 魚礁材質도 복잡한 것보다는 손쉽게 얻을 수 있는 바위, 建築殘存物 등이 대부분이며, 材質에 대한 環境保護 次元의 規制가 엄격하다. 1988 年代 통나무 운반선을 가라 앉혀 만든 것이 시초이며, 약 600 개의 魚礁가 許可되어 있다. 大西洋 沿岸 15개 州는 魚礁 投入 및 管理를 위하여 별도의 協議體를 구성하였으며, 현재 247 개 漁場에 魚礁 投入이 완료되었고, 26개 魚場에 魚礁를 投入할 예정이다.

그외 프랑스, 영국, 등 先進國을 비롯하여, 대만, 필리핀, 인도 및 중남미 제국을 포함한 40 여개국에서 魚礁投入에 박차를 가하고 있다. 魚礁材質은 콘크리트 構造物, 廢船舶, 등이 많이 사용되지만, 대부분 低, 中開發國에서는 모래 주머니, 바위, 대나무 또는 망그로브 줄기를 엮어 만든 土俗的 魚礁를 사용하고 있다.

魚礁投入에 따른 漁獲量 增加는 대략 20 - 200 % 내외로 집계되지만 이스라엘과 쏘련에서는 1,000 % 이상의 漁獲量 增加가 보고되고 있을 정도로 場所에 따라 많은 차이를 나타내고 있다.

濟州道 城山浦 沿岸에 설치한 魚礁의 生物相을 調査한 結果 魚礁投入 후 3 - 4 年이 經過하면 주변의 硬性底質의 生物相과 類似한 群集構造가 이루어 진다는 것이 밝혀졌다. 보다 정확한 魚礁上의 底棲生物 群集의 遷移調査를 위하여 1991 年 11 月 濟州道 城山浦 日出峰 西岸에 최초로 설치되는 삼각기둥형 魚礁에 콘크리트로 만든 30 x 30 ㎝ 크기의 附着板을 水平 및 垂直 방향으로 각 각 26 개씩 설치하였다.

설치 3 個月 後, 垂直 및 水平 附着板 간에 底棲生物의 種造成에는 별 차이가 없었지만, 生物量에서는 水平 附着板이 越等하였다. 이는 優點種인 감태와 불레기 말이 水平 附着板에서 成長이 훨씬 빨랐기 때문이다. 이 들 외에 총 10 種의 生物이 出現하였다.

結合建議
綜合建議

魚礁投入은 沿岸漁業을 활성화 시킬수 있는 확실한 방법으로 생각된다. 그러나, 地域과 魚礁種類에 따른 변화가 매우 크기때문에 사전에 철저한 調査가 수행된 후 魚礁施設을 하여야 하며, 施設前 다음과 같은 事項이 고려되어야 한다.

- 魚礁投入 海域의 生物相 및 海況
- 魚礁投入에 따른 航海 등, 일반적 海上活動에 대한 障害 有無
- 魚礁材質의 安定性
- 魚礁形態의 適切性
- 試驗魚礁 設置를 통한 장기 모니터링

SUMMARY

1. Title

A study on the succession of benthic organisms on the artificial reef

I. Present status of the artificial reef technics

2. Significance and objectives of the study

The artificial reef, as a well established fishery resource enhancement tool, has been introduced in Korea in 1971. Since then, about 400 thousand pieces of the reefs were placed over the area of 55 thousand hetars of fishing grousands along the coastal waters of Korea. A series of intensive studies on the effectiveness of the artificial reef have been conducted by National Fisheries Research and Development Agency since 1975. However, little attention have been paid on the succession of the benthic communities on the reef.

The study on the succession of benthic communities on the reef is one of the most efficient tools for evaluating the productivity potential of a given fishing ground. The living organisms on the reef serve as the prey and thus attract fish. Therefore, it is necessary to study the benthic communities to evaluate the effectiveness of the artificial reefs in enhancing the fisheries resources as well as restoring the quality of natural habitats in coastal waters.

The main objectives of the study are to analyse the present technics on the artificial reefs around world, to visualize the succession process of the benthic communities on the artificial reefs, and to provide guide line information for installment of the artificial reefs to be used in marine ranching program.

III. Scope of the study

As this is the first year of the three-year study, and it is required at least three years to understand the succession of benthic communities on the artificial reefs, the emphasis in the present study was put on the analysis of the recent technics on the artificial reefs around the world, and to determine the methods for the installment and recovery of the experimental (artificial) substrates.

IV. Results of the study and suggestions

Results of the study

Artificial reefs were first introduced into the shallow wasters of korea in 1971. With the initiation of the marine ranching program in 1987, the number of the reef modules placed increased sharply and reached up to 400,000 pices by 1990. Among the several types of the reef nodules, dice, tube, turtle and jumbo modules are most commonly used. Beside to these, triangle modules have been used since November, 1991.

It is appeared that the combined force of wave and current acting on the artificial reefs placed in the coastal waters of Korea was smaller than the friction force against sliding and rotation, and the reefs appread to be in stable condition.

There was no clear increase of fish catch observed among different types of the reef. However, fishing grounds with the reefs provided about 2.5 times more fish than the ground without the reefs in term of catch per unit effort.

There were several written records suggesting that Japanese were arleady in use of the artificial reef in the early 19th century. By the year of 1966, more than one million artificial reefs were placed in Japanese waters. They have been invested about six hundred billion Yens during the first and second phases of the Ensei Program(1973 - 1987), and are going to invest four hundred and eight billion Yens during the next six years (1988 - 1993) for the artificial reef building. The main concept of the artificial habitat construction in Japan is gradually changing from reef building mainly for fish aggregation to a long term socio-economic program to improve fisheries and fishing communities in accordance with the maintaining fisheries supply and accomplishing balanced development of the land.

The feature of artificial habitat construction in the United State is characterized by less shophisticated and more frugal materials are used for the reef building and targeting the promotion of sport fishing rather than commercial fishing. They persue comprehensive and long term evaluation including ecological and socio-economic perspectives.

About six hundred artificial reefs of various sizes have been placed under permission of the U.S. Army Corps of Engineers by 1990. Florida is the most active reef building state with 112 reefs and followed by North Carolina with 66 reefs and California with 39 reefs. Members of the Atlantic State Fisheries Commission have established an Atlanthic Interstate Artificial Reef Program to boost the mutural management of the artificial reefs.

There has been a rapidly growing interest on the artificial reef in about 40 countries including France, United Kindom, Taiwan, Philippines, India and most of the countries in the Middle America. Materials used for reef building are fabricated concrete blocks, old ships and quarry rocks in the advanced countries, and bamboo or mangrove modules sanked with sand bags in the under or less developed countries.

It was censused that the artificial reefs resulted in increased fish catchs from 20 to 200 %. Over 1,000 % increased fish catch was also reported in Israel, Russia and Ivory Coast.

A diving research conducted by KORDI showed that whole surface of the artificial reefs have been covered with the benthic organisms within a year after the installation. However, it took three to four years to attain to similar biotic communities of natural hard bottoms.

Fifty-two experimental substrates made of concrete (quadrate, 30 x 30 cm in size) were placed on the surface of newly installed artificial reefs. Half of them were set vertically and remainders were put horizontally. Four experimental substrates, two of horizontal and vertical, were collected seasonally for the examination of the succession of the benthic communities.

There was no clear difference observed in species composition between horizontal and vertical substrates after three months of installation. However, horizontal substrate showed a higher biomass than that of vertical substrate. Sea trumpet and oyster thief were the dominant marine algae. A few number of tube building amphipoda, polychaetes and bryzoans were also founded on the experimental substrates.

Suggestions

Artificial reefs are known as a well established fishery resource enhancement tool being used in the shallow coastal waters around the world. Since the effectiveness of the reefs have been differ to each case, it is recommended that following considerations should be checked before the design and construction of the artificial reefs.

1) Sea conditions and biotic communities,
2) Harzardousness of the reefs for navigation, fishing (trawling), and other activities,
3) Stability and safty of the reef building materials to minimize environmental risks,
4) Appropriatness of the reef types pertaining to fishing grounds (bottom topography, sediment types),
5) Monitoring results from ready installed artificial reefs adjacent to to planing sites or experimental reefs.

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1. Introduction

Korea is one of the leading fisheries countries in the world as she has been ranked among the top 10 countries in terms of total catches as well as export of fishery products. She was ranked the world's 8th and 4th in terms of fishery yield and export of fishery products during the last decade, respectively.

Recent trends, however, shows that the Korean fisheries is being faced with many difficulties because of depleted resources and increased fishing costs. The total catches in 1988 declined by 27 % in distant water fisheries and 13 % in coastal water fisheries since 1986. The main reasons for the recent stagnation of Korean fisheries are primarily due to decrease of fishery resources, loss of fishing grounds and deteriolation of fishing conditions in both adjacent and distant waters. In particular, the coastal water fisheries are being encountered with decreased fish stocks owing to over fishing and shrinkage of nearshore fishing grounds by coastal land reclamation and industrial activities.

On the contrary, consumption of fishery products (as sea food) has been increasing considerably every year. Annual per capita consumption of seafood in recent years is over 32 Kg which is well above the world's average.

If this trend continues, Korea will soon become an importing country of seafood from the status of a world leading exporter. To keep the coastal water fisheries thriving, an intensive Marine Ranching Program is being launched

since 1987.

Artificial reefs are known as a well established fishery enhancement tool being used in the coastal waters around world (Mathews 1985). Artificial reefs are very effective in protecting and increasing the living resources, as they not only provide excellent habitats for fish but also prevent illegal trawling which is a major cause of the depletion for the bottom dwelling fishery resources.

The reefs were first introduced into the shallow coastal waters of Korea in 1971. Since then, about 400 thousand pieces of the reefs have been installed over the area of 55 thousand hectare of coastal fishing grounds.

The present study aims at providing guidelines for a better installation of the artificial reefs in Korean coastal waters. For this, special efforts were concentrated on the technical analysis of the artificial reefs around the world and identification of the process of succession of the biotic communities on the artificial reefs.

II. Present status of artificial reef technics in the world

A. Korea

1. Fisheries of Korea

Korean fisheries has made a remarkable progress during last few dacades.

The fishery yield reached up to 3.3 million metric tons in 1989 from less than a half million tons in 1962. This was about 8 fold increase from the 1962's (Table 1).

Table 1. Fishery yield by fishing sector and year in Korea.

Unit: 1,000 tons

Sector \ Year	1962	1972	1976	1980	1984	1988	1989
Adjacent Waters	448.1	956.3	1,255.1	1,370.3	1,521.6	1,512.5	1,510.3
Distant Waters	0.7	224.1	724.2	458.2	658.3	774.2	930.3
Aquaculture	18.7	160.4	410.7	540.6	678.3	886.6	848.2
Inland waters	0.9	1.2	15.0	39.2	50.1	35.8	30.5
Miscellaneous	1.8	1.6	1.9	2.0	1.5		
Total	470.2	1,343.6	2,343.6	2,410.3	2,909.8	3,209.1	3,319.4

Source: Statistical Yearbook of Agriculture, Forestry and Fisheries. ROK. 1990.

The most notable progress was in the distant water fisheries and aquaculture while very mild gain was made in the adjacent water fisheries. For example, total catch of the distant water fisheries was 774 thousand tons in 1988, about thousand times increase from 1962. In aquaculture, the yield in 1988 amounted to 887 thousand tons which is about 45 times greater than the yield of 1962. In adjacent waters, however, the increment was merely 2 - 3 times during the same period.

As a result, relative importance of the coastal fisheries is diminished considerably, whereas the aquaculture and distant water fisheries are

promoted. In other words, the catches from coastal waters comprised more than 80 % of the whole fishery yield in 1968, but dropped to 47 % in 1988 (Fig. 1). The proportions of both aquaculture and distant water fisheries have been grown up to 27 % and 24 %, respectively from less than few percent.

Nevertheless, the coastal fisheries is becoming more significant industry than before, as the international circumstance for the distant water fisheries are being aggravated due to advent of the New Ocean Regime.

2. Marine Ranching Program

Long term projection shows that the demand of fishery production in 1996 and 2001 are 4.3 million tons and 5.02 million tons, respectively (Table 2). Thus, Korea have to produce more than 1.2 million tons of fishery products within 10 years. Otherwise, Korea, one of the world leading exporters, will soon become an importing country of fishery products.

As one of the counter measures for the present problem, Korea launched a Marine Ranching Program. The program, initiated by the Office of Fisheries Administration, is a 15-year long program from 1987 through 2001. Goals of the program are to meet the growing demand of fishery products, to maintain more than 6 % of the annual fishery growth, and to increase the income of fishermen (Huh 1987).

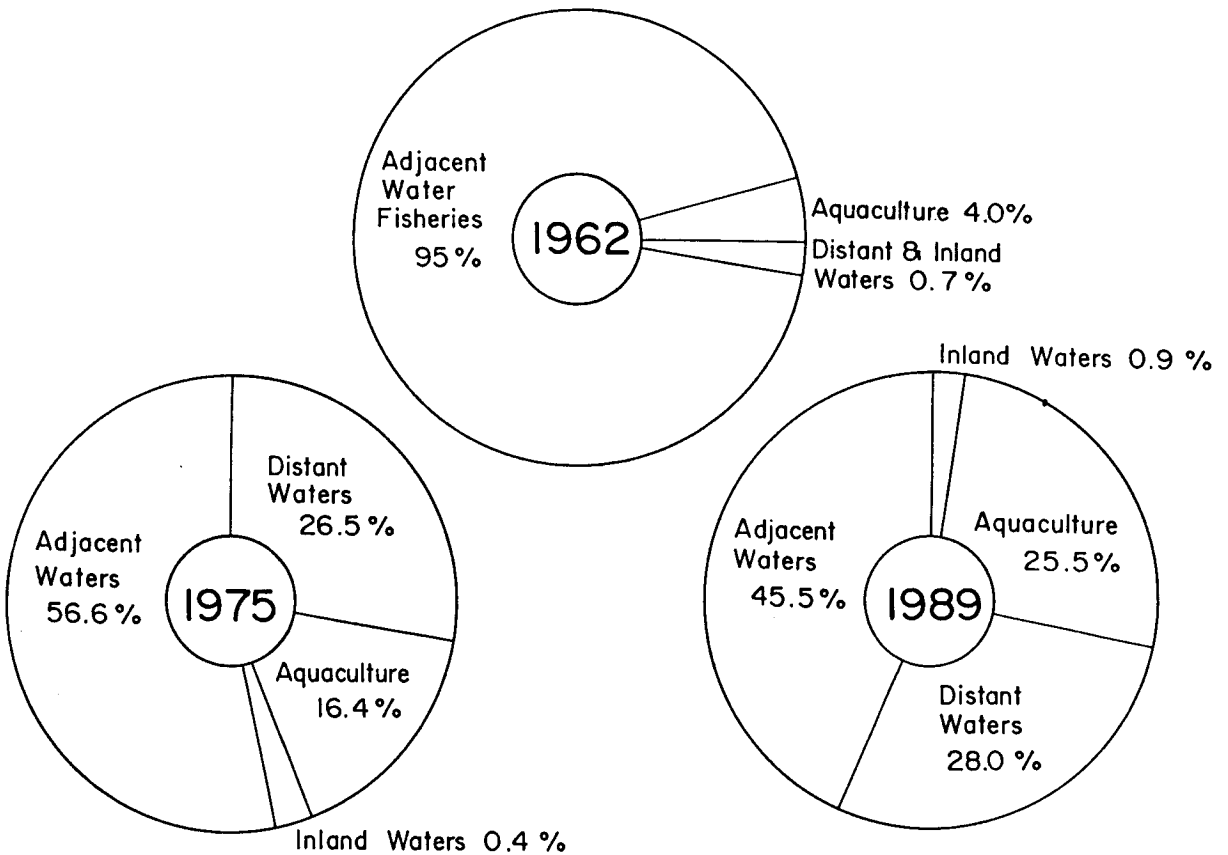

Fig. 1. Comparison of fishery production in percent by fishing sector.

Table 2. Estimated demand of fishery products in Korea.

Unit: 1,000 tons

	1991			1996			2001		
	Local	Export	Sum	Local	Export	Sum	Local	Export	Sum
Fin fish	1,768	392	2,160	1,992	441	2,433	2,255	499	2,754
Shell fish	357	268	625	439	278	718	593	290	883
Crustacean	103	11	114	126	11	137	170	12	182
Algae	320	178	498	377	189	566	455	198	653
Others	294	57	351	361	60	421	487	62	550
Total	2,841	906	3,747	3,295	980	4,275	3,961	1,061	5,022

Source: Korea Institiute of Rural Economy. 1987.

The program includes an improvement of production systems and facilities, protection of resources and fishing grounds, artificial propagation of seedlings, development of culture technics for conventional and new species, etc. It will emphasize upon the installment of artificial reefs, study on environmental control and disease prevention, intergration of biological and engineering technologies to ensure the optimum production of the coastal waters.

The selected target species are salmons, trouts, sea breams, flatfish, rockfish, swellfish, yellowtail, large shrimps, sea squirts, sea urchin, and more species will be added as the program progresses. During the first 5 year(1987 - 1991), approximately $300 million are being invested for the program.

Several new hatcheries have been built to speed up the production of seelings. Ten hatcheries are now in operation through which nearly one billion seedlings of fish and shellfish have been released into the coastal waters during 1976 - 1988, and about 30 million seedlings of marine species have been released every year since 1989 (Table 3).

Table 3. Seedlings released by hatcheries in 1989.

Unit: 1,000 ind.

Hatchery	Species	No. of seedling
North Cheju	abalone, red sea bream	1,754
South Cheju	red sea bream, bastard halibut	100
Chumunjin	abalone, sea squirt	2,490
Yeochun	abalone, sea bream, blue crab	3,151
Youngil	abalone, sea squirt	418
Keoje	abalone, sea squirt, bastard halibute	13,636
Wando	abalone, sea squirt, red sea bream	5,330
Boryung	abalone, rock fish, large shrimp	3,272
Buan	abalone, rock fish, large shrimp	255
Total		30,406

Source: Office of Fisheries Administration. ROK. 1990.

3. Installation of artificial reefs and its effectiveness

Artificial reefs were first introduced into the shallow coastal waters of Korea in 1971. However, the importance of the reefs emphasized after the initiation of Marine Ranching Program (Fig. 2). During the first four years (1987 - 1990) about 180 thousand artificial reefs were placed over the area of 55 thousand hectare of coastal fishing grounds.

About a dozen different modules of fabricated concrete reefs are currently used in Korean waters. Among these dice, tube, turtle, jumbo and triangle modules are most commonly used (Fig. 3, 4). The triangle module (Fig. 6) is a newly developed module and the module has been placed along the coast of Cheju Do in November 1991.

To investigate the effectiveness of the fishing reefs placed in the Korean coastal waters, National Fisheries Research and Development Agency (NFRDA 1989) conducted a 5 year survey during 1984-1988 at 27 artificially intensified grounds with the reefs (Fig. 6).

Number of the reefs in each survey area were 100 to 2,680 pieces depending on the types of modules. Sampling of oceanographic data (water temperature, salinity, dissolved oxygen) and fish were made once in months of May, July, September, and November of each year. Fish samples were collected at each station using a trammel gill net (30 m in length, 3 m in height), long line with 100 hooks and single line with 4 hooks. The trammel gill net was

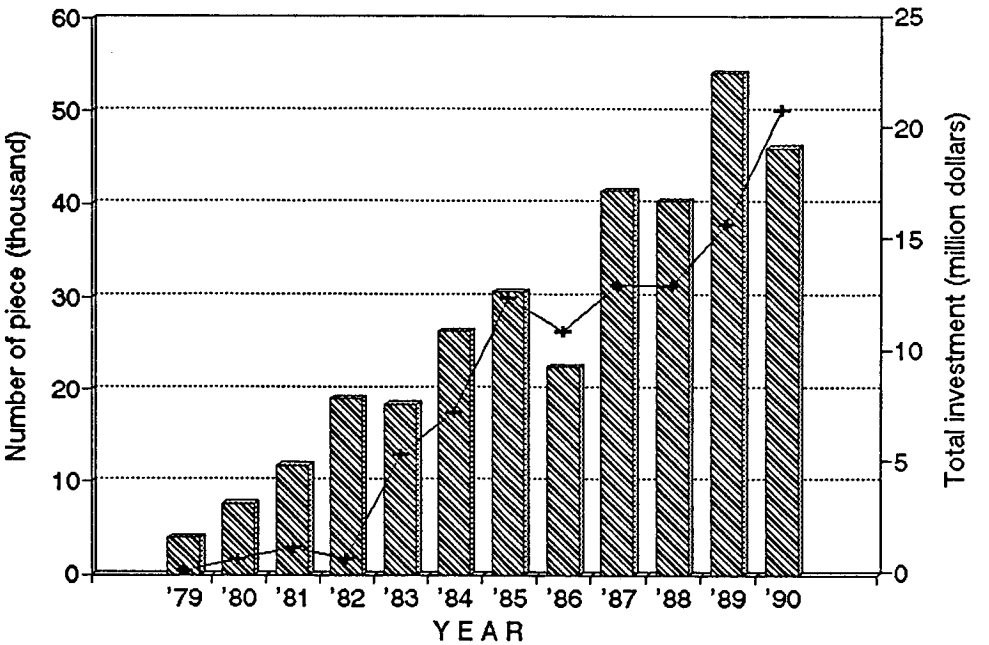

Fig. 2. Installment of artificial reefs in Korea.

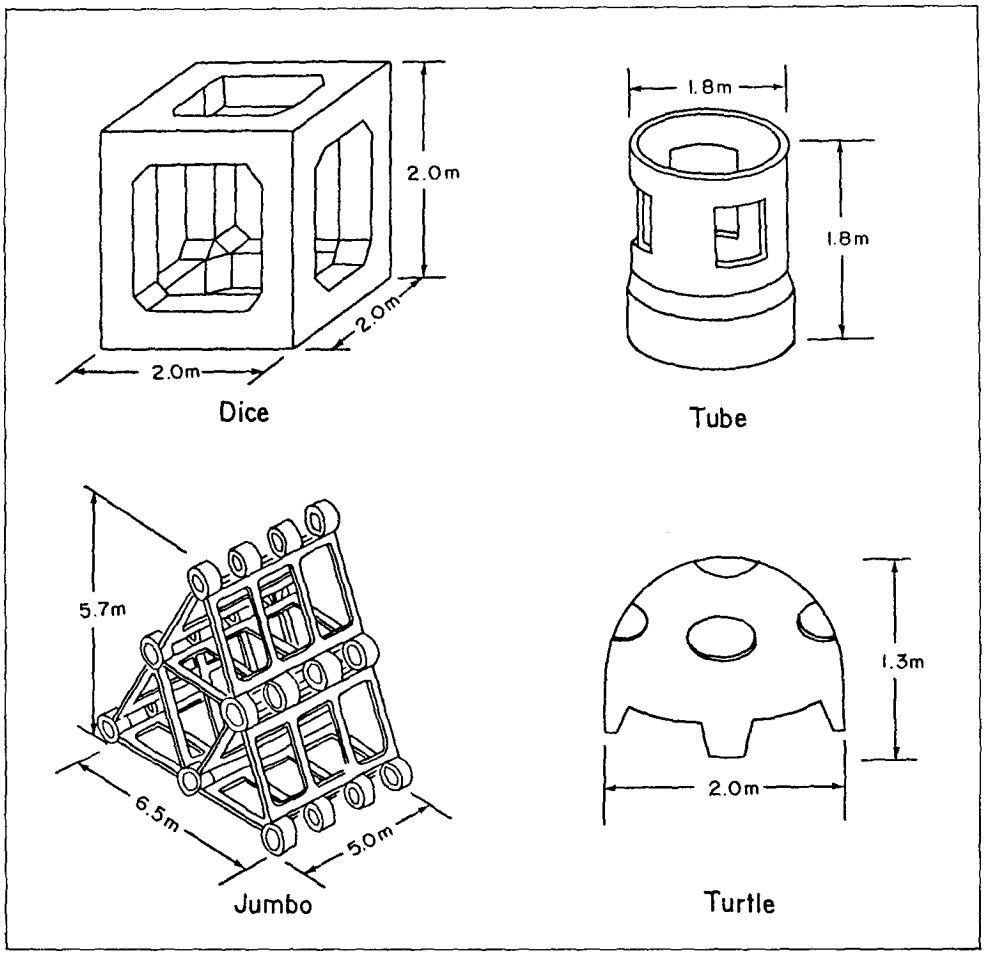

Fig. 3. Typical artificial reefs used in Korea.

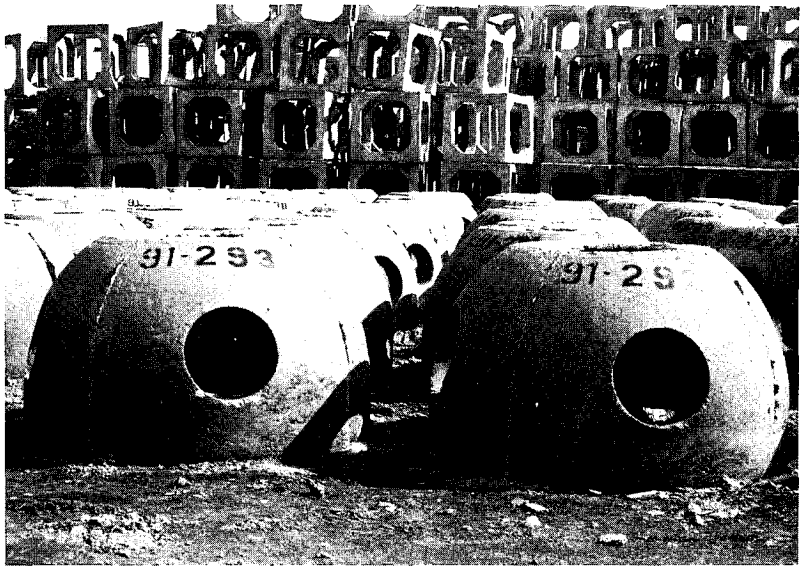

Fig. 4. Dice(back) and turtle(front) modules.

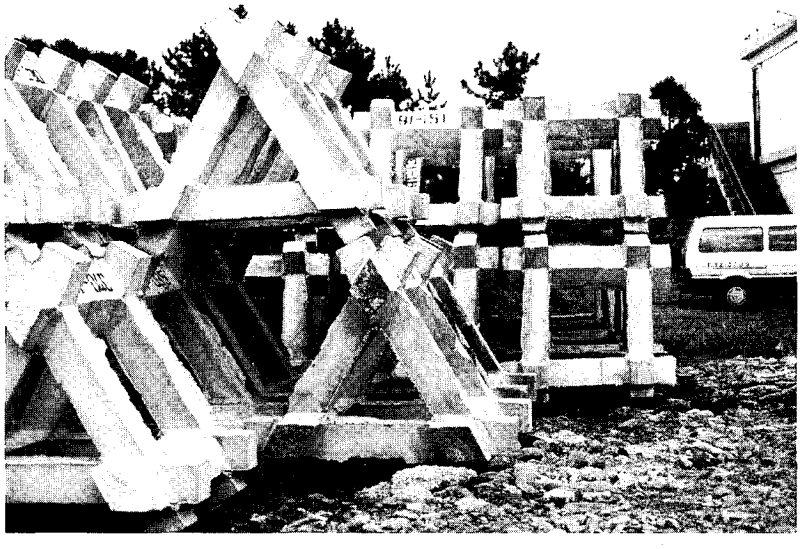

Fig. 5. Triangle modules which is newly introduced in November 1991.

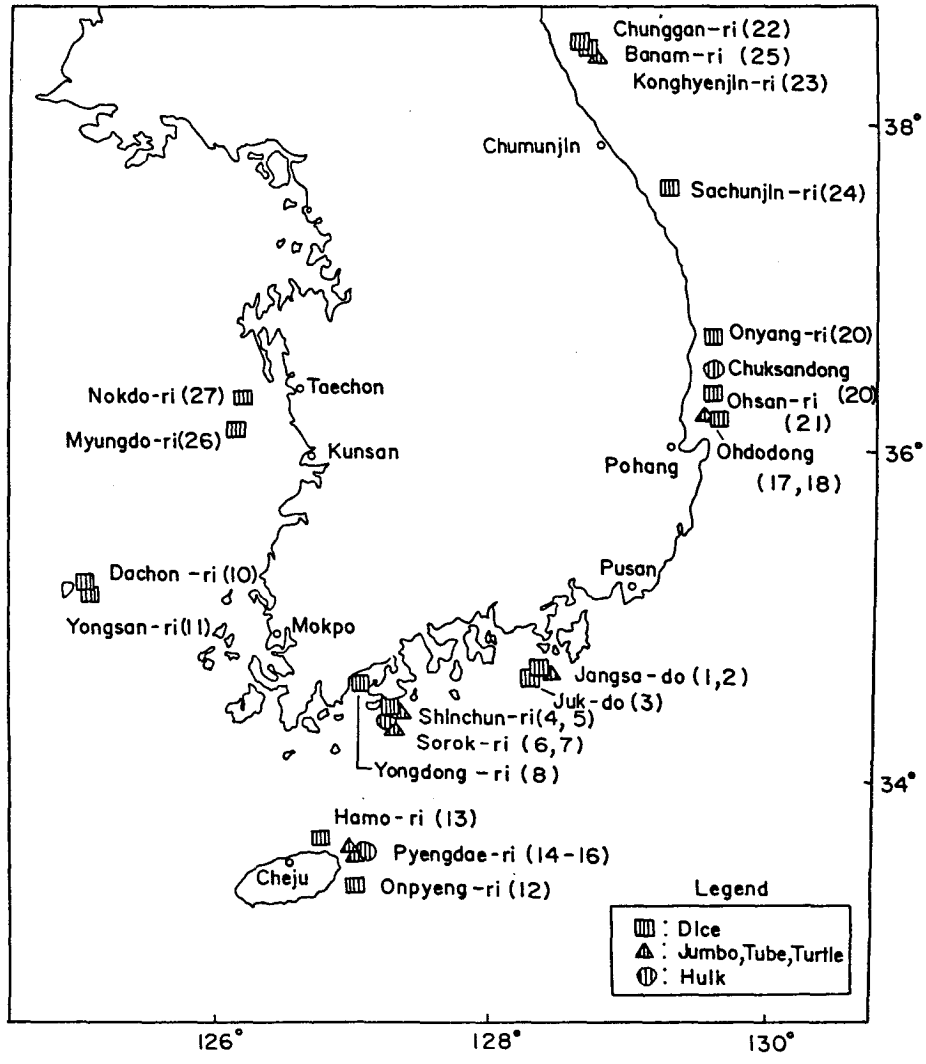

Fig. 6. Location of surveyed areas for the artificial reefs.

placed before sunset and recovered after 12 - 15 hours. Setting time for the long line was 1-2 hours and 6 hours for the single line. In addition to this, a diving survey was conducted at station 12 in October 1991 by KORDI.

The results of the survey for the effectiveness of artificial reefs on the productivity of coastal waters of Korea are summarized as follows:

A. The combined force of wave and current acting on the artificial reefs at all sites were smaller than friction force against sliding and rotation. The combined forces were between 0.04 and 0.37 ton/m ^{2}, while the friction forces against sliding and rotation were 0.56 ton/m ^{2} and 0.7 ton/m ^{2}, respectively (Table 4). Thus the reefs appeared to be in stable condition.

Table 4. The combined wave and current forces acting on the artificial reefs.

Station	Depth (m)	W. H. (m)	W. L. (m)	W. P (sec)	C. S. (cm/sec)	F. S. (ton/m^2)	F. R. (ton/m^2)	F. A.. (ton/m^2)
1	26	0.72	60.18	6.21	51.44	0.56	0.70	0.12
4	25	0.95	50.00	5.62	92.59	0.56	0.70	0.31
10	24	0.95	50.00	5.62	92.59	0.56	0.70	0.31
12	29	1.36	77.56	7.05	66.87	0.56	0.70	0.20
17	20	1.27	73.70	6.87	47.32	0.56	0.70	0.16
22	28	1.27	73.70	6.87	15.43	0.56	0.70	0.04
26	24	1.36	77.56	7.05	92.59	0.56	0.70	0.37

W.H.: wave height, W.L.: wave length, W.P.: wave period, C.S.: current speed, F.S.: friction against sliding, F.R.: friction against rotation, F.A.: force acting on the reef

B. Artificial fishing reefs placed at depths of 10-50 m in the coastal waters increased fish catches in a certain degree. In average the catches per unit effort by a trammel gill net and was 2.7 times greater than that of control area while long and single lines yielded 2.3 times more fish (Fig. 7).

C. The reefs placed in the eastern coast appeared to be more effective in attracting fish than the other areas. In fishing test by a trammel gill net, about 3.5 times more fish were caught compare to control area. Eastern coast has simple coastline with virtually no embayment, island or natural reef. And thus the reefs may attract relatively easily the migratory fish which will otherwise pass through.

D. There was no clear difference on the number of fish species depend on the type of the reefs, however dice and tube seemed to attract more fish species (Fig. 8). It seemed that flounder, bastard halibut and cod were attracted by tube and turtle reefs while rock fish, sawadged perch and mackerels by dice and jumbo reefs. The preference for a specific reefs by a species was not clearly observed and futher study is necessary to confirm this (Fig. 9).

F. Of the 104 species of fish collected, 49 species could be divided into 5 patterns (Fig. 12) according to responses of fish to the reef as described by Ogawa (1968).

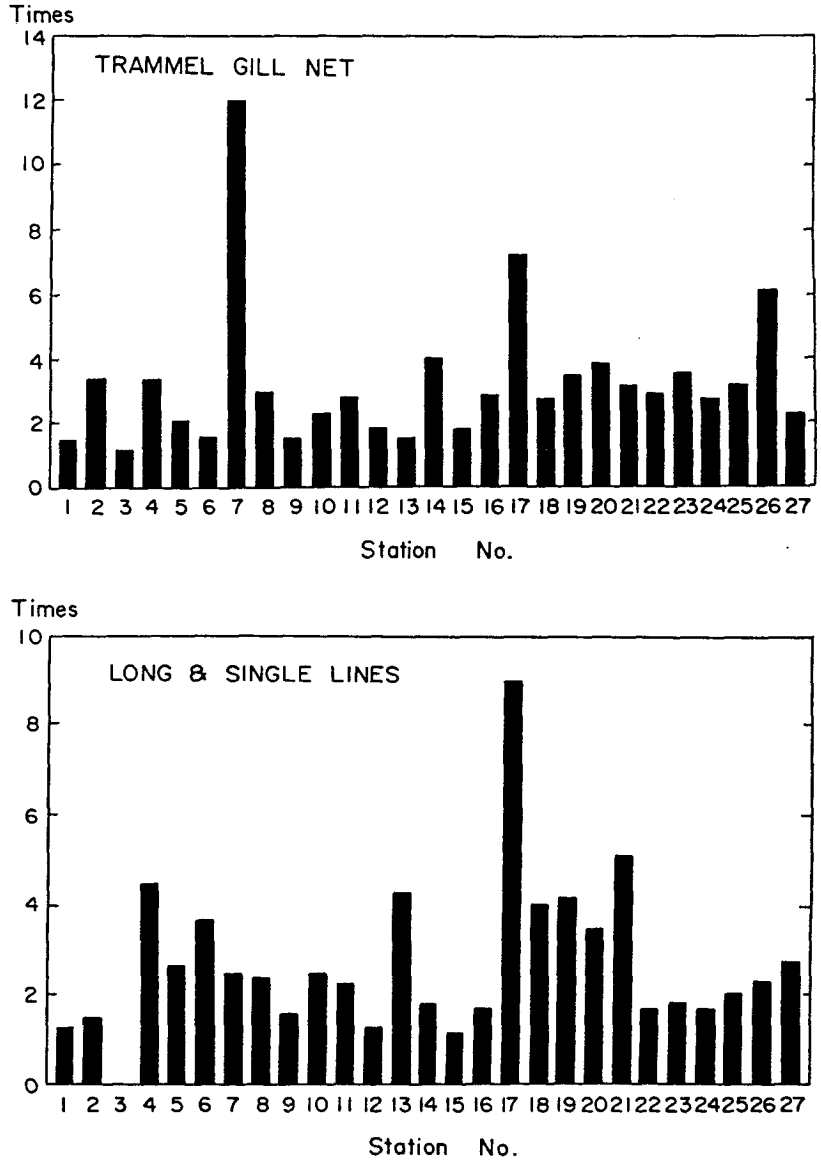

Fig. 7. Catch effectiveness by trammel gill net, long and single lines in the artificial reefs. Bar indicates catches at the reef divided by catches at control area.

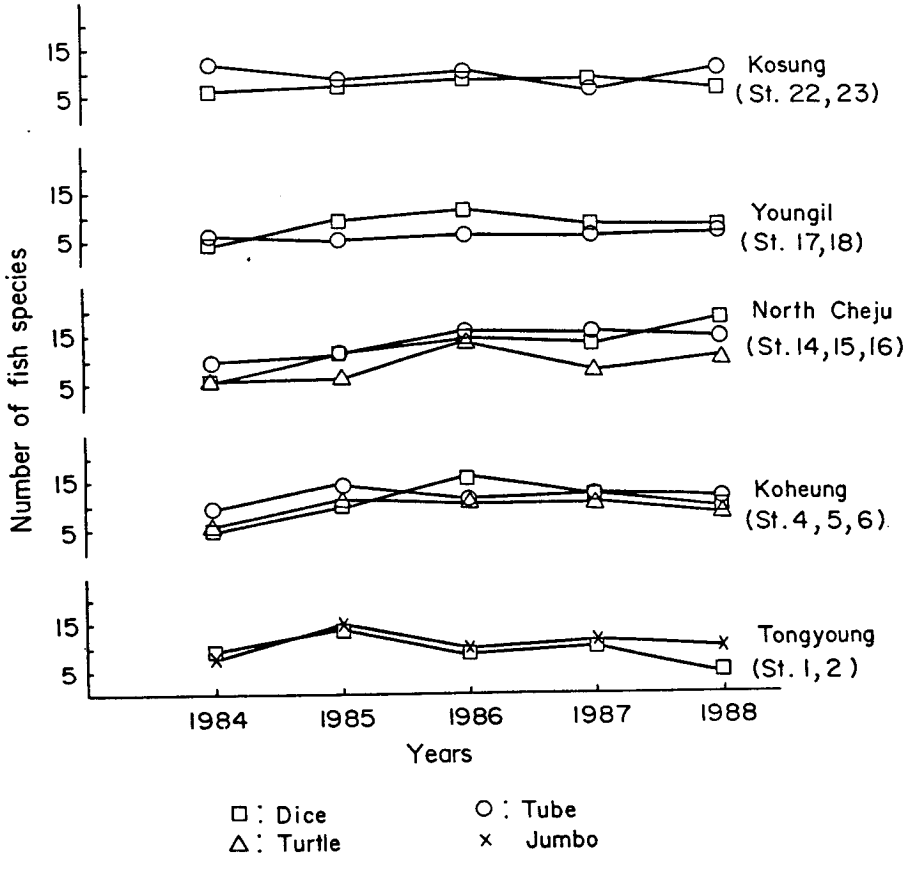

Fig. 8. Comparisons of number of fish species caught by a trammel gill net at different type of the artificial reefs.

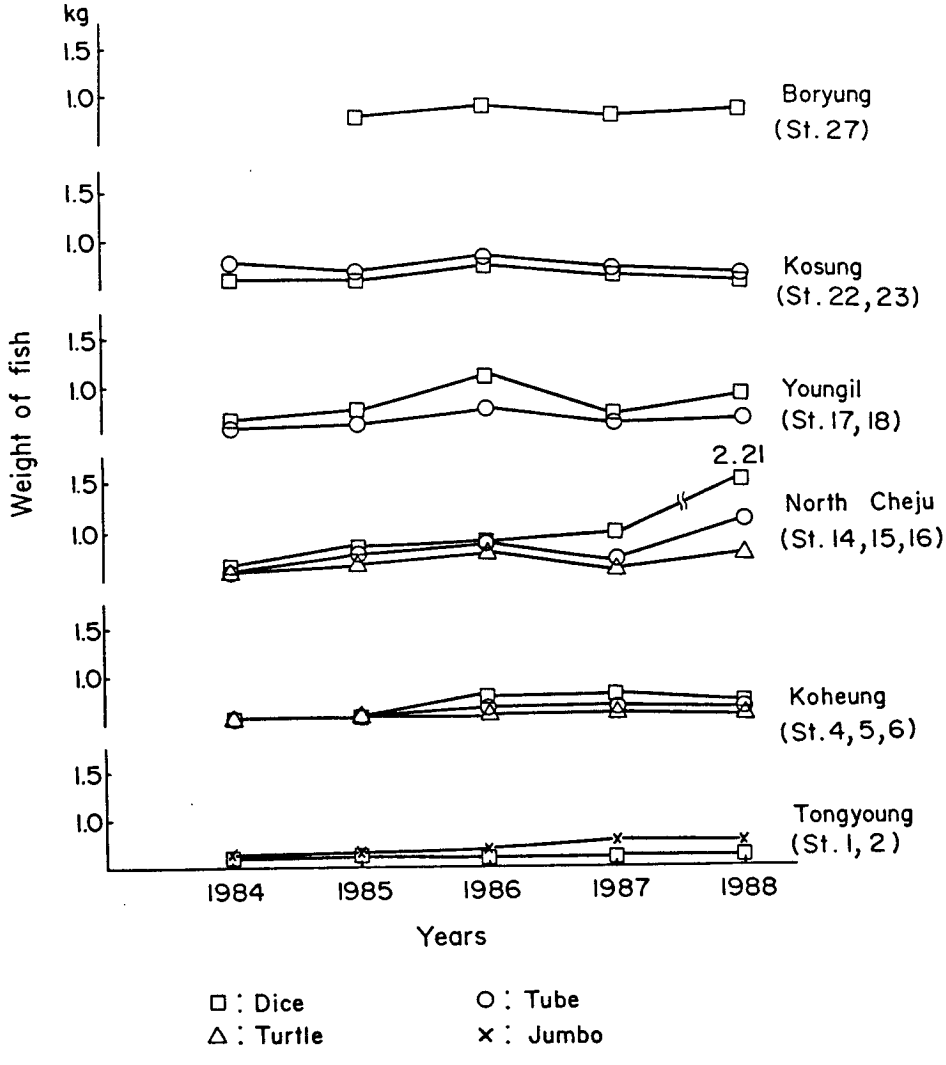

Fig. 9. Comparisons of catch per unit effort by a trammel gill net at different type of the artificial reefs.

Pattern I : The species preferring strong physical contact with body against a hard object ; 4 species such as bastard halibute (Paralichthys olivaceus), sea eel (Conger myriaster) and fine spotted flounder (Pleuroichthys cornutus).

Pattern II : Fish which like to have touching with a hard object by part of their body, pectoral fin or belly ; 11 species such as rock fish (Sebastes schlegeli), sea bass (Epinephelus septemfasciatus), cold pogy (Semicossyphus sp.) and rainbow fish (Halichoeres tenuispinis).

Pattern III : The species remaining only in close proximity to a hard object ; 26 species such as red sea bream (Pagrus major), file fish (Stephanolepis cirrhifer), rock bream (Oplegnathus fasciatus) and black sea bream (Acanthopagrus schlegeli).

Pattern IV : The fish occupying temporaly position relative to a hard object only when it is present : 4 species such as yellowtail (Seriola quinqueradiata) and Japanese mackerel (Scomberomorus niphonius).

Pattern V : The fish indifferent to the presence of a hard object : 4 species such as anchovy (Engraulis japonica) and sardine (Sarinops mellanostica).

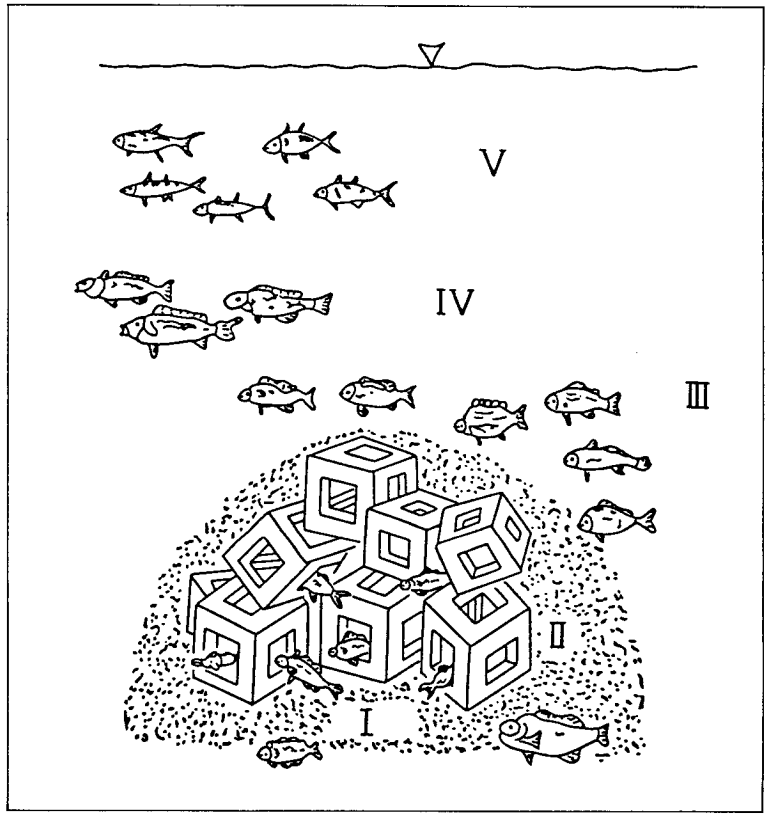

Fig. 10. Patterns of fish response to the artificial reefs.

B. Japan

1. Fisheries of Japan

From the 1960's to the 1970's, Japanese fisheries made a rapid expension from the coastal waters to offshore waters, and then to distant waters. In 1970, the total catch reached to about 9.3 million tons. Sine then the total landings of fishery products have increased continuously and reached up to 12.8 million tons in 1988 (Table 5). This meant that Japanese yielded approximately 13 % of the world total, making it the top rank in the world. However, the catches in the distant water fishery has continuousely declined due to the world wide proclamation of exclusive economic zones since 1976. The diminishing yields in the distant waters was balanced by increased

Table 5. Trend of Japan's fishery landings.

Unit: Million tons

Year	Total (A)	Landings by fhsheries sectors			B / A (%)
		Coastalr water (B)	Aqu - culture	Distant water	
1970	9.315	2.438	0.549	3.429	26
1973	10.545	2.708	0.773	3.187	26
1980	11.122	3.029	0.992	2.167	27
1985	12.171	3.356	1.088	2.111	28
1988	12.784	3.442	3.327	2.247	27
1989	11.913	3.395	1.272	1.976	28

Source: Nagahata (1991).

landings in the offshore and coastal waters. Thus the coastal fisheries in Japan has became more important than ever before.

2. History of Artificial reefs

There are several written records suggesting that Japanese were already in use of artificial reefs in Kansei era (1789 - 1801). In the late 18th century, fishermen in Awaji Province recognized that fish were thronging around sunken ships from which an idea of man made fish shelters was born. In 1804, fishermen of Manzai, Awaji Province made large wooden frames mounted with sandbags, bamboo and wooden sticks, and placed them on the sea bed in waters about 20 fathoms deep. About 100 days later, the fishermen netted a far greater number of fish than they used to catch around sunken ship (Ino 1974).

It was early 20th century that the fishermen started installing artificial reefs on a collective basis rather than individual basis. Scrap iron structure, sand bags and small ships loaded with stones had been installed to attract fish until 1930 when Ministry of Agriculture and Forestry granted subsidies for installing artificial fish shelters to increase fish catch.

In 1952, a five-year long goverment project was initiated to encourage the construction of artificial reefs made of concrete blocks. The reefs were divided into two categories; the artificial reefs for fin fish and benthic

organisms. Three official categories of reef size were recognized under this project: small, medium and large types having about 400 ㎥, 2,500 ㎥ and 30,000 ㎥ in bulk volume per site, respectively. The large type reefs have been promoted since 1958 and the amount of the artificial reefs installed off Japanese coastal waters increased tremendously. By 1966, a total of 721,065 pieces of ordinary reef modules(volume of 1 ㎥) were placed and 328,271 pieces of large reef modules (voulme of 1.3 ㎥) were installed. Between 1962 and 1970 the equivalent of 920,000 ㎥ of ordinary reef modules were installed at 3,427 localities while 1,320,000 ㎥ of large reef modules were installed at 429 localities.

With initiation of Ensei Program in 1973, the super size artificial reefs (appx. 150,000 ㎥ per reef site) have been placed. During the first and second period of the Ensei Program (1973 - 1987), a total of US$ 1.6 billion have been used for the placement of artificial reefs and more than 7,000 fishing grounds have been constructed.

The materials used for the construction of artificial reefs are concrete, steel and fiber-reinforced plastics, and a large number of manufacturers have developed a wide variety of blocks and modules. The choice of a specific type of the artificial reef is solely subject to project owner.

Since high-valued fishes are selectively targeted in Japan, increased fish catches by artificial reefs were estimated to be about 70 % in volume but as much as 160 % in value (Grove and Sonu 1991).

3. Case study

Japanese fisheries have faced various problems brought by such monentous situations as loss of distant and deep sea fishing grounds by international regulation, deterioration of nearshore fishing grounds by over exploitation and ever increasing pollutants input, and frictions between coastal recreation and the resident fishery activities. Therefore, long term plans to improve fishing conditions and accomplishing balanced development of the land have been carried out since the early 1970's:

a) Ensei Program : Coastal Fishing Ground Enhancement & Development Program

Ensei Program has been implemented since 1973, as a part of the public service aiming to enhance Japanese coastal fisheries (Nagahara 1991). The Coastal Fishing Ground Enhancement and Development Program Act defines the Ensei Program as follows: "The Ensei Program's primary missions are to place artificial reefs, to deploy wave-absorbing devices, and to conduct dredging in sizable water bodies which can hopefully be enhanced or rehabilitated into excellent coastal fishing grounds, and further to remove contaminated deposits in coastal waters in order to rehabilitate coastal fishery grounds where productive functions have deteriorated."

Individual Ensei Programs comply with the long-range plans which reviced every 6 years. The current Ensei Program fall under the third step, covering a 6 year period between 1988 and 1993. The total amount of investment for the Ensei program is estimated to be about 1,080 billion Yens (Table 6).

Table 6. Project types and investment of Ensei program.

Unit: Billion Yen

Project type	1st Phase (1973 - 1981)	2nd Phase (1982 - 1987)	3rd Phase (1988 - 1993)	Total
Placement of artificial reefs	75	140	140	355
Placement & construction of aqucculture grounds	100	190	200	490
Maintenance of coastal fishing grounds	10	10	10	30
Reserve fund	15	60	130	205
Total	200	400	480	1,080

Source: reconstructed from Nagahata (1991).

The program consisted of 1) placement of artificial reefs with the object of attracting fishes for higher fishing efficiency, 2) construction of suitable habitats for living marine species with emphasis on enhancement of important fisheries resources, and 3) creation of aquaculture grounds by constructing breakwaters and other devices in previously under-utilized areas. However, in this report, the construction of artificial reefs has received a special attention.

b) Marinovation Plan

The Marinovation Plan has been developed as a long term socio-economic program to improve fisheries and fishing communities in accordance with the maintaining fisheries supply and accomplishing balanced developement of the land. The basic roles of the plan comprised following four areas: 1) stable supply of seafood products, 2) revitalization of fishery industries. 3) formulation of regional marinovation zones, and 4) preservation of marine related cultural heritage (Nagano 1991).

The Marinovation Plan concept can be categorized into four different types as follows:

1) Marine Combinat: Establishment of a large-scale urban complex featuring fishing and seafood industries, along with suitable management of its offshore marine resources.

2) Maritime Village: A group of fishing villages catering to fish-farming activities.

3) Marine-tech: Research and development efforts aming to introduce leading technology in the fishing industry.

4) Marine Culture: Futherance of marine-related cultural heritage and preservation of environmental quality of fishing grounds.

Actual work under this program has been started at 5 localities in 1990 and mapping basic plans for a total of 55 marinivation zones were scheduled for completion during FY 1991.

C. United States

1. Artificial habitat enhancement

The first constructed artificial reef in the United America was sunken log huts off South Carolina in 1880's, although field studies began three decades ago (Stone et. al, 1991). The artificial reef building in the United State initially promoted sport fishing interest. Today, however, interest being moved toward commercial as well as sport fishing, fishery resources management, environmental mitigation and restoration, waste disoposal and recycling, and tourism. Thus the term artificial habitat, rather than artificial reef, is commonly being used.

The feature of artificial habitat construction in the United State can be characterized as follows:

1) Less sophisticated and more frugal structure using natural and scrap materials for reef building.
2) Atificial habitat not only to promote fishing, but also to enhance and restore the quality of natural habitats.
3) The technology is still experimental, and persue comprehensive and long-term evaluation including ecological and socio-economic perspectives.

With endorsing of the National Fishing Enhancement Act in 1983, national policy on the construction of artificial reefs is aiming to: 1) enhance fishery resource to the maximum extent practicable, 2) improve access and utilization of facilities by recreational and commercial fishermen,

3) minimize conflicts among competing uses of water covered under the Act and the resources in such waters, 4) minimize environmental risks and risks to personal health and property, and 5) be consistent with generally accepted unreasonable obstruction to navigation.

About 600 artificial reefs of various size have been placed under permission of U.S.Army Corps of Engineers until 1990. Florida is the most active State with 112 reefs and followed by North Carolina (66 reefs), California (39 reefs), Washington (30 reefs), and so on. Including incidental and unpermitted reefs, the number of the artificial reefs seemed to be more than several thousands (Stone et. al 1991). Of particular interest is the proliferation of fresh-water reefs. In 1984, it was censused that the number of fresh water reefs was 44,643. Approximately 70 % of the fresh water bodies containing reefs were lakes and reservoirs and the remaining 30 % were streams.

2. Case study

a) California Department of Fish and Game Artificial Reef Plan

Sport fishing is more important than commercial fishing in California. It provides $4.2 billion a year to the State's economy and 60.4 thousand full time jobs while commercial fishing contributing $643 million annually and providing jobs for 14.9 thousand fishermen. Thus the most of the reef constructions are aiming to attract sport and recreational activities.

Materials for reef construction should be persist for at least 30 years, should be free of contaminants, and should have at least twice the specific gravity of sea water. Thus quarry rocks, concrete rubble, pier piling and vessels should be clean before placing. Wooden or aluminum structures, plastics, automobile bodies, and tires are not permited to avoid turing the ocean into a repository for trash (Wilson 1991).

The experimental artificial reefs in California are listed as follows:

1) Pendleton Artificial Reef
   - built : in 1980 at depth of 13 m
   - cost : $250,000
   - materials: 9,078 tons of quarry rocks
   - shape : arranged in eight 30 x 20 x 4.5 m modules spacing 18 m apart
   - purpose : to investigate value of reefs for mitigating loss of kelp forest communities.

2) Pitas point Artificial Reef
   - built : in 1984 at depth of 8.5 m
   - cost : $187,200
   - materials: 6,536 tons of quarry rocks
   - shape : arranged in four 36 x 15 x 3 m modules spacing 18 m apart
   - purpose : to investigate value of reefs and habitat for kelp and associated communities.

3) Marina Del Rey Artificial Reef

- built : in 1985 at depth of 20 m
- cost : $245,000
- materials: 9,986 tons of quarry rocks
- shape : arranged in twor retangular complexes of eight modules (15 m in diameter and 3 m high) each
- purpose : to investigate the effect of spacing on the reef biota

4) Santa Monica Bay Artificial Reef

- built : in 1987 at depth of 13 - 22 m
- cost : $360,000
- materials: 18,156 tons of quarry rocks
- shape : placed in 48 modules of 152.2 m diameter and arranged in eight pairs at each of 3 depths: 13 m, 17 m, and 22 m
- purpose : to investigate the effect of depth, relief, and rock size on the reef biota

b) Atlantic Artificial Reefs : an interstate management

The Atlantic State Marine Fisheries Commission and its member states have formed an Atlantic Interstate Artificial Reef Prgram to boost the development and assessment of a coastwide database on reef programs, to review and prioritization of Atlantic coast research needs, and to establish and regulatory recommendations related to the artificial reef for Atlantic coast states. 14 states and the District of Columbia have participated in this program (McGurrin 1991).

There are 273 permitted reef sites along the Atlantic coast, with 26 of these still waiting for deployment of reefs in 1990 (Table 7). Together with North Carolina and Florida account for 65% of the total permitted reef sites.

Table 7. Number of permitted artificial reef sites and types of reef sites along the Atlantic coast.

Sites	Number of reefs	Types of Reefs			Water types		
		Benthic	Midwater	Mixed	Federal	state	inland
New England (ME,NH,MA, RI,CT)	2	2	0	0	0	2	0
Mid-Atlantic (NY,NJ,DE, MD,VA,DC)	55	51	2	2	20	10	25
S. Atlantic (FL,GA,SC, NC)	216	198	4	14	133	43	40
Total	273	251	6	16	153	55	65

Source: Reproduced from McGurrin(1991).

Among a total of 273 Artificial sites, 92 % are benthic reefs and 6 % consist midwater fish aggregating devices. About 56 % of the reefs are located in federal waters and 24 % of the reefs are placed in inland waters.

D. Other regions

With greater awareness of the world's deteriorating marine environments, there is increasing reliance on artificial aquatic habitats in the world and about 40 countries on six continents prcaticing the artificial technology for enhancement of aquatic habitat (Grove and Sonu, 1991).

The most popular materials for reef building is the fabricated concrete cube block(used in about 15 countries including Twiwan and Italy). A next popular material is a tire module, which is either floting or bottomed (used in about 20 countries) and followed by recycled materials such as ships, cars, drums, and fishing nets and quarry rocks. In South East Asia, low-cost artisanal reefs featuring local ingenuity such as bamboo modules and mangrove brushpile have been used.

Grove and Sonu (1991) have censused the effectiveness of the artificial reefs and have reported that the artificial reefs resulted in increased fish catch from 20 to 4,000 %. Degrees of fish catch increased among the most of the countries ranged between 20 and 200 %. However, incredible increase of fish catch have been reported in Israel (1,000 - 2,000 %), Russia (1,000 %) and Ivory Coast (4,000 %).

III. Study on the succession of benthic organisms on the artificial reef

A. Meterials and methods

A diving observation was made to investigate the general structure of the benthic communities on the artificial reefs which were installed during 1987 - 1988 at western coast of Sungsanpo, Cheju Do in August, 1991. For the study on the succession of biotic communities on the artificial reefs, 52 experimental substrates of quatrate shape (30 x 30 m) made of concrete were attached on the surface of triangler artificial modules which were palced in November, 1991 at western coast of Inchulbong, Sungsanpo, Cheju Do. Sample collections were made seasonally and examined at the laboratory.

B. Results and discussion

It was found that the surface of the artificial reefs have been covered with the benthic organisms, to a certain degree, within a year after the installation. However, it took 3 - 4 years to reach similar biotic communities of natural hard bottoms near by (Fig. 11, 12).

Fig. 11. Surface photograph of a three year old artificial reef (turtle module) placed at western coast of Sungsanpo, Cheju Do.

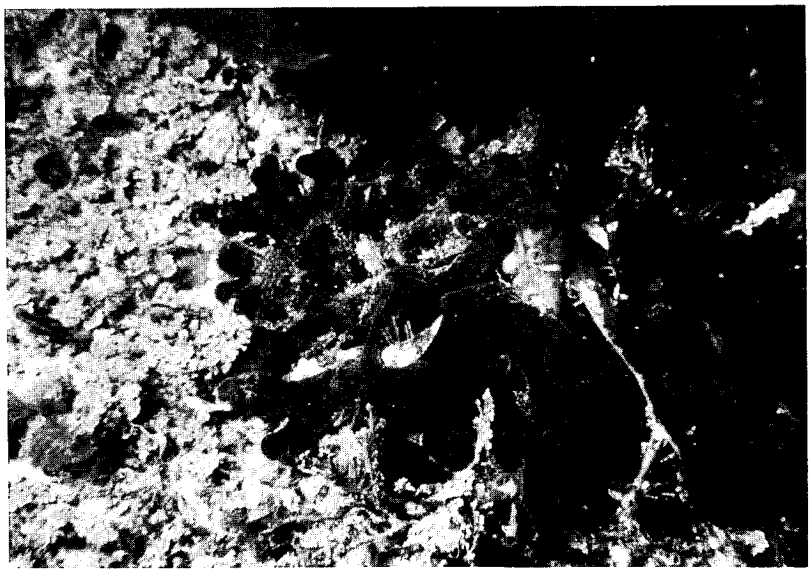

Fig. 12. Close up photograph of Fig. 11.

The first step of the succession of marine organisms on the surface of 3-month old experimental substrates were summarized as follows.

1) There was no clear difference between horizontal and vertical substrates in species number and compositions. However, horizontal substrates showed a higher biomass than the vertical substrate.

2) A total of 12 species (Table 8) were found from the horizontal and vertical substrates. The dominant species were sea trumpet (Ecklonia cava), oyster thief (Colpomenia sinuosa) and followed by green confortii (Enteromorpha compressa).

3) Animals on the substrates were poor and a few number of tube building ampipods, bryozoans and polychaetes were found.

Table 8. List of species on the experimental substrates in Feb. 1992.

Species	Horizontal	Vertical
Algae		
Ecklonia cava	+++	++
Colpomenia sinuosa	++	++
Enteromorpha compressa	++	+
Gloiosiphonia capillaris	+	
Polychaeta		
Hydroides ezoensis	+	+
Perinereis brevicirris	+	
Dexiospira sp.	+	+
Polyplacophora		
Ischnochiton sp.	+	
Amphipoda		
Erictonius brasiliensis	+	+
Ascidiacea		
Molgula sp.		+
Bryozoa		
Lichenopora radiata	++	+
Dakaria bidentata	+	+
Total no. of species	11	9

+++ : very abundant, ++ : abundant, +: present

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