BSPE 00317-957-3

人工魚礁에 附着하는 底棲生物相에 관한 研究

A Study on the Succession of Benthic Organisms on Artificial Reefs

1997. 2

韓國海洋研究所

提 出 文

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本 報告書를 " 人工魚礁에 附着하는 底棲生物相에 관한 硏究 " 事業의 最終報告書로 提出합니다.

1997 年 2 月

韓 國 海 洋 硏 究 所

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要 約 文

I. 題 目

人工魚礁에 附着하는 底棲生物相에 관한 硏究

II. 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 1660 여억원을 投入하여 약 90 만 ha의 沿岸漁場에 55 만개 이상의 人工魚礁를 投入하였으며, 앞으로도 人工魚礁 事業을 계속 추진할 계획이다. 또한, 우리 나라의 全海域에 대한 海洋牧場化 事業을 위한 기초연구를 1994 年 부터 착수하여 2001 년에 완성할 예정에 있다. 현재까지 알려진 바에 의하면 沿岸 水産資源 增大를 위한 방법 중 가장 확실한 것은 人工魚礁이기 때문에 海洋牧場化 事業에 있어서도 人工魚礁는 가장 중요한 부분으로 대두될 것으로 판단된다. 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 어류들을 모여들게 하는 역할을 하므로, 魚礁의 정확한 效果判定을 위하여서는 魚礁 위에 遷移되는 生物相에 관한 研究가 先行되어야 한다. 따라서 本 研究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함으로서 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사업의 최종보고서로 우리 나라의 水産業 現況調査, 國內 外의 魚礁 現況調査 및 附着板을 이용한 魚礁 표면의 底棲生物相 調査를 포함하고 있으며, 底棲生物相 調査는 附着生物의 時期別 種變化, 生物量의 變化 및 優占種의 分析에 중점을 두고 실시하였다. 우리 나라의 水産業 現況과 世界各國의 海洋牧場 現況은 1 次年度 報告書에서도 言及하였지만, 正確을 기하기 위하여 새로운 資料를 追加하여 再作成하였다.

V. 研究開發 結果 및 活用에 대한 建議

究開發結果

우리 나라의 水産物 所要量은 2001 年에 약 5 백만톤으로 추정되고 있는데 현재의 生産體系로는 2001 年의 生産量이 약 400 백만톤

에 불과할 것으로 추정되기 때문에 100 만톤 이상의 水産物 부족현상이 예상된다. 따라서 이를 극복하기 위한 적극적인 養殖技術開發, 環境管理, 未利用資源開發, 魚種別 資源管理모델 開發 등 水産生物 生産力를 획기적으로 增大시킬 수 있는 體系的인 海洋牧場化事業이 필요하다.

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. 1995 年 까지 약 80 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 상태를 유지하고 있었다. 國立水産振興院의 調査結果를 보면 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 일찍이 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 시작되어 1, 2 段階事業 (1973 - 1987)에 6 천억 엔이 投資되었고, 3 段階事業 (1988 - 1993)에는 약 4.8천억 엔이 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에 폐선 어초를 허가한 이후 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.

濠洲는 B. C 2000 년경부터 原住民들이 보다 많은 어류를 잡기 위하여 原始的인 魚礁를 사용하였다는 考古學的 증거가 있다. 본격적인 魚礁設置는 1960 년대 초기부터 시작하였는데, 1991 년 현재까지 72 곳에 魚礁가 설치되어 있다. 어초의 材質은 폐타이어 (29 개 魚礁)와 폐선박 (22개 魚礁)이 주로 사용되고 있으며, 이 외에 콘크리트 構造物과 바위 등이 쓰이고 있다.

生産量 基準으로 世界第一의 水産國인 中國의 경우 아직 海洋牧場의 概念이 定立되어 있지 않지만 제 8 차 5 개년 계획 중 24 개의 試驗魚礁를 설치하였으며 新養殖漁場 개발 및 新養殖品種 개발에 주력하였다. 生命工學技術의 養殖産業利用은 제 9차 5개년 계획의 중요 과제이다.

그 외 프랑스, 英國, 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, 등이 많이 사용되지만, 低, 中開發國에서는 모래 주머니, 바위, 대나무 또는 망그로브 줄기

를 엮어 많든 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 소련에서는 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 설치되는 삼각기둥형 魚礁에 콘크리트로 제작한 30 x 30 cm 크기의 附着板을 水平 및 垂直 방향으로 각 각 26 개씩 設置하였다. 硏究期間 中 총 34종의 海藻類와 64 종의 底棲動物이 확인되었다.

海藻類에서는 감태가 전 연구기간에 걸쳐 가장 優占種이었으며, 최대 生體量은 약 10 kg/m^{2}에 달하였다. 底棲動物의 경우 초기에는 機會種으로 판단되는 태충류인 *Likenopora radiata*, 다모환충류인 *Dexiospira spirillum* 등이 번식하지만 점차 시간이 지남에 따라 해면류인 *Haliclona permollis*, *Halicondria* spp. 따개비 (*Balanus trigonus*) 및 다른 태충류로의 遷移가 일어났다. 전체적으로 볼 때, 附着板의 저서생물군집의 遷移는 감태의 繁殖과 밀접한 관계를 가지고 있는데, 감태의 附着器는 다른 모든 종을 救蹴할 수 있는 한편 다시 타종류의 底棲生物이 그 위에서 繁殖할 수 있는 제2의 附着基質을 제공하고 있었다. 또한 따개비의 어린 개체는 태충류에 의하여 구축되지만 어느 정도 성장한 후에는 반대로 태충류 구축하는 것으로 보여진다. 成長速度가 빠른 해면류는 대부분의 다른 저서생물을 塗抹할 수는 있다고 보여진다. 附着板 설치 초기 3 個月 後에는 垂直 및 水平 附着板 간에 底棲生物의 種造成과 生體量에 별차이가 없었지만, 이 후 生物量에서는 水平 附着板이 被覆度에서는 수직 부

착판이 비교적 優越하였다. 이는 優點種인 감태와 불레기말이 水平附着板에서 成長이 빨랐기 때문이다.

調査結果 魚礁投入 후 3 - 4 年 정도가 經過하면 주변의 硬性底質의 生物相과 類似한 群集構造가 이루어진다고 보여진다.

綜合建議

魚礁投入은 沿岸漁業을 活性化 시킬 수 있는 확실한 方法으로 생각된다. 그러나, 地域과 魚礁種類에 따른 變化가 매우 크기 때문에 사전에 철저한 調査가 수행된 후 魚礁施設을 하여야하며, 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 長期 모니터링

S U M M A R Y

I. Title

A study on the succession of benthic organisms on artificial reef

II. Significance and objectives of the study

Artificial reef, as a well established enhancement tool of fishery resources, has been introduced in Korea since 1971. More then 550 thousand pieces of artificial reef modules were placed around the area of 90 thousand hectares of fishing grounds along the coastal waters of Korea. A series of intensive studies on the effectiveness of artificial reefs 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 artificial reefs.

Studies on the succession of benthic communities on the artificial reef surface is one of the most efficient tools for evaluating the productivity potential of a given artificial reef. Living organisms on artificial reefs serve as a prey and thus attract fish. Therefore, it is necessary to study the succession of benthic community in order to evaluate the effects of a given artificial reef on the fisheries resources

in surrounding water.

The main objectives of the study are to analyse the present technics of artificial reefs around world, to visualize the succession process of the benthic community on it, and to provide a guide line information to be used in the Marine Ranching Program.

III. Scope of the study

As this is the final report of a three-year study, this report contains a contemporary information on the technics of artificial reefs and the effectiveness of artificial reefs in Korean waters. For the latter, special efforts were made to understand the succession process of benthic organisms on the artificial reef complex which was placed in the coast of Sungsanpo, Cheju-Do in November, 1992.

The present status of Korean fisheries and the technical assessments of marine ranching in foreign countries had received a special attention in the first year report, however it was reviewed again using the latest data. Data used for the evaluation of Chinese fisheries was collected from various sources, and thus tables and figures possibly did not coinside to its actual values.

V. Results of the study and suggestions

Results of the study

Artificial reef has been introduced into the shallow wasters of korea since 1971. With the initiation of the marine ranching program in 1987, the number of the placed reef modules has increase sharply and reached up to 800 thousand pieces by 1995. Among the several types of the modules, dice, tube, turtle and jumbo types were commonly used. Beside to these, triangle type have been used since November, 1991.

It was appeared that the combined forces of wave and current acting on artificial reef modules placed in the coastal waters of Korea were smaller than the friction forces against sliding and rotation, and the modules appeared to be in a stable condition.

There were no clear increase of fish catches observed among different types of the reef modules. However, fishing grounds with artificial reefs yielded about 2.5 times more fish than the grounds without the reefs in term of catch per unit effort.

There were several written records suggesting that Japanese were already in use of artificial reefs in the early

19th century. By the year of 1966, more than one million artificial reef modules were placed in Japanese waters. Japan has launched an intensive project on fisheries enhancement through installation of artificial reefs, the Ensei project. They invested about six hundred billion Yens during the first and second phases of the Ensei Program(1973 - 1987), and invested about five hundred billion Yens during the third phase of the program(1988 - 1993). The main concept of artificial habitat constructions in Japan has being changed gradually from reef building mainly for fish aggregation to a long term socio-economic program to improve fisheries and fishing communities in accordance with maintaining fisheries supply and accomplishing a balanced development of the land.

The feature of artificial habitat construction in the United State is characterized by using of less sophisticated and more frugal materials for artificial reef building and targeting the promotion of sport fishing rather than commercial fishing. However they are pursuing a comprehensive and long term evaluation of the effectiveness of artificial reefs including ecological and socio-economical perspectives. About six hundred artificial reefs of various sizes have been placed under permission of the US. 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. The Atlantic Interstate Artificial Reef Program has been established in order to boost the mutual management of artificial reefs.

There is archaeological evidence that Australian aboriginals used artificial reefs to grow aquatic organisms from about 2,000 B. C. However interest in artificial reefs started in the early of 1960s. By the year of 1991, 72 artificial reefs have been constructed by state fisheries authorities and recreational fishing clubs. The majority (29) of the reefs were constructed of tires, while 22 were vessel reefs, with the remaining reefs being made of concrete, rock and other materials.

The leading fisheries country in the world in terms of production, China do not has a solid concept on marine ranching yet. However 24 experimental fish reefs were installed and efforts also had paid on the development of new culture grounds as well as new target species during 8th 5 year plan. The application of biotechnology on aquaculture is a newly arisen topic for 9th 5 year plan.

A rapidly growing interest on the artificial reef have existed among more than than 40 countries including Taiwan, India and countries in Middle America. Materials being used for reef building are fabricated concrete blocks, old ships and quarry rocks. Bamboo or mangrove modules with sand bags being used in less developed countries.

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

A study on the succession of benthic community on an experimental substrata have conducted. During a thirty month study period, a total of 34 algal species and 64 zoobenthos found. *Ecklonia cava*, Phaeophyta dominated the community with the maximum biomass of about 10 kg/m^2 and can be called as the canopy species. The species smothered all other species, however on the other hand it provided a new substrate for new comers. Some opportunistic species such as *Likenopora radiata* (Bryozoan) and *Dexiospira spirillum* (Polychaeta) occurred at the early of the experimental period, however with time went, *Haliclona permollis* and *Halicondria* spp.(Porifera), *Balanus trigonus* (barnacle) and other bryozoans outbreaked. In general, young barnacle seemed to be excluded by bryozoans. However when the barnacle grew to a certain size, on the contrary, bryozoans was excluded by barnacle. Rather rapid growing poliferans such as *Haliclona permolis* and *Halichondria japonica* seemed to suffocate other sessile zoobenthos. No apparent difference between vertically and horizontally installed substrates in terms of species composition and biomass during the very early stage of succession. Thereafter owing to a rapid growth of *E. cava*, the horizontal substrates showed a higher biomass while the vertical substrates showed a higher coverage compare to each other. It seemed that bryozoans can bulldoze younger banacle, however the bryzoans possibly be bulldozed by adult barnacle. Depend on the time series, benthic process on thr experimental substrata can be classified into three stages: the initial stage, the build up stage and the regulatory stage.

Suggestions

Artificial reef is known as a well established tools for fisheries resource enhancement and being used in shallow coastal waters around the world. However, the effect of an artificial reef is subject to vary depend on its size, shape and local environment. Thus it is recommended that following considerations should be made before installation of artificial reefs.

1). Oceanographic condition including biotic communities on the proposed site
2). Relationship of artificial reefs for fishing (trawling), recreation, and other activities,
3). Use of stable and nontoxic materials for artificial reefs reef building to minimize environmental risks,
4). Appropriateness of artificial reefs pertaining to fish
5). Long-term monitoring of benthic process and propagation of fisheries resources on and around artificial reefs

C O N T E N T

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Chapter I. Introduction

Korea is one of the leading countries in fisheries as she had been ranked among the top ten countries in terms of fisheries yield and export of fisheries products during the last decade(FAO 1993). Recent trends, however, shows that the Korean fisheries is being faced with many difficulties because of depleted resources and increased fishing costs. The main reasons for the recent stagnation of Korean fisheries are primarily due to decrease of fisheries resources, loss and deterioration of fishing grounds in both distant and adjacent waters. In particular, the distant water fishery have lost many of its fishing grounds due to world wide resources nationalism. In addition to this, coastal water fisheries is being encountered with decreased fish stocks owing to over exploitation and shrinkage of near-shore fishing grounds by coastal land reclamation and industrial activities.

On the contrary, consumption of fisheries products(as sea food) has been increasing considerably every year. Annual consumption of sea food per capita is about 40 Kg in recent years which is well above the world's average. Fish protein accounted for around 50 % of the total animal protein in Korea. If this trend continues, Korea will soon became an importing country of sea foods from a leading exporter. In fact, Korea have imported 380 thousands tones of fisheries products (

US$ 726 millions) in 1994. The only solution of the present problem is might be marine ranching. This paper aims to introduce the Korean fisheries and activities to keep the adjacent water fisheries thriving.

The main objectives of the study are to analyse the present technics of artificial reefs around world, to visualize the succession process of the benthic community on it, and to provide a guide line information to be used in the Marine Ranching Program. The present status of Korean fisheries and the technical assessments of marine ranching in foreign countries had received a special attention in the first year report, however it was reviewed again using the latest data.

The authors would like to express their cordial thanks to the director and staffs of Cheju Fisheries Research Institute for their assistance in field sampling. Whithought help of Mr. D. G. Kim, this study was unable to conduct. Thanks also due to Mr. Hyun, J. M. at Univ. of Cheju and Mr. H. S. Park of KORDI for their help during the study.

Chapter II. Present Status of Fisheries and Marine Ranching in the World

1. Korea

A. Present status of fisheries

Korean fisheries has made a remarkable progress during the last three decades and Korea had been one of the leading countries in fisheries as she had been ranked among the top 10 countries in terms of fisheries yield and export of fisheries products during the last decade (FAO 1993). The fisheries yield amounted to about four million tons in recent years from less than a half million tons in 1962 (Table 1).

During this period, the most notable progress was accomplished in the distant water fisheries and aquaculture while very mild gain was made in the adjacent water fisheries. For example, the total yields from the distant water fisheries and aquaculture in recent years are about 900 and 40 times greater than those of 1962, respectively. The relative importance of the coastal fisheries is diminished considerably, whereas the aquaculture and distant water fisheries are promoted. In other hand, the catches from coastal waters comprised about 70 % of the whole fisheries yield in 1970's,

Table 1. Fisheries yield by fishing sector in Korea

Unit : 1,000 /T

	1962	1972	1980	1984	1988	1990	1991	1992	1993	1994
Adjacent F.	449	958	1372	1524	1512	1542	1304	1295	1526	1518
Distant F.	1	224	458	658	774	925	873	1024	741	887
Mariculture	19	161	541	678	887	772	776	936	1038	1072
Inland F.	1	1	39	35	25	15	16	14	12	10
Inland Aqua.				15	11	16	14	20	18	20
Total	470	1344	2410	2910	3209	3276	2983	3281	3335	3477

Sources : Statistical Yearbook of Agriculture, Forestry and Fisheries. ROK. 1962 - 1994.

but dropped to 50 % from the late Of 1980's. The proportions of both aquaculture and distant water fisheries have been grown up to 25 % and 28 %, respectively, from a few percent.

Recent trends, however, shows that the Korean fisheries is being faced with many difficulties because of depleted resources and increased fishing costs. The main reasons for the recent stagnation of Korean fisheries are primarily due to decrease of fisheries resources, loss and deterioration of fishing grounds in both distant and adjacent waters. In particular, the distant water fishery have lost many of its fishing grounds due to world wide resources nationalism. In addition to this, coastal water fisheries is being encountered with decreased fish stocks owing to over exploitation and shrinkage of near shore fishing grounds by coastal land reclamation and industrial activities. Thus, fisheries became a less profitable business and the number of fisheries workers declined some sharply from 280 thousand persons in 1980 to 190 thousand persons in 1995. The contribution of fisheries to national income dropped, simultaneously, to 0.8 - 0.9 %.

On the contrary, consumption of fisheries products as sea food has been increasing considerably every year (Table 2). Annual consumption of sea food per capita is about 40 Kg in recent years which is well above the world's average. Fish protein counted for around 50 % of the total animal protein in Korea. If this trend continues, Korea will soon became an importing country of sea foods from a leading exporter. In fact, Korea have been import 380 thousands tons of fisheries products (equivalent US$ 726 millions) in 1994. The only solution of the present problem is might be marine ranching. This paper aims to introduce the Korean fisheries and activities to keep the adjacent water fisheries thriving.

B. Aquaculture

To keep steady increase of fisheries yield to meet the

Table 2. Estimated demand of fisheries products in Korea

Unit: 1,000 M/T

	1996			2001		
	Local	Export	Sum	Local	Export	Sum
Fin fish	1,992	441	2,433	2,255	499	2,754
Shell fish	439	278	718	593	290	883
Crustacean	126	11	137	170	12	182
Algae	377	189	566	455	198	653
Others	361	60	421	487	62	550
Total	3,295	980	4,275	3,961	1,061	5,022

Source : Reconstructed from Huh (1987).

nation's demand, the only choice might be rebuild coastal fisheries resources and propagation of aquaculture.

The climatic conditions for aquaculture practice in Korea is in some respect quite pessimistic. That is, its coastal water temperature in Korea is very high for summer (as high as 26℃) and very severe for winter (as low as 7 ℃ for near shore waters and as low as 3 ℃ for in side of bay waters). Therefore, neither stenothermal warm water fish nor cold water fish can survive throughout year in the confined rearing facilities which are usually set up near shore in highly restricted waters. This distinct water temperature is on the other hand very attractive for the eurythermal mollusks and seaweeds because its fluctuations regulate the life cycle pattern very much distinctive. Further more, optimistic point of view, either warm water species or cold water species can be cultured if we develop proper technics.

Although artisanal culture of laver (*Porphyra* spp.) and oyster (*Crassostrea* spp.) has started as early as 5th century and exported to China, industrialized aquaculture did not emerge until 1960's. With the development of the raft and rope culture for oyster and undaria during the 1960's to early of 1970's, the production has begun to increase sharply year by year and reached to a half million tons in 1980 and the nominal yield was a little more than one million tons in 1994 (Table 3). More than 10 thousand marine farms are in operating and about 110 thousand hectares of shore waters are used for aquaculture at present.

1). Culture of seaweeds

From the early days in history people in Korea have enjoyed dried laver (*Phophyra* spp.) and sea mustard (*Undaria pinnatifida*) soup. Korea has a old proverb saying " couldn't eat sea mustard soup after delivering". It means extremely poor condition or so poor as to starve. The seaweeds in recent years

Table 3. Aquaculture production in Korea

unit : 1,000 M/T

Year / Items	1970	1980	1986	1988	1990	1992	1993	1994
Marine Fish	+	+	3	1	3	5	4	7
Fresh W.Fish	+	+	5	11	16	20	+	+
Mollusks	75	283	399	421	326	338	346	264
Crustacean	+	+	+	+	+	+	+	+
Seaweed	44	258	524	442	412	580	664	750
Others			21	23	32	12	23	31
Total	120	541	952	899	789	955	1,039	1,072

+ : < 1000 M/T,

Sources : Statistical Yearbook of Agriculture, Fores. & Fish. ROK. 1962 - 1994.

not only occupy major portion of the mariculture but also exceeds the other farmed product combined.

Laver and sea mustard, frequently, be over harvested and create some economical problems to seaweed farmers. The next important species is fusiforme (*Hijikia fusiforme*) and followed by kelp (*Laminaria japonica*) and green laver (*Enteromorpha* spp. and *Ulva* spp.). Among these species, sea mustard outpaces all other species in amount, however in the economical point of view laver is in most outstanding position. The total production of cultured algae was about 664 thousand tons (US$341 millions) in 1991 (Table 4).

Table 4. Aquaculture vs fishing yield of seaweed in Korea, 1993

Unit : M/T, US$ million

Type / Production Species	Aquaculture※		Fishing	
	amount	value	amount	value
Phophyra spp.	235,272	260.1	42	0.2
Undaria pinatifida	372,182	46.0	5,271	3.0
Hijikia fusiforme	27,621	21.3	6,458	6.0
Entermorpha & *Ulva* spp.	12,053	7.2	597	0.5
Laminaria spp.	17,180	6.2	511	0.2
Others	10	0.1	9,307	7.6
Total	664,318	340.9	22,186	17.5

Sources : Statistical Yearbook of Agriculture, Forestry and Fisheries. ROK. 1993.

2). Culture of mollusks

Bottom culture of bivalves such as pacific oyster, hard clam, short necked clam, blood clam and mussel was the major method until the modern aquaculture technics has been developed. The raft culture technics of oyster developed in the early of 1960's opened a new era of aquaculture in Korea.

Knowledges accumulated through oyster culture transferred to other mollusks quickly. With aquaculture driving policy the oyster production exceed 100 thousand tons in 1975 and jumped to 300 thousand tons in 1980's. Due to the world wide lean harvest the oyster production was about 250 thousand tons in recent years (Table 5).

Table 5. Aquaculture vs fishing yield of bivalves in Korea, 1993

Unit : M/T, US$ million

Type / Production / Species	Aquaculture		Fishing	
	amount	value	amount	value
Crassostrea gigas	258,326	129.7	28,215	27.3
Tapes philippinarum	10,046	14.6	31,202	36.4
Scapharca broughtonii	11,613	77.4	553	1.2
Anadara spp.	3,290	5.6	3,269	5.7
Mytilus edulis	55,183	21.2	2,271	2.9
Atrina pinnata	13	0.1	3,321	11.8
Meretrix lusoria	145	1.1	1,407	7.3
Haliotis spp.*	83	3.9	278	12.1
Others	7,111	6.8	298,448	122.3
Total	345,696	260.4	386,964	277.0

* : Under estimated due to direct dealing

The first attempt of ark shell (*Scapharca broughtonii*) culture has been conducted in 1975 and the production has been rapidly increasing since then and become the next most important mollusks with annual harvesting of around 60 thousand tons. Short necked clam (*Tapes philippinarum*), cockles (*Anadara* spp.), mussel (*Mytilus edulis*) are also important for bottom culture. Hard clam (*Merectrix lusoria*) was one of the most important items for aquaculture during 1960's. However the production was sharply decreased due to devastation of culturing ground by over populated culture. Beside to this ever increasing farms and endless exploitations of natural resource eventually destroyed the habitat of hard clam. And thus, the clam culture was demolished in the early of 1970's. Up to know, two decades from the demolition, still unable to recover the 1960's production.

Abalones (*Haliotis* spp.) is one of the important gastropod species for aquaculture. Some hundreder of private and community farms scattered along the coast of Korea. However the nominal production was always far less than actual production due to direct dealings between culturists and consumers.

3). Culture of invertebrates

Prawns like *Peneus japonica* and *P. orientalis* are the major crustaceans with about 400 to 500 tons of harvesting. Sea squirts (*Halocythia roretzi* and *Styela clava*) culture is commonly cultured tunicate and the production is around 20 thousand tons recently. Sea urchins, cucumbers, mitten crab, and scallops are the newly developed species for aquaculture.

4). Culture of fin fish

Fresh water fish culture has some what old history, but it stayed primitive stage until the early of 1970's while the demand of a high quality fish increased and newly created dammed lakes available for aquaculture. Until 1980 the aquaculture productions of fresh water fish were less than five hundred tons. Thereafter it grew very rapidly, and reached up to ten thousand tons in 1988 and 20 thousand tons in 1991. It seems that the maximum capacity of fresh water fish culture is about 20 thousand tons per year. The most widely cultured species are common carp of local and Israel strain (12.6 thousand tons) and followed by eel(2.6 thousand tons), rainbow trout (2.5 thousand tons), catfish (1.5 thousand tons) and tilapia (0.5 thousand tons).

Aquaculture of marine fish has started rather slowly compare to fresh water fish and is being practiced by an increasing number of scientists. Merely few hundred tons of cultured fish were harvested in 1984. However owing to the development of seed production technics, the nominal deals reached to five thousand tons in 1994 (Table 6). Marine fish frequently be dealt directly between culturists and consumers. Unpublished census has appealed that the direct deal is three to four times greater than the nominal deal.

Table 6. Aquaculture vs fishing yield of marine fish in Korea, 1993

Unit : M/T, US$ million

	Aquaculture*		Fishing	
Species	amount	value	amount	value
Paralichthys olivaceus	4,029	65.0	2,454	24.5
Seriola quinqueradiata	153	1.6	2,740	10.3
Lateolabrax japonicus	205	2.5	1,523	22.8
Pagrus major	8	0.1	399	7.0
Sebastes schlegeli	679	10.3	1,340	13.9
Others	397	6.5	983,914	1,674.8
Total	5,471	86.0	992,370	1,753.3

* under estimated due to direct dealing

Bastard halibute (*Paralichthys olivaceus*) and rock fish (*Sebastes schlegeli*) cultures have grown very fast during the last five years and have become the most popular target organisms for mariculture. Refer to seed production and fish feed consumption the aquaculture production of these two species seemed to be over 30 thousand tons in recent years.

The most important problem in fish culture, as mentioned above, is severe winter temperature. Most of all the fish in Korean waters spawn in spring to early summer and few of them can attain the marketable size in a single growing season, therefore over wintering is very important. A noticeable recent advance of artificial spawning technics have solved the problem. That is, producing fish seed in late Fall and nursing them in land based farm with heating facility until late spring. With this technics, fish culture has achieved a rapid development.

Fish belong to Salmonidae has been added to mariculture since 1988. Smolts produced in freshwater farm can be cultured to marke size (2 kg) during the winter idle time of marine fish farm. Small yellow croaker (*Pseudosciana polyactis*), croaker (*Nibea imbricatus*), stergeon (*Ancipenser sinensis*), Sea bass (*Epinephelus septemfasciatus*), Spotted halibute (*Verasper variegatus*), and stone flounder (*Kareius bicoratus*) are expected to be cultured soon.

Beside to this, technics on the genetic engineering such as selective breeding, production of mono sex group and polyploidy and fish immunology will be applicable for commercial fish culture by 1998.

C. Marine ranching program

As one of the counter measure for the present problem Korea launched a Marine Ranching Project. The project, initiated by the Office of Fisheries Administration, is a 15-year long project from 1987 through 2001. Goals of the project are to meet the growing demand of fisheries products (5 billon tons by 2000), to maintain more than 6 % of an annual fisheries growth, and to increase the income of fishermen (Huh 1987).

The total budget of the project has been estimated to be about US$ 1200 millions, and approximately US$ 300 millions have been invested during the first 5 years (1987-1991). The project includes an improvement of production systems and facilities, protection of resources and fishing grounds, aquatic habitat enhancement through installation of artificial reefs, artificial propagation of seedlings, development of culture technics for conventional and new species, and integration of biological and engineering technologies to ensure the optimum production of the coastal waters (Huh 1987).

1). Artificial reef

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 the Marine Ranching Project.

Approximately 300 thousand hectares of coastal waters will be received artificial reefs by 2000. Of the total area planned, about 30 % are already installed with about 800 thousand pieces of artificial fish reefs (Fig. 1). About dozen different modules of concrete reefs are currently used in Korean waters. Among these dice, tube, turtle and jumbo blocks are the most commonly used model of the artificial reefs (Fig. 2). The triangle module is a newly developed model and the module has been placed along the coast of Cheju-Do in November 1991.

Case studies for the effectiveness of the artificial reefs (NFRDA 1989) on the fishing yields and artificial seaweed bed (Kim and Chang 1992) revealed positive results in terms of number of catch as well as CPUE. Fishing yields from the immediate vicinities of the reef were 2.7 times greater than those from the controlled areas with more than hundred species of fishes were found around the reefs and the growth rate of top shell on the reef recorded 54%/year, respectively.

2). Improvement of production systems and facilities

Several new hatcheries have been built or being under

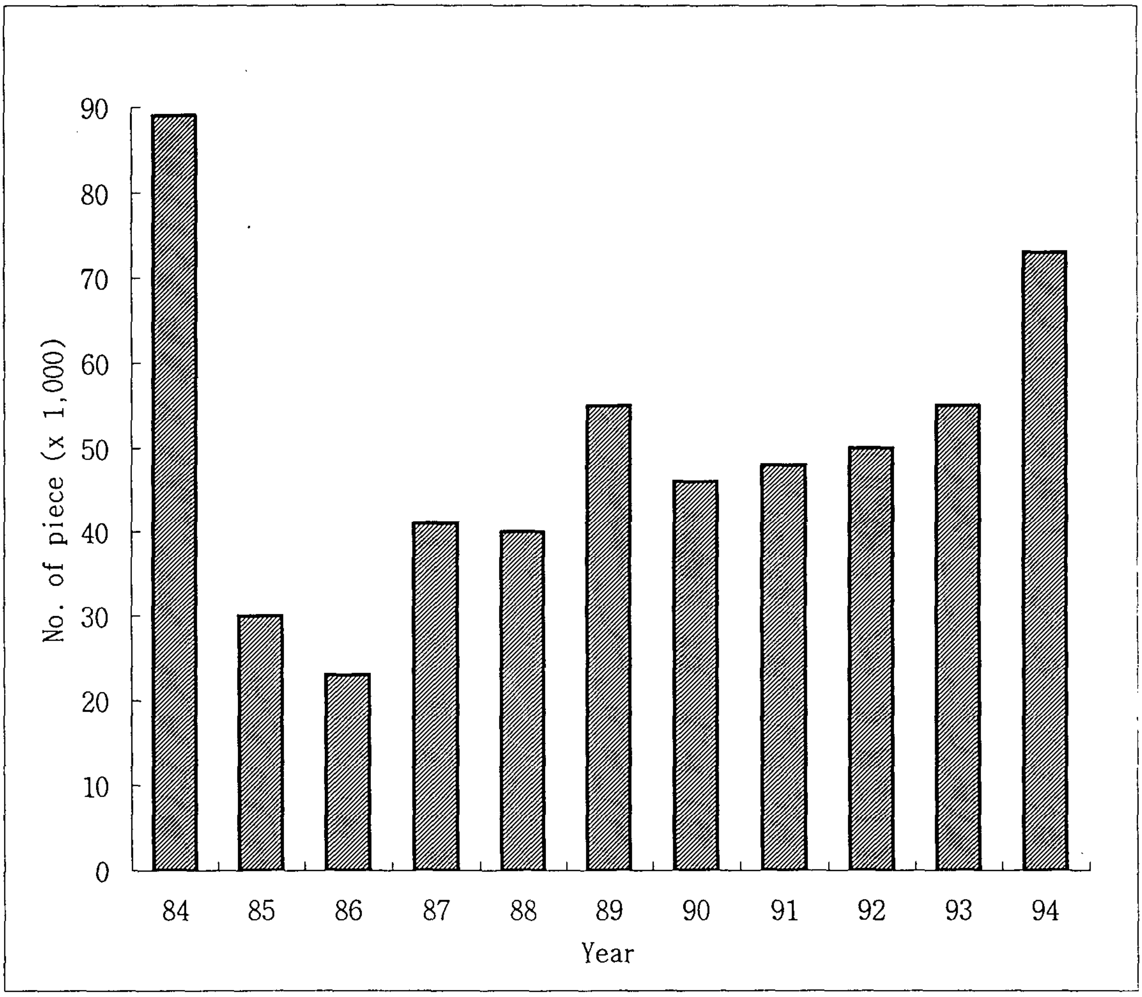


Fig. 1. Number of installed artificial reefs in Korea(1980 - 1995).

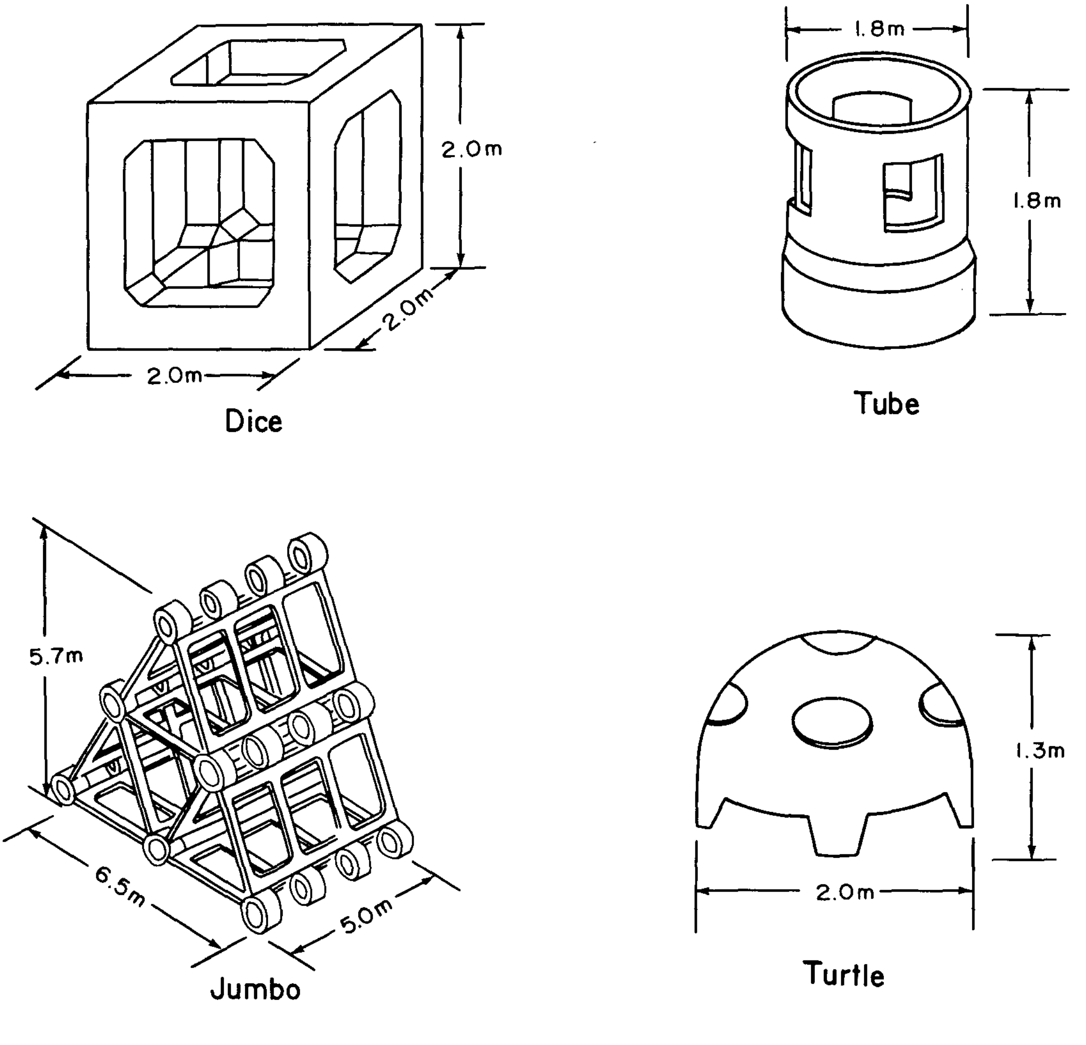


Fig. 2. Four typical artificial reefs used in Korea.

construction to speed up the production of fish seedlings. Ten governmental hatcheries are now in operation through which nearly 20 million seedlings of marine species were released in recent years (Table 7). The target fin fish were trouts, sea breams, black sea bream, bastard halibut and rock fish. As the tecnincs grows seed productions of sweetfish, mullet, puffer, and sea bass have been available from 1990.

High-valued invertebrates such as large shrimps, barley shrimp, blue crab, mitten crab, sea squirts, sea urchin, abalone, top shell, pearl oyster are being produced in captivity. and more species will be added as the program progresses. As the natural spat collection of oyster became harder and harder due to the world wide lean harvest the oyster, some government and private hatcheries extended their effort to oyster, and started to produce seed oysters in recent years. In 1995 the total production of seed oyster estimated to be around 350 millions.

3). Future prospect

Efforts to support the Marine Ranching Project have been paid by the government, research institutes and university staffs. However, the major activities of Marine Ranching Program during the last 5 years were installation of artificial reefs and construction of new hatcheries so far. Thus, more

Table 7. Seed production for aquaculture in Korea, 1995

Unit : 1000 ind.

Common name	Scientific name	Gov.*	Private#
Bastard halibut	*Paralichthys olivaceus*	720	6,000
Red sea bream	*Pagrus major*	400	500
Rock fish	*Sebastes schegeli*	205	70,000
Black mouth	*Oplegnathus fasciatus*	100	
Sweetfish	*Plecoglossus altivelis*	1,000	
others		334	1,000
Sum. of Fish		2,759	77,500
Abalone	*Haliotis japonicus*	1,715	3,000
Top shell	*Rapana thomasiana*	210	
Pearl oyster	*Pictada furcata*	4,000	
Oyster	*Crassoystrea gigas*	150,000	200,000
Others		260	2,000
Sum.of Mollusks		156,185	250,000
Barley shrimp	*Penaeus japonicus*	3,000	15,000
Large shrimp	*Penaeus orientalis*	25,450	225
Blue crab	*Portunus trituberculatus*	2,000	3,000
Mitten crab	*Eriocheir sinensis*	301	500
Others		790	
Sum. of Crustacean		30,751	18,725
Other Invertebrates		790	3,000
Total		190,485	349,225

* : Produced by governmental hatcheries

: The least estimation based on feed consumption,

elaborate reset up of the project appeared to be urgent.

The government of Korea, as the second phase of the project, is going to start a new Marine Ranching Project. It will be a multi- institutional project. Efforts of the project will be paid on the application of genetic engineering technics on aquaculture, development of species specific models for resources management, multi stratified use of coastal waters for aquaculture and simplification of national management tool of coastal waters. The first elaborated study of marine ranching conducted (KORDI 1995) recommended that the establishment of a steering committee whish able to design and conduct the program with an exclusive power and authority. The progress of the marine ranching project seems to be slow, however it is expected that the master plan of the marine ranching in Korea will be completed by 2000.

2. Japan

A. Present status of fisheries

From the 1960's to the 1970's, Japanese fisheries made a rapid extension 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 8). This meant that Japanese yielded approximately 13 % of the world total, making it the top rank in the world. As the distant water fishery has continuously declined due to the world wide proclamation of exclusive economic zones since 1976. The diminishing yields in the distant waters was partly compensated by increased landings in the offshore and coastal waters. Thus the coastal fisheries in Japan has became more important than ever before. However, the total yield have gradually declined to 8.1 million tons in 1993 (FAO 1993).

Table 8. Trend of Japan's fishery landings

Unit: Million tons

Year	Landings by fisheries sectors				B/A (%)
	Total (A)	Coastal water (B)	Aqua - 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
1991	9,301				
1993	8,128				

Source: Nagahata (1991), National Fisheries Administration (1992), FAO (1993)

B. 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 government project was initiated to encourage the construction of artificial reefs made of concrete blocks. The reefs were divided into two categories; artificial reefs for fin fish and benthic organisms. Three official categories of reef sizes were recognized under this project : small, medium and large types having about 400 m³, 2,500 m³ and 30,000 m³ in bulk volume per site, respectively. The large type reefs have been promoted since 1958 and the amount of artificial reefs installed off Japanese coastal waters have increased tremendously. By 1966, a total of 721,065 pieces of small reef modules(volume of 1 m³) were placed and 328,271 pieces of large reef modules (volume of 1.3 m³) were installed. Between 1962 and 1970 a sum of 920,000 m³ of small reef modules were installed at 3,427 localities while 1,320,000 m³ of large reef modules were installed at 429 localities.

With initiation of Ensei Program in 1973, the super size artificial reefs (appx. 150,000 m³ per 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.

As the high-valued fish are selectively harvested in Japan

Japan, fish catches around artificial reefs were estimated to be increased by 70 % and 160 % in terms of volume and value, respectively (Grove and Sonu 1991).

C. Case study

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

<u>Ensei Program</u>

The Ensei Program is Coastal Fishing Ground Enhancement & Development Program which 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 revised every 6 years. The current Ensei Program fall under the fourth step, covering a 6 year period between 1994 and 2000. The total amount of investment for the Ensei Program is estimated to be about 1,080 billion Yens (Table 9).

Table 9. Project types and investment of Ensei program in Japan

Unit: Billion Yen

Project type	1st Phase (1973-1981)	2nd Phase (1982-1987)	3rd Phase (1988-1993)	Total
Artificial reef	75	140	140	355
Construction of mariculture farm	100	190	200	490
Maintenance of fishing ground	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.

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 development 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 Combinant; 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 technology; Research and development efforts aiming to introduce leading technology in the fishing industry. (4) Marine Culture; Furtherance of marine-related cultural heritage and preservation of environmental quality of fishing grounds. The program has been started at 5 localities in 1990 and mapping of basic plans for a total of 55 marinivation zones were scheduled for completion during FY 1991.

3. United States

A. Artificial habitat enhancement

The first constructed artificial reef in the United America was a 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 for an interest on sport fishing. Today, however, the interest being moved toward commercial as well as sport fishing, fishery resources management, environmental mitigation, restoration, waste disposal 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) Artificial 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 risks on environmental and personal health, and (5) be consistent with generally accepted unreasonable obstruction to navigation.

About 600 artificial reefs of various size have been placed under permission of US Army Corps of Engineers by 1990. Florida is the most active state with 112 reefs and followed by North Carolina (66 reefs), California (39 reefs) and Washington (30 reefs). Including incidental and not permitted reefs, the number of 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, the number of fresh water reefs was 44,643. Approximately 70 % of the fresh water bodies containing reefs were lakes and reservoirs.

B. Case study

California Department of Fish and Game Artificial Reef Plan : Sport fishing is more important than commercial fishing in California. It provides US$ 4.2 billions a year to the State's economy and 60.4 thousand of full time jobs while commercial fishing contributing US$ 643 millions 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 permitted to avoid turing the ocean into a repository for trash (Wilson 1991). The experimental artificial reefs in California are listed as follows:

<u>Pendleton Artificial Reef</u>

built : in 1980 at depth of 13 m

cost : US$ 250,000

materials: 9,078 tons of quarry rocks

shape : arranged in eight 30 x 20 x 4.5m modules spacing 18 m apart

purpose : to investigate value of reefs for mitigating loss of kelp forest communities.

Pitas point Artificial Reef

built : in 1984 at depth of 8.5 m

cost : US$ 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.

Marina Del Rey Artificial Reef

built : in 1985 at depth of 20 m

cost : US$ 245,000

materials: 9,986 tons of quarry rocks

shape : arranged in two rectangular complexes of eight modules (15 m in diameter and 3 m high) each

purpose : to investigate the effect of spacing on the reef biota

Santa Monica Bay Artificial Reef

built : in 1987 at depth of 13 - 22 m

cost : US$ 360,000

materials: 18,156 tons of quarry rocks

shape : placed in 48 modules of 152.2 m i 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

Atlantic Artificial Reefs : an interstate management

The Atlantic State Marine Fisheries Commission and its member states have formed an Atlantic Interstate Artificial Reef Program to boost the development and assessment of a coastal wide 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 10). Together with North Carolina and Florida account for 65 % of the total permitted reef sites.

Among a total of 273 sites, 92 % is reefs and 6 % is mid-water fish aggregating devices. About 56 % of the reefs is located in federal waters and 24 % is placed in inland waters.

Table 10. Number of permitted artificial reef sites and types of reef sites along the US Atlantic coast*.

Sites	No. reefs	Types of Reefs			types of water		
		Benthic	Midwater	Mixed	Federal	state	inland
ME, NH, MA, RI, CT	2	2	0	0	0	2	0
NY, NJ, DE MD, VA, DC	55	51	2	2	20	10	25
FL, GA, SC NC	216	198	4	14	133	43	40
Total	273	251	6	16	153	55	65

* Reproduced based on McGurrin(1991). Inicials are name of states.

4. China

A. Present status of fisheries

Although China has over 32,000Km of continental and island coastal line and also has the most inland waters in the world, the development of fisheries industry was rather slow by the end of 1970's. With the reforming and opening of the nation in the early of 1980', the degree of development has been accelerated and has became the leading fisheries country in the world since the early of 1990′ in terms of production both for catch fisheries and aquaculture. China landed more than 21.4 million tons of fisheries products in 1994 (MAPRC 1994). Among them fresh water fisheries Marine catch fisheries accounted for 7.7 million tons and mariculture comprised 3.5 million tons (Fig. 3). The waters received the highest fishing intensity were East China sea (34.4%) and followed by South China Sea (29.2%), Yellow Sea (17.2%) and Bohai Sea (11.1%). The long distant fisheries have developed rather slowly and only 130 fishing boats engaged in 1990 (Deng and Yang 1992).

With increasing of fisheries landing, the amount of export also increased since 1980′s. In 1984, China exported about 100 thousand tons of aquatic products and the export increased more than 50 times within an decade and reached up to 548 thousand tons (Table 11).

Table 11. Export of fisheries products in China*

unit: 1000 M/T and US$ million

Year	1978	1981	1984	1987	1990	1991	1992	1993	1994
Amount	92	102	100	227	371	378	516	548	633
Value	260	340	270	720	1370	1180	1680	1650	3360

* : Recunstructed based on MAC(1949-1994).

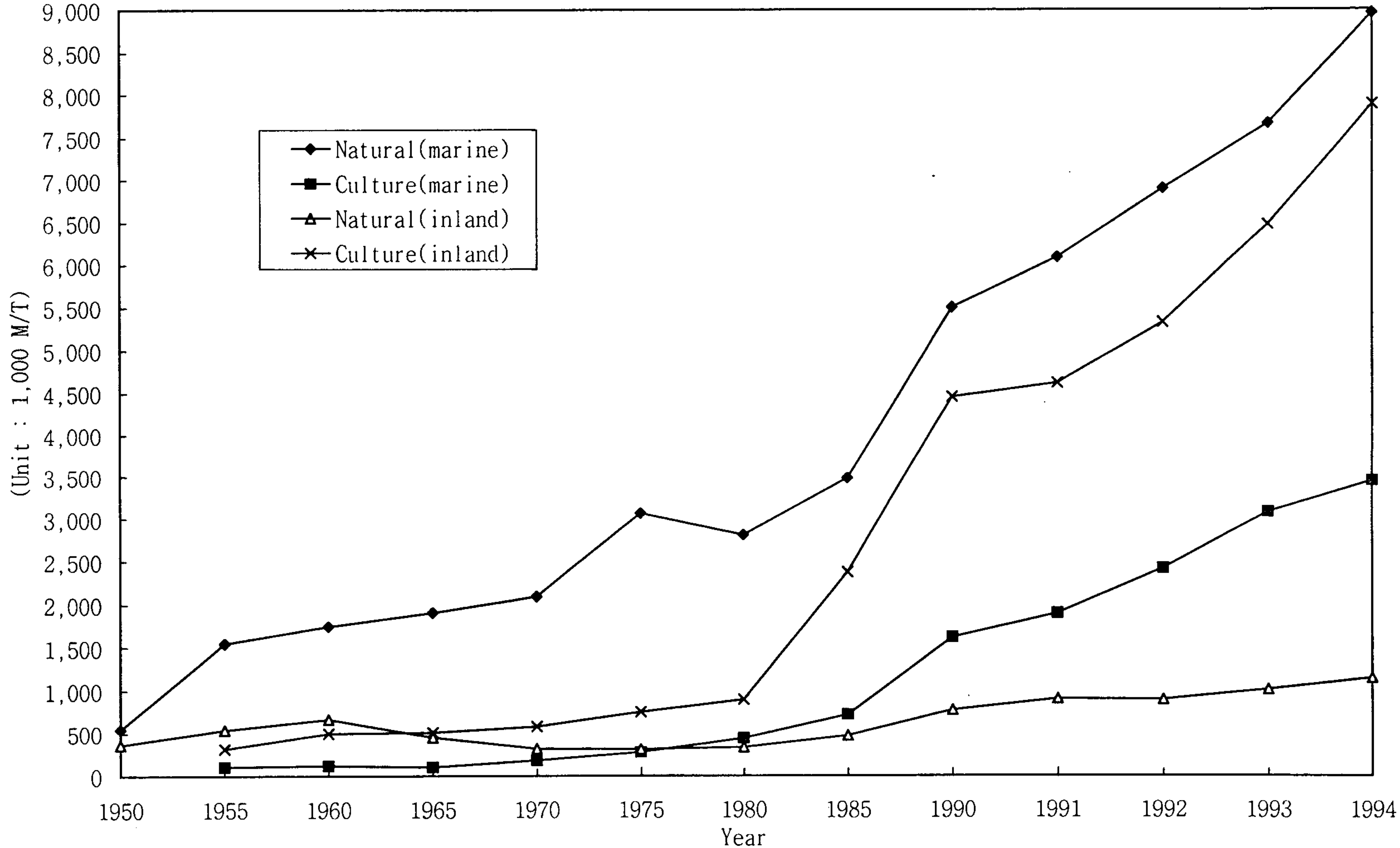


Fig. 3. Fisheries yield by sectors in China (1949 - 1994).

B. Aquaculture

History of Chinese aquaculture is quite long. It has born with civilization simultaneously, i. e. 2000 BC and the first treatise on fishculture was written in 475 BC (Fan 0000). As other Asian countries, inland artisanal fisheries and aquaculture have developed to meet the demand of animal protein. Despite of the long history of fresh water fish culture, Chinese mariculture had been stagnated by 1950's when the artificial breeding technics of kelp was developed. In the 1960's, technics for laver and oyster were developed. The seeding technics of mussel has been completed in the 1970's and prawn has been cultured in captivity since the early 1980's. However the total mariculture productions were less than 500 thousand tons until the early of 1980. With the adoption of open policy, Chinese mariculture developed rapidly and the production reached up to 3.5 million tons in 1994 (Table 12).

Different technics are used in different locations. Bottom seeding is applied for intertidal culture while raft and cage culture are adopted for shallow water culture. Moreover, mixed cultures such as prawn and scallop, shellfish and algae have been widely practiced recently. A total of 653.5 thousand hectare was exploited for mariculture in 1994. Of which, bay and shallow water cultures comprised 169.5 and 113.4 hectares, respectively.

Table 12. Production of mariculture in China

unit : M/T

Year	Fin Fish	Crustacean	Shellfish	Seaweed	Total
1983	10,192	9,564	28,281	242,495	290,532
1884	9,358	22,021	342,791	264,340	638,537
1985	13,653	42,665	386,190	269,786	712,294
1986	19,036	85,367	522,880	230,309	857,592
1987	29,464	156,004	711,137	204,010	1,100,615
1988	32,671	202,319	944,826	244,703	1,424,519
1989	34,609	190,223	1,055,327	293,680	1,573,839
1990	43,354	189,171	1,122,364	269,176	1,624,065
1991	47,182	225,560	1,234,976	396,629	1,904,347
1992	58,716	215,464	1,597,467	552,965	2,424,612
1993	71,672	104,438	2,221,468	681,483	3,079,061
1994	101,110	92,014	2,522,755	730,063	3,445,942

※ : Recunstructed based on MAC(1949-1994).

1). Seaweed culture

Records showed that Chinese, one of the seaweed favorite people, had imported kelp (*Laminaria* spp.) from Korea and Japan as early as 1,500 years ago (Wu 1993). Culture experiments were conducted in Dalian and Yantai during 1927 - 1945. Summer seedling technic developed in 1957 made the culture of kelp possible as south as Zhejian and Fujian. In the 1960's, studies on the ecological and morphological characteristics of thallus of kelp was carried out.

Laver has been harvested by Fujian coast fishermen since 300 years ago. In the early of 1950's the sexual reproduction cycle of *Phophyra* spp. was turned on the light by a Chinese scientist. Based on this study an artificial breeding and seedling techincs were developed in 1960's. The dry yield of laver reached 15 thousand tons in 1989 and 20 thousand tons in recent years. Beside to this, sea mustard, *Gelidium* spp., *Gravilaria* spp. and *Eucheuma* spp. are ready for commercial scale culture. Recent harvesting of cultured algae reached up to 730 thousand tons per year.

2). Fish culture

Probably the first mankind who kept the live fish (believed to be carp) for food and decoration. Chinese harvested 7.9 million tons of fresh water fish, believe or not, by aquaculture in 1994. At present, more or less 35 % of the total fisheries landing was recorded by inland fish culture. The major target species are common carp, grass carp, silver carp, tilapia etc..

In spite of the much success of fresh water fish culture, marine fish culture was not received a spot light before the last two decades. By the year of 1984, the yields of marine fish culture were no more than ten thousand tons and the culture activity was mainly restricted to Guangdong Province.

As the demand of marine fish increased quickly after adoption of the open policy, experiences learned from fresh water fish culture have been applied to marine fish culture, and then the yields of cultured marine fish were doubled every years. At present about 30 species of marine fish such as sea bass, bastard halibuts, mullet, red seab ream and puffer are cultured in commercial scale and the yield of marine fish culture was fairy over a hundred thousand tons in 1994. Sea horse, rock fish, *Epinephelus* sp. and *Sparus* sp. were widely spread in the southern part of China (Yang 1992, Chen 1990).

3). Invertebrates culture

The history of shrimp culture in China has started in the beginning of 18th century. However, the yields of cultured shrimp was less than 1300 tons by 1980. The large scale breeding technics developed during the 7th National Five-year Plans made the Chinese enable to breed some tens billion juvenile prawn and the shrimp culture industry developed dramatically. From the end of 1980's Chinese was able to produce several ten billions of prawn larvae. The prawn culture has formed a complete industry from breeding to processing. The major species are *Penaeus chinensis, P. monodon, P. japonica, P. penicillatus, P. merguiensis* and *Metapenae affinis.* A semi-intensive culture method are widely adopted. The harvest from shrimp culture reached its maximum value of 220 tons in

1991 and shrank dramatically afterwards owing to world wide shrimp disease.

Marine crabs such as *Scylla serrate* and *Portunus tribuberculatus* are culture in China in captivity, although the juvenile crabs are mainly collected in nautical waters.

Shellfish culture is not only traditional maricuture items as well as most important cultured items in terms of quantity. The seedlings, in past, were collected in natural sea beds. As artificial, partly semi-artificial breeding technics have developed, the productions have increased rapidly and the number of target species also diversified. The annual harvest of cultured shellfish was about 2.5 million tons accounting for 73 % of the total mariculture product in 1994 (Fig. 4). Bay scallop (*Argopecten inradians*) was introduced to China in 1982 and became one of the important mariculture items. In 1994, the seedling production ofscallops recorded to 65.4 billions and the harvest reached to 826 thousand tons (Fig. 4) and it was followed by mussel (415 thousand tons), oyster (313 thousand tons), razor clam (253 thousand tons) and other bivalves.

Beside to this, sea cucumber, sea urchin, horseshoe crab , lopster and polychaetous worms are received special attentions and could be the new aquaculture items soon.

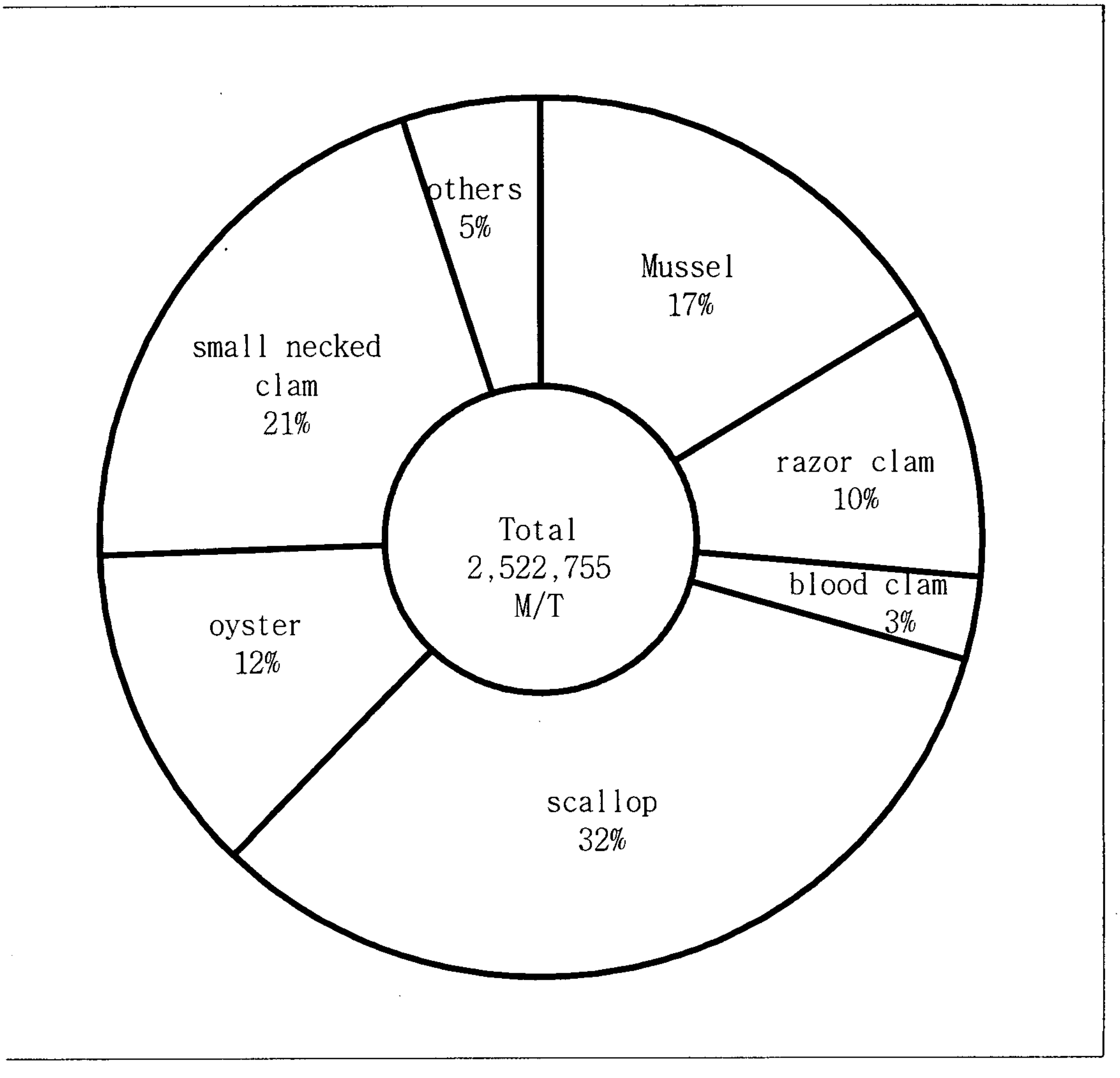


Fig. 4. Production of shellfish by aquaculture in China (1994).

C. Marine ranching program

Marine ranching have been developed to some scale in China which is relatively later than other countries. The concept of marine ranching is "to establish a steady and high efficient ecosystem, by using the natural conditions, promising reproduction of the high-value species and controlling the low-value species (Deng, 1988)". Eleven provinces and municipalities along the coast of China have practiced marine ranching. Construction of artificial reefs and seaweed beds, resources addition through releasement of artificial seedlings are commonly used methods.

1). Artificial reef

It was in 1979 that the first installation of artificial reef in Chinese water. By the year of 1990, 24 artificial reef centers with the total of 28,700 modules were installed along the shore waters of Jiansu, Liaoning, Zhejian, Guangdong and Guangxi Porvince. The total volume of the reef centers are 120,000m^3. A case study in Liaoning Province "1646 marine ranching program" where installed 651 modules of artificial reefs with the total volume of 11,410m^3 showed that sea cucumber and fish productions increased about four and two times, respectively, than before the reef installation (LOC 1996). The Liaoning "1646 Marine Ranching Program" involves construction nine hatcheries and production of 2 billios of fish seedlings per year. Yang (1993) have reported that the artificial fish reef have been used to attract fish and shrimp and have given out good result.

2). Artificial resources addition

Efforts on the marine ranching in China seemed to be more or less concentrated on the resources enhancement by releasing of seedlings (Lin 1987: Fan, Yu and Dai 1989: Ni and Zhang 1994). Releasement of prawn larvae was received a special attention. By the year of 1990, a sum of 20 billion prawn larvae were released (Table 13) and recatch was roughly estimated to 32 thousand tons.

Table 13. Release of prawn larvae for resources enhancement in China

Unit : million larvae

Year	By 1985	1986	1987	1988	1989	1990
No. of larvae	55.7	274.1	125.6	484.8	601.5	475.3

Source : Recunstructed from Tseng, Zhou and Li (1993).

Artificial resources addition of sea cucumber, sea urchin, scallop, abalone and crab were also practiced in north China, especially in Liaoning and Shandong provinces. In Dalian, Liaoning Province released 17 millions of sea cucumber seedlings and 5 millions of abalone seedlings from 1984 to 1989. Which in turn increased the production of sea cucumber and abalone from 30 tons to 69 tons (60% of Chinese total) and from 15.6 tons to 114 tons (88% of Chinese total), respectively.

Artificial propagation of fresh water fish also important in China since more than 40% of the total fisheries product was comprised by inland fishing which was mainly consisted by fish. The total production of fresh water fish seedling was about 250 billions and 92% of them was artificial (Table 14).

Table 14. Release of fresh water fish seedling in China

Unit : billion inds.

Year	1989	1990	1991	1992	1993	1994
No. of seedling	145.3	145.3	141.8	155.8	207.8	228.3

Source : Recunstructed from Tseng, Zhou and Li (1993).

5. Australia

Archaeological evidence showed that Australian aboriginals used artificial reefs to grow marine organisms from about

2,000 B. C. However use of modern technics on artificial reef constructions have started since early of 1960s. Australian defined the artificial reef as human made objects that provides a reef habitat which did not previously exist.

The first artificial reef which was made by 400 tones of concrete pipes was laid by the Victorian Department of Fisheries and Wildlife over an area of four hectares in 1965. Seventy two trials of artificial reef constructions have done since early of 1960s, however most of the trials in 1960s were unsuccessful because of hard oceanographic conditions (bottom conditions, storms and bottom currents) and using of rustable materials for the reefs. The major materials for artificial reefs used in Australia are cheap and easily obtainable materials, mainly tires and followed by obsolete vessels. Fabricated concretes and quarry rocks are also used in some areas. They are clustered around large population centers, mainly state capitals or popular tourist destinations.

Most of the reefs are situated in depth of between 3 and 25 meters, except obsolete vessels those which were sunken down below 25 meters. Among 72 artificial reefs in Australia, South Australia (23 reefs) and New South Wales (16 reefs) have the largest numbers of artificial reefs. Nothern Terriory has started a project on the artificial propagation of trochus (*Trochus niloticus*, Gastropoda).

6. Artificial reefs in the Other regions

With greater awareness of the importance of 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). The next popular material is a tire modules which are 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 artificial reefs and have reported that 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 catches have been reported in Israel (1,000 - 2,000 %), Russia (1,000 %) and Ivory Coast (4,000 %).

Chapter III. Succession of Benthic Organisms on the Artificial Reef

1. Introduction

Artificial reef is a world wide tools which employed for the artificial enhancement of marine habitat in order to conserve fisheries resources as well as fisheries itself. Among more than 40 countries which practicing the artificial reef (Grove and Sonu 1991), Korea is belong to one of the top three in terms of the number of nodules which have been installed in recent years. Up to present, about 700 thousand nodules of specially designed reefs were implanted by 1996.

Surface of a just installed artificial reef is a new substratum for benthic organisms and the biological process on the substratum could differ to the natural succession. Not only shapes and materials of the reef but also time and position of installation affects the succession of a benthic community on it. Furthermore, fish aggregation effect of an artificial reef is directly or indirectly relates to the degree of the succession. However the biological process on the reef surface have received a little attentions in Korea (Song 1985, Yi 1987, Kim and Chang 1992).

Experimental approach using artificial substrata is now a classical methods in the study of benthic fouling communities (Wilson 1925, WHOI 1952, Haderlie 1970, Goren 1979, Southerland 1981, Kennelly 1983, Nandakumar and Tanaka 1993) because it allows a direct observation in stead of a blind observation (Hedgpeth 1978).

The aim of the present work was to understand the development of benthic community on the artificial the artificial reefs so as to provide a guideline for the reef construction.

2. Material and methods

The study area is located at the southeastern part of Cheju-do where an edge of the Kuroshio affects the water characteristics (Fig. 5). The annual temperature variation was about 12 ℃ and the monthly averages ranged between 13.9 ℃ and 25.1 ℃. The water mass over the study area seemed to be under the oligotrophic condition. Medium sand was the main component of the bottom sediment.

The experimental substrata used in this study were concrete blocks (30 x 30 cm, same as the artificial reef). Each of twenty six experimental substrata were attached

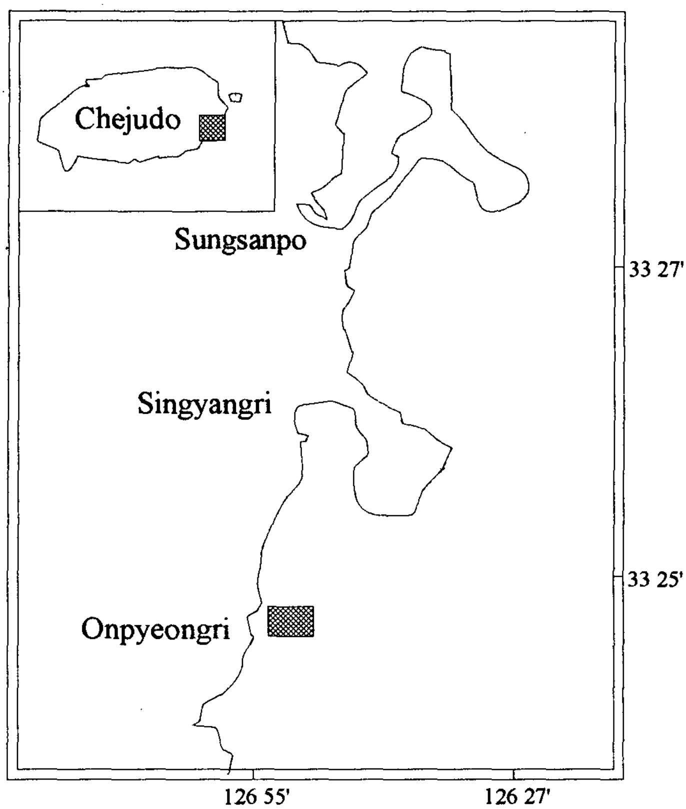


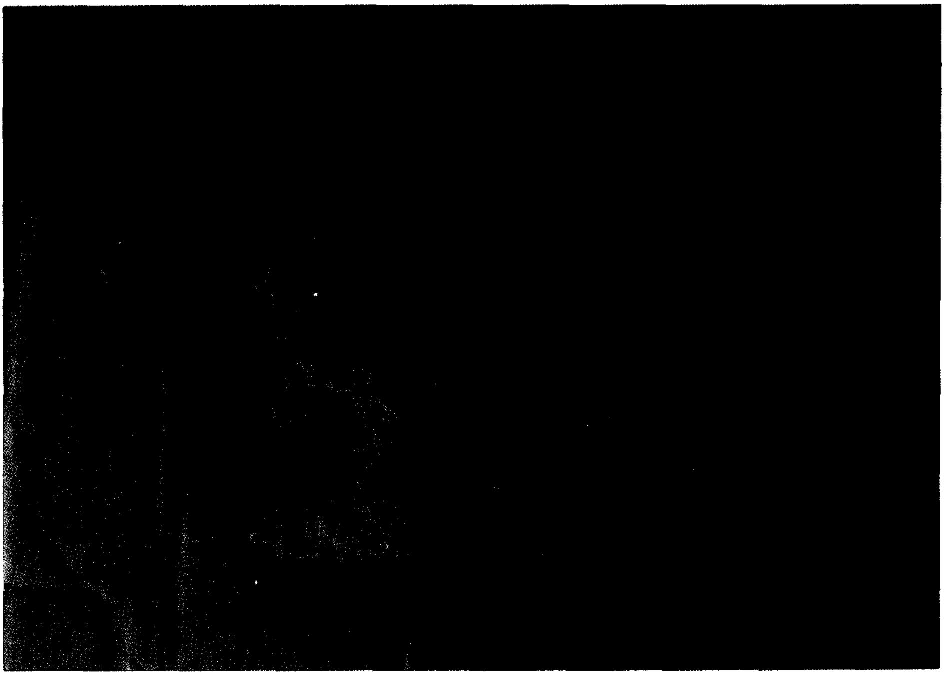
Fig. 5. Map showing the study area, Sungsan-po, Cheju-do.

vertically and horizontally on the surface of triangler artificial reefs using coated wire, respectively (Fig. 6). Then the reefs were placed as a complex body in November, 1991. The water depth of the reef complex site ranged 15 to 20 m. So far as the weather permit, it was able to observe by snorkeling.

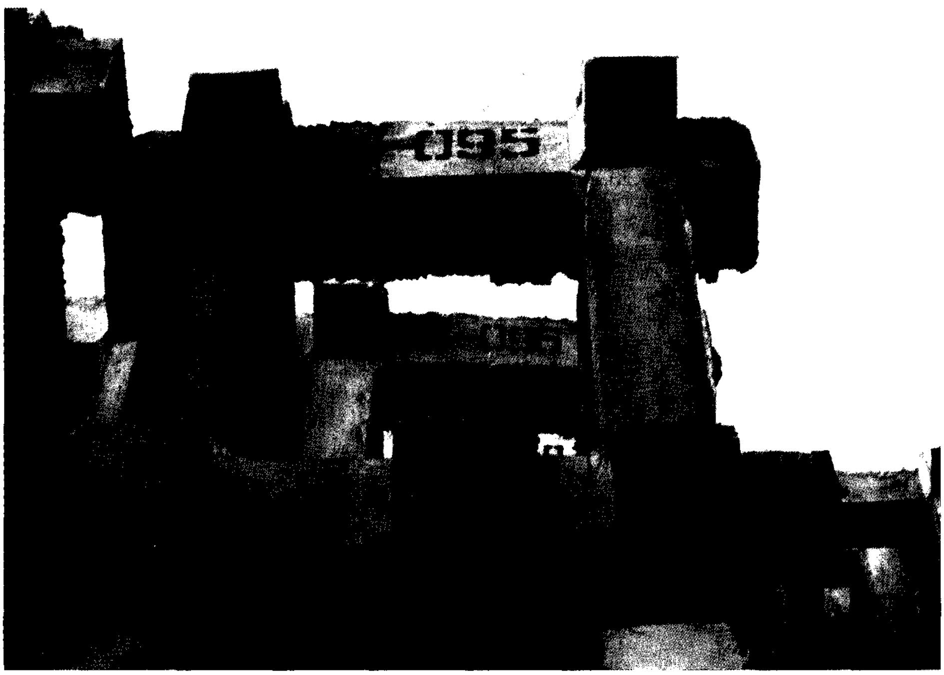
From three months after installation, two substrata from the each poison group were collected by Feb., 1994. To prevent the loss of organisms during recovery, each substratum was put into a plastic bag by
scuba divers before surfaced. The whole substrata were immediately fixed by 10 % neutral formalin. In laboratory, the epiphytes and mobile zoobenthos on the substrata were separated, identified and the total wet weight of each species measured to the nearest 0.01 g. In case of algae the total area of each blades and holdfasts were determined to the o.1 mm^2. Then the substrata were covered with transparent section papers and the distribution patterns of sessile organisms on the substrata were drawn to figure out the coverage of the each species. After drawing the sessil organisms were collected by shaving the surface of substrata and the total wet weight of each species measured to the nearest 0.01 g.

3. Result and discussion

A total of 98 species including 34 species of benthic



A. An experimental substratum(30x30cm) made of concrete.



B. Horizontal and vertical position of artificial substrata.

Fig. 6. Experimental substrata attached to an artificial reef and ready for installation.

algae, 45 species of sessile zoobentos and 19 species of mobile zoobenthos were identified.

A. Benthic algae

A total of 34 species of algae wes identified during the study. Among them, Rhodophyta which comprised 19 species was the most abundant group and followed by Phaephyta with 8 species and Chlorophyta with 6 species (Table 15).

Although the recruitment of new species as well as young individuals of algae on a substratum differs to another, the algal community encountered in the present study comprised most of the species inhabited in the vicinity of the study area. The development of the community on the experimental substrata was relatively slow. Three month old experimental substrata carried only five species of algae, then the species number increased to 13 species during another three months. The maximum species number of 20 was observed 15 months after installation.

The most dominant algal species in terms of seasonal occurrence, biomass and area of fronds was *Ecklonia cava*, Phaephyta. At the early stage of succession it seemed to be an opportunistic species, then quickly over whelmed any other species and had become the canopy species (Dayton 1975) six months after installation of the substrata. The maximum biomass

Table 15. Occurrence of algae on the experimental substrata attached to an artificial reef complex at Sungsanpo, Cheju-Do (1992. 2 - 1994. 2)

	92-2		92-5		92-8		92-11		93-2		93-5		93-8		93-11		94-2	
	h	v	h	v	h	v	h	v	h	v	h	v	h	v	h	v	h	v
Chlorophyta																		
Bryopsis sp.																		-
Cladopora sp.	-		-			-									-	-		
Codium contractum			-					-		-					-	-	-	-
Derbesia marina			-	-	-													
Ulva japonica	-		-	-	-		-	-	-				-	-	-		-	-
Ulva pertusa																		-
Phaeophyta																		
Colpomenia sinuosa	-	-	-	-	-		-		-	-								
Dictyota dichotoma								-							-	-		-
Dictyopteris latiuscula											-		-		-		-	
Ecklonia cava	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-
Hecatonema sp.															-		-	-
Padina crassa					-			-	-	-								
Pandia arborescens	-																	
Sphacelaria variabilis							-											
Zonaria sp.													-	-	-	-		
Rhodophyta																		
Acrosorium sp.							-								-	-		-
Amphiora crassisima										-								
Amphiroa dilatata					-		-	-	-	-			-	-	-			-
Callophyllis japonica												-			-	-	-	
Ceramium fastigiramosum							-	-	-									
Clathromorphum sp.			-	-	-			-	-	-								
Corallina pilulifera			-	-	-			-	-	-	-		-		-		-	-
Erythrotrichia carnea							-								-			
Gelidium amnensii			-	-			-	-		-								-
Jania sp.			-	-											-	-		-
Laurencia pinnata			-															
Lithothamnion cystocarpiodeum								-		-	-	-					-	-
Lomentaria catenata			-	-														
Marginisporum crassissima								-						-	-	-	-	-
Peyssonnelia caulifera							-	-			-		-		-		-	-
Plocamium telfairiae			-	-				-			-		-		-		-	-
Prionitis sp.									-	-								
Symphyocladia marchantioides							-	-										-
S. pennata							-											
No. of species	5		13		9		20		13		7		9		17		18	

and frond areas of the species on the horizontal substrata were observed to be 10.5 kg wt./m^2 and 13.3 m^2/m^2 in Feb., 1993 (15 months after installation). And the average weight and frond area of an individual *E. cava* were 22.9 g and 296 cm^2, respectively. Even though *E. cava* lost most part of the frond during summer, no one species able to compete to this species in terms of biomass (Fig. 7). Kim and Chang (1992) have found about 20 species of algae with a maximum biomass of 6.2 kg/m^2 during a three year last study of an artificial seaweed bed at same place to this study. They also have reported that *Sargassum horneri* could be the second dominant and overcame *E. cava* in terms of biomass during the last quarter of the study. But the study accompanied an artificial seedling and far from the natural succession.

About one thirds of *E. cava* survived, however the average biomass was less than 30 % of the maximum stage. Refer to the first recruitment of the species was observed two years after installation of the substrate, adult *E. cava* play a role in preventing the growth of other algae in any way. As the first settled group of *E. cava* diminished in November, 1993, *Peyssonnelia caulifera* quick out broke and became the second dominant species in terms of biomass, however it was replaced by the newly settled *E. cava*. It meant that the growth of the species affected the species richness. The higher species number, both in the horizontal and vertical substrata, were

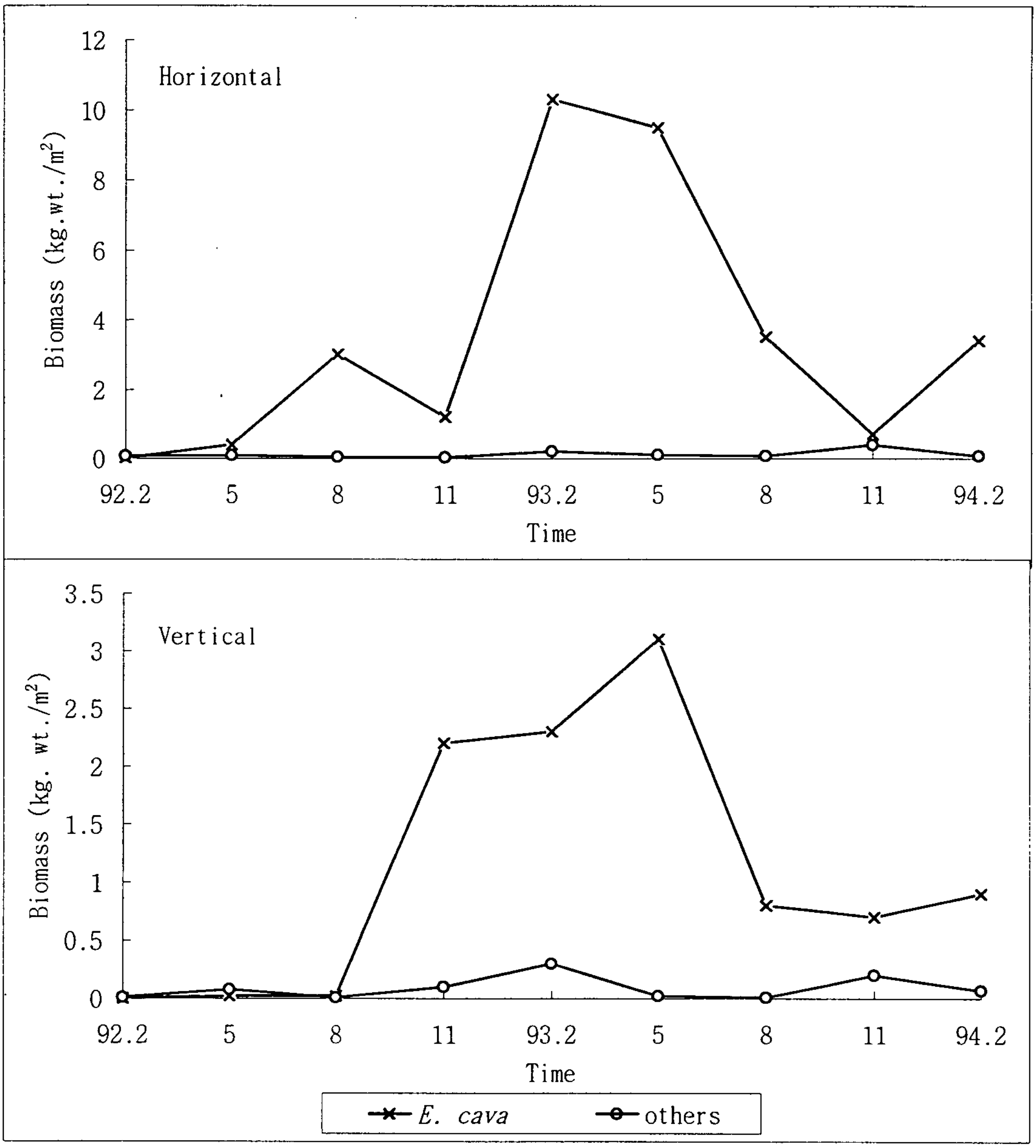


Fig. 7. Biomass of *E. cava* and remaining algal species on the experimental substrata attached to an artificial reef complex at Sungsanpo, Cheju-Do(1992. 2 - 1994. 2).

observed with the lower biomass of the *E. cava*, simultaneously. The relatively lower biomass of *E. cava* observed in November of 1992 and 1993 were seemed to be caused by the summer death of the species. Sine *E. cava* was erectile fauna, the upper part of the vertical substrata were available for the species. Thus, the lower part of the vertical substrata was available for other algae and showed a more dynamic species composition compare to the horizontal substrata.

Species such as *Ulva japonica, Codium japonica, Corallina pilulifera, Amphiora dilatata, Gelidium ammensii* and *Plocamium telfairia* seemed be the year round species. *Colpomenia sinuosa, Derbesia marina, Padia crassa, Clathromorphum* sp. and *Lomentaria catenata* had occurred during the first half of the study. On the other hand, *Dictyota dichotoma, Dictyopteris latiuscula, Zonaria sp., Lithothammnion cystocarpiodeum* and *Marginisporum crassissima* had occurred during the second half of the study. However it is not necessarily meant that the former group was replaced by the latter.

Generally speaking, the number of species on the horizontal substrata were more than that of the vertical substrata. However the vertical substrata carried more species than the horizontal during the winter. On the vertical substrata interspecific competition for light was more severe than the horizontal and *E. cava* settled on the top margin of the substrata can survive. It meant, more space were available to less dominant species. However Kim and Chang (1992) have reported that the turtle type reef more attractive than the plained type reef in terms of biomass of algae on the reefs when the artificial seedlings applied.

The number of young *E. cava* on the vertical and horizontal substrata during the early period of the study (by Aug., 1993) were almost same but thereafter the individual number and the average individual biomass of the species on the vertical substrata were decreased and became about one thirds of the horizontal substrata. Species used this chance were *Bryopsis* sp., *Codium* sp., *U. pertusa, D. dichotoma, Amphiora crassisima* and *Symphyocladia marchantiodes*.

Dayton (1975) identified intertidal algae into three categories. The canopy species, the obligatory understory species and the fugitive species. The present study did not include a removal experiment of any species, thus unable to identify the obligatory understory species. However refer to a higher number of algal species observed coincide to the lower biomass of *E. cava* (Nov., 1992 and 1993) supported that the species belongs to the canopy species.

On the other hand, Vandermeulen and DeWreede (1986) found that the removal of dominant overstory species had no effect upon the seasonal abundance of *Colpomenia peregrina* and defined the species as an opportunistic species in the sense of Littler and Littler (1980) or possibly a fugitive species in the sense of Dayton (1975). *Colpomenia sinuosa* and *Padina crassa* observed in the present study had a similar ecology to *C. peregrina,* however they occurred only the first half of the study with a noticeable biomass.

The occurrence of the erect Corallinaceae such as *Amphiora dilatata* and *Corallina pilulifera* were seemed to relate to the abundance of *E. cava,* while the epiphytic Corallinaceae such as *Clathromorphum* sp. and *Lithothamnion cystocarpiodeum* were suffered by challenged zoobenthos for space. The maximum coverage of *Clathromorphum* sp. and *Lithothamnion cystocarpiodeum* an artificial substratum reached up to 21.8 % and 5.2 %, respectively. however they diminished as the propagation of bryozoans and barnacle.

B. zoobenthos

A total of 64 species were encountered during the study (Table 16). Among them, 46 were sessile or least mobile while the remainders were mobile.

Three months after installation, the surface of the

Table 16. Occurrence of zoobenthos on the experimental substrate attached to an artificial reef complex at Sungsanpo, Cheju-Do (1992. 2 - 1994. 2)

	92- 2		92- 5		92- 8		92-11		93- 2		93- 5		93- 8		93-11		94- 2	
	h	v	h	v	h	v	h	v	h	v	h	v	h	v	h	v	h	v
Porifera																		
Haliclona permollis						-	-	-	-	-	-		-	-	-	-	-	
Halichondria japonica									-	-	-		-	-				
Halichondria sp.																		
Sycon ? sp.			-															
Porifera unid.															-		-	-
Hydrozoa																		
Dynamena crisioides							-	-	-	-			-	-				
Sertularella giganta							-	-						-				
Sertularia sp.									-				-					
Anthozoa																		
Anthopleura sp.											-		-	-	-	-		-
Anthozoa unid.											-	-						
Bryozoa																		
Amastigia rudis														-	-			
Bowerbankia impricatus								-	-	-								
Celleporina sp.							-	-					-	-	-	-	-	
Crisia sp.											-	-	-	-	-	-	-	-
Escharoides sauroglossa													-	-		-		
Likenopora radiata	-	-	-	-	-	-	-	-		-								
Scrupocellaria sp.					-	-	-	-								-		
Watersipora platypora	-	-	-	-	-	-	-	-			-	-	-	-	-	-	-	-
Bryozoa unid. 1													-	-	-	-	-	
Polychaeta																		
Amphitrite cirrta											-	-						
Chone teres							-	-			-	-						
Dexiospira spirillum	-		-	-	-	-												
Eunice tibiana	-				-		-			-			-	-			-	
Hydroides ezoensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Neanthes sp.							-											
Nepthys ciliata			-				-	-									-	
Perineris brevicirris	-	-																
Periserrula leucophryna																	-	-
Platyneris bicanaliculata																	-	-
Spirobis sp.																-		

Table 16. continued.

	92- 2		92- 5		92- 8		92-11		93- 2		93- 5		93- 8		93-11		94- 2	
	h	v	h	v	h	v	h	v	h	v	h	v	h	v	h	v	h	v
Polyplacopoda																		
Achantochitonna delilippi																		-
Ischnochiton sp.	-		-															
Lepidozona coreanea																		-
Liolophura sp.										-	-	-						
Placiphorella japonica							-											
Gastropoda																		
Discodoris sp.																	-	-
Haliotis discus											-							
Notoacemea schrenkii			-				-	-			-	-						-
Notria shirikishinaiensis													-	-				-
Pleurobranchaea sp.							-	-										
Serpulorbis imbricatus																		-
Gastropoda 1															-			
Bivalves																		
Anomia chienesis							-	-	-		-	-						
Chama fragum													-	-				-
Chlamis farrei farrei													-		-		-	
Claudiconcha japonica													-	-				
Glycydonta marina													-	-				
Mitylus edulis									-									
Musculus senhousia							-	-	-	-			-				-	-
Ostrea denselamellosa							-	-										
Porterius dalli									-									
Crustacea																		
Balanus trigonus						-	-	-	-	-	-	-	-	-	-	-	-	-
Caprella califoniansis			-	-														
Cirolana sp.											-	-						
Erictonius brasiliensis	-	-		-														
Ibacus ciliatus																	-	
Leptodius extratus											-	-					-	-
Paradexamine sp.							-	-										
Solenocera sp.							-	-										
Others																		
Amaroucium pliciterum																-		
Halocynthia sp.	-								-									
Molgula sp.		-														-		
Tunicate 1																		
Hermicentrotus pulcherrimus											-						-	

experimental substrata were almost bare with four to seven species of sessile zoobenthos. Even by nine months after installation the total number of zoobenthos on a substratum was only eight to ten species (Fig. 8). Then the species number, especially for sessile form, increased rapidly up to 21 and became more or less stable. Refer to a slower development of zoobenthos community compare to other studies (Song 1985, Yi 1987), a relatively long lag phase seemed to exist. It was not clear that the lag phase was caused by seasonal variation of the recruitment or the harmful effects of the substrata made of concrete.

There were only two species, *Hydroides ezoensis* (Polychaeta) and *Watersipora platypora* (Bryozoa, except in Feb. 1993) had occurred from the beginning to the end of the study. A bryozoan, *Likenopora radiata* and a polychaete, *Dexiospira spirillum* had settled at the beginning of the experiment, however had failed to survive more than a year as *Balanus trigonus* (barnacle), *Haliclona permollis* (sponge), *Anthopleura* sp. (sea anemone) and other bryozoas such as *Celleporina* sp., and *Crisia* sp. had propagated on the substrata. Thereafter the latter group had governed the other species in terms of biomass and coverage. Bivalves such as *Amomia chinensis, Musculus senhousia, Cama fragum* and *Chlamis farrei farrei* had occurred from the mid-stage, however they were seemed to be an occasional presenters.

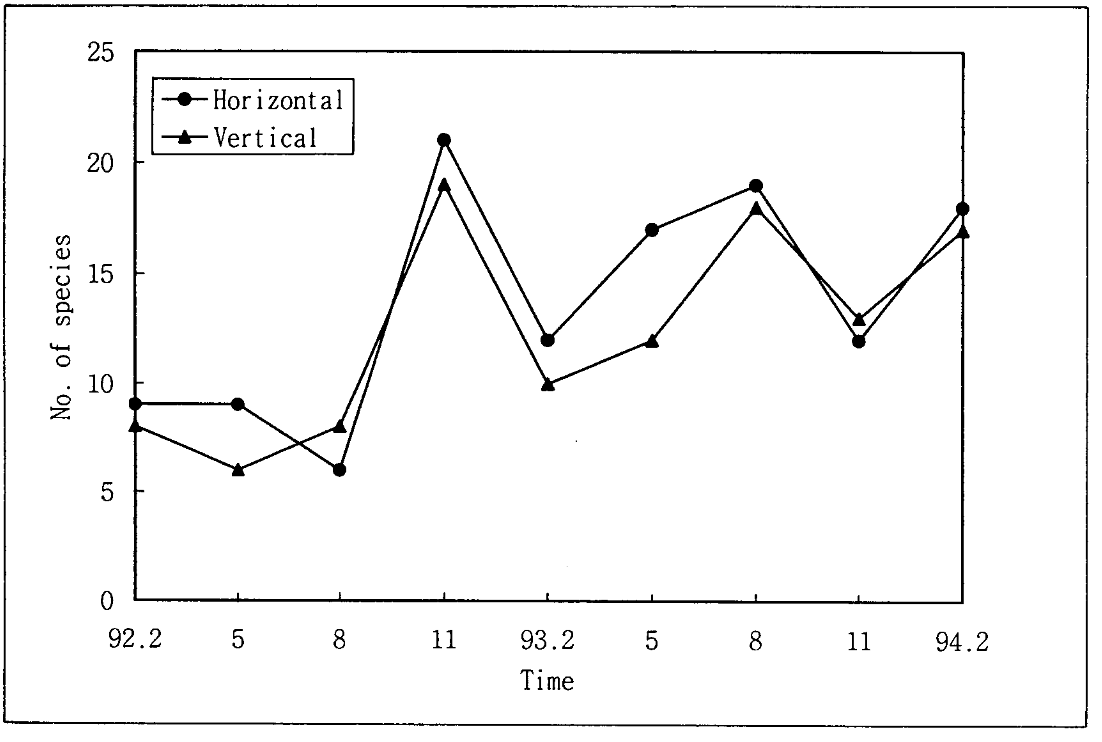


Fig. 8. Number of species of zoobenthos on the experimental substrata attached to an artificial reef complex at Sungsanpo, Cheju-Do(1992. 2 - 1994. 2).

Development of the zoobenthic commuinity on the experimental substrata seemed to be classified into three stages: initial stage, build up stage and regulatory stage. The initial stage was characterized by large individual number of smaller species such as *H. ezoensis, Dexiospira* sp. and *L. radiata*. This stage lasted for a six month (Fig. 9, 10). The built stage was identified by a rapid increase of the biomass and coverage. The build up stage can be further subdivided into two substages. The first substage was characterized by a rapid fill up of empty space by bryozoans, Poriferans and barnacle. However no severe interspecific competition for space occurred. This stage lasted to another six months. During the first substage the biomass and coverage on the horizontal substrata increased to about 200 g/m^2 and 20 %, respectively. The second substage started with the propagation of poriferans and the growth of barnacle. Bryozoan biomass and coverage decreased due to suffocation by rapid growing poriferans and bulldozing by larger barnacle. During the second substage, the biomass increment was more or less stagnated while the coverage increased continuously. On the other hand, the build up stage on the vertical substrata started a little bit later than the horizontal substrata, however the build up speed was faster and the biomass reached to about 350 g/m^2 with a year after installation. There was no clear interjunction of substages on the vertical substrata. It seemed that this unclearness of the substage was caused by poorer vegetation of *E. cava* and

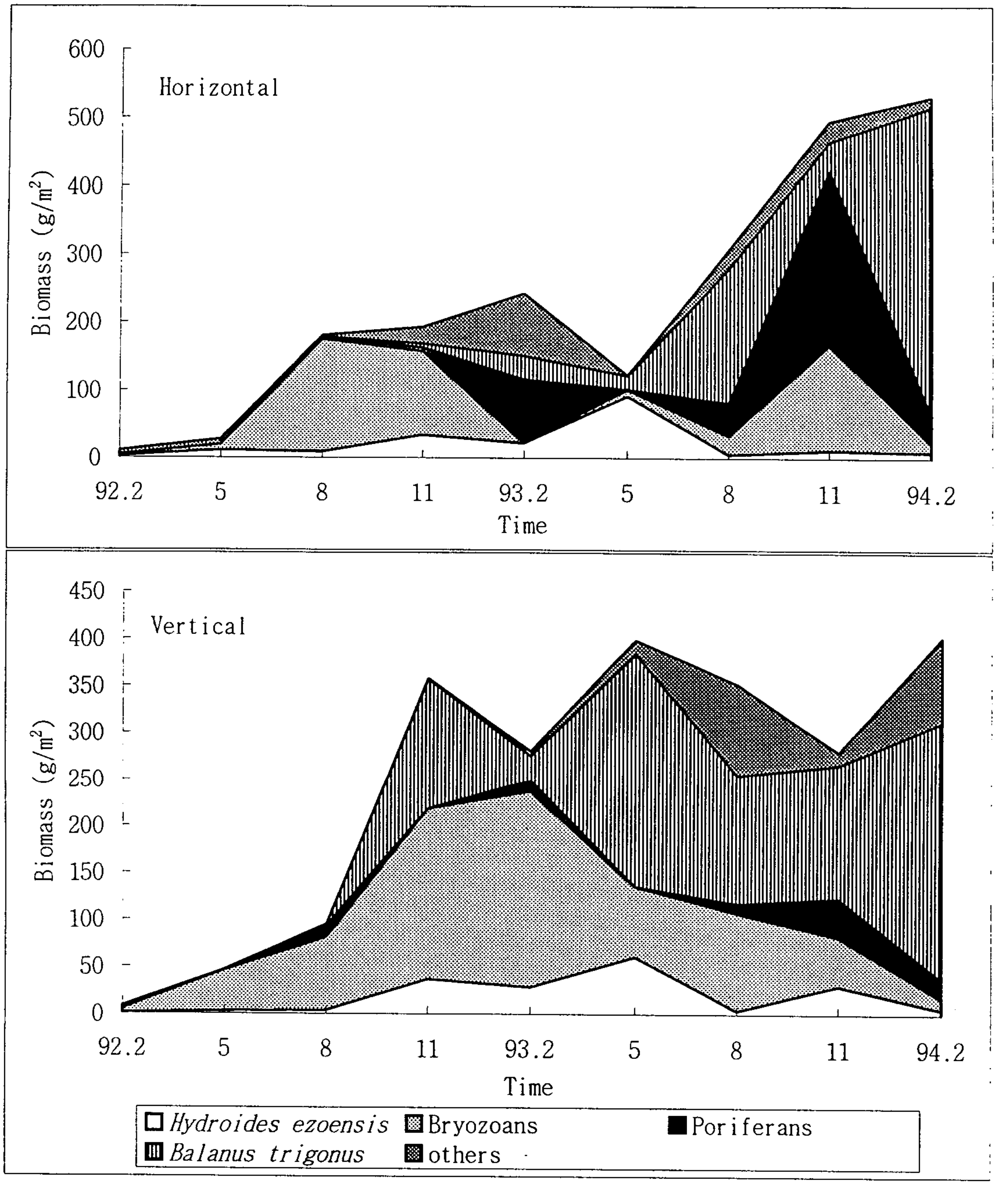


Fig. 9. Biomass of zoobenthos on the the experimental substrata attached to an artificial reef complex at Sungsanpo, Cheju- Do (1992. 2 - 1994. 2).

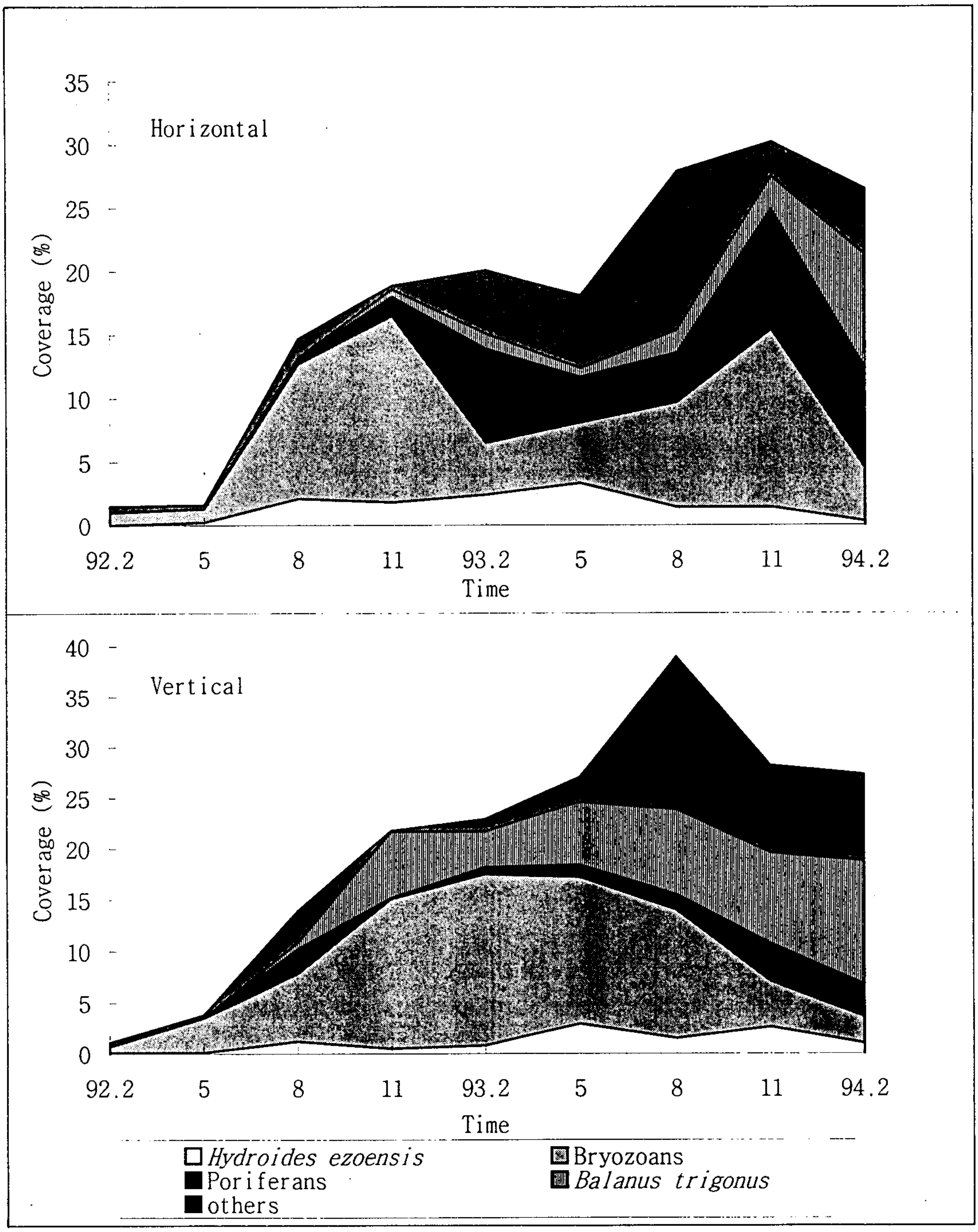
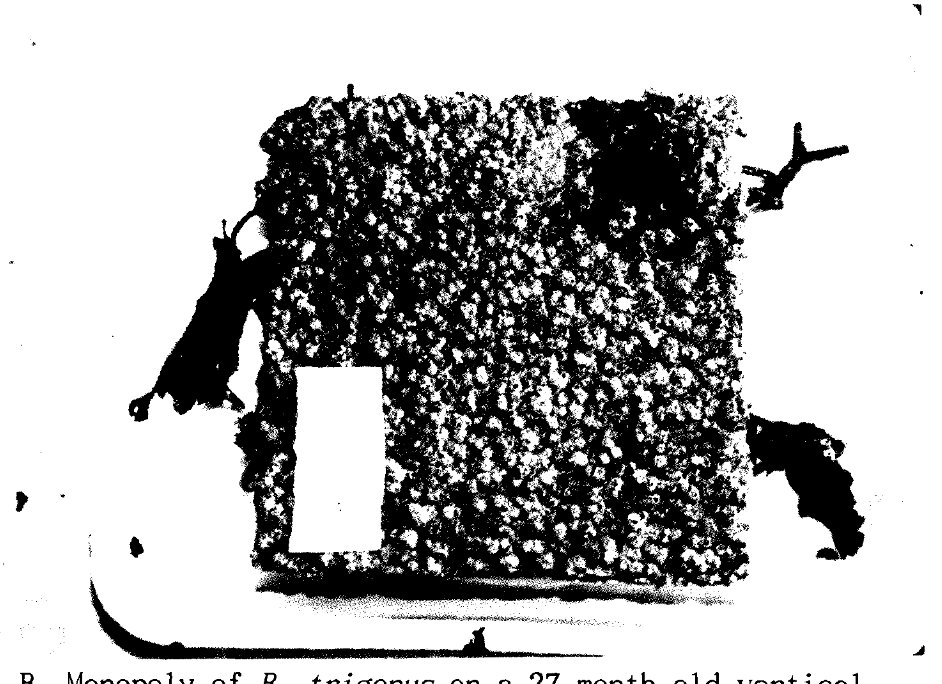


Fig. 10. Percent coverage of zoobenthos on the the experimental substrata attached to an artificial reef complex in Sungsanpo, Cheju-Do(1992. 2 - 1994. 2).

poriferans. One and half year after installation, benthic process entered into the regulatory stage. In this stage the importance of *B. trigonus* and poriferans increased while than that of bryozoans decreased. The biomass and coverage, both for horizontal and vertical, increased continuously and reached to about 500 g/m^2 and 30 % for horizontal substrata and about 400 g/m^2 and 27 % for vertical substrata, respectively. The highest coverage of 30 % observed in Aug., 1993 on the vertical substrata was owing to the present of bivalves.

Two exceptional cases of monopolizing the space were observed form extra samples. The first case was rapid colonizing of *D. spirillum* over an empty space on a 21 month old horizontal substratum (Fig. 11-A). The space was created in consequence of the summer death of *E. cava*. *D. spirillum* had settled inclusively all over the experimental substrata during the initial stage with a density of about 1.4×10^4 ind./m^2 and had eliminated as the build up stage had began. Tubes of *H. ezoesis* which were covered by newly settled *D. spirillum* were empty. Refer to *D. spirillum* was unable to propagate over any other alive zoobenthos, it seemed that *H. ezoesis* had died before the settlement of *D. spirillum*. The black web like material on the upper right part of the figure was roots of alive *E. cava*. The another case was monopolizing of the hole available space, except upper right part where the species was overtaken by *H. permolis* (Porifera) on a 27 month old vertical

A. Rapid clonization by *D. spirillum* on space created by death of *E. cava* on a 21 month old horizontal substratum.



B. Monopoly of *B. trigonus* on a 27 month old vertical substrata.

Fig. 11. Exceptional cases of monopoly on the experimental substrata attached to an artificial reef complex at Sungsanpo, Cheju-Do.

substratum by *B. trigonus* (Fig. 11-B). The density of alive *B. trigonus* was 9 x 10^3 ind./m^2 and most of them were adults. There were almost same number of empty corpses of the species. Although the vertical substrata showed a higher density of *B. trigonus* compare to the horizontal substrata, however the maximum density of the ordinary sample was less than 7.3 x 10^3 ind./m^2 (May, 1993) which mainly consisted of young individuals, and decreased to 1.8 x 10^3 ind./m^2 within six month. One possibility is that the species had settled in previous year might succeed to exclude other neighboring species and had died, in any way, just before the next spat settlement. And the empty space had available for newly settled cyprids, then the they also might succeed to exclude other new comers.

C. Summary

Difficulty in the study of benthic community using the artificial substrata is impossibility of placing the substrata in an unique environment. An artificial reef complex is consisted by some hundred nodules of individual reefs and shape of the complex is irregular. The current velocity and direction, the light intensity and the food availability which seems to be important control factors for recruitment of benthic organisms are differ to place to place within the complex.

The benthic process on the substratum employed in the present study differs to another and unable to analyse the interspecific competition using competition indices (Kenneth 1986, Nandakumar and Tanaka 1993). However based on the findings it can be concluded as following.

1). There was a lag phase exist. It was not clear that the lag phase was caused by seasonal variation of the recruitment or the harmful effects of the substrata made of concrete.

2). A 27 month lasting study of the development of benthic communities on the experimental substrata resulted 98 species which including 34 species of benthic algae, 45 species of sessile zoobentos and 19 species of mobile zoobenthos.

3). The most dominant algal species in terms of seasonal occurrence and biomass and area of fronds was *Ecklonia cava*, Phaephyta. And it can be considered to be a canopy species and play a role in preventing the growth of other algae in any way.

4). Generally speaking, the number of species on the horizontal substrata were more than that of the vertical substrata. However the vertical substrata carried more species than the horizontal during the winter.

5). Development of the zoobenthic community on the experimental substrata can be classified into three stages: initial stage, build up stage and regulatory stage. The initial stage was characterized by large individual number of smaller species such as *H. ezoensis, Dexiospira* sp. and *L. radiata*. The built stage was identified by a rapid increase of the biomass and coverage. The build up stage can be further subdivided into two substages. The first substage was characterized by a rapid fill up of empty space by bryozoans, Poriferans and barnacle. However no severe interspecific competition for space occurred. In the regulatory the importance of *B. trigonus* and poriferans increased while than that of bryozoans decreased.

6). *E. cava* suffocated any other nearby species, however it provided a new substrata for late comers. Bryozoans suffocated other small zoobenthos including barnacle by overtaking, on the other hand it was bulldozed by adult barnacles. Poriferans suffocated all benthos when they succeeded to grow in a certain size.

Chapter IV. Conclusion

Korea is one of the leading countries in fisheries as she had been ranked among the top ten countries. Recent trends, however, shows that the Korean fisheries is being faced with many difficulties because of depleted resources and increased fishing costs. On the contrary, consumption of fisheries products(as sea food) has been increasing considerably every year. If this trend continues, Korea will soon became an importing country of sea foods from a leading exporter. The only counter action is might be marine ranching.

Artificial reef has been introduced into the shallow wasters of korea since 1971. With the initiation of the marine ranching program in 1987, the number of the placed reef modules has increase sharply and reached up to 800 thousand pieces by 1995. Among the several types of the modules, dice, tube, turtle and jumbo types were commonly used. Beside to these, triangle type have been used since November, 1991.

There has been a rapidly growing interest on the artificial reef in about 40 countries including France, United Kingdom, Philippines Taiwan, India and Middle America. Materials being used for reef building are fabricated concrete blocks, old ships and quarry rocks in the advanced countries, and bamboo or mangrove modules with sand bags in the under or less developed countries. It was censused that artificial reefs resulted an increased fish catches from 20 to 200 %. Over 1,000 % increased fish catches were also reported in Israel, Russia and Ivory Coast.

A study on the succession of benthic community on the artificial substrate experimental have conducted. During a twenty seven month study period, a total of 34 algal species and 64 zoobenthos found. *Ecklonia cava*, Phaeophyta dominated the community with the maximum biomass of about 10 kg/m^2 and can be called as a canopy species. The species smothered all other species, however on the other hand it provided a new substrate for new comers. Some opportunistic species such as *Likenopora radiata* (Bryozoan) and *Dexiospira spirillum* (Polychaeta) occurred at the early of the experimental period, however with time went, *Haliclona permollis* and *Halicondria* spp.(Porifera), *Balanus trigonus* (barnacle) and other bryozoans outbreaked. In general, young barnacle seemed to be excluded by bryozoans. However when the barnacle grew to a certain size, on the contrary, bryozoans was excluded by barnacle. Rather rapid growing poliferans such as *Haliclona permolis* and *Halichondria japonica* seemed to suffocate other sessile zoobenthos.

No apparent difference between vertically and horizontally installed substrates in terms of species composition and biomass during the very early stage of succession. Thereafter owing to a rapid growth of *E. cava*, the horizontal substrates showed a higher biomass while the vertical substrates showed a higher coverage compare to each other. It seemed that bryozoans can bulldoze younger barnacle, however the bryzoans possibly be bulldozed by adult barnacle. Depend on the time series, benthic process on the experimental substrata can be classified into three stages: the initial stage, the build up stage and the regulatory stage.

It is highly recommended that following considerations should be made before installation of an artificial reef complex.

1). Oceanographic condition including a biotic community on the proposed site
2). Hazardousness of artificial reefs for fishing (trawling), recreation, and other activities,
3). Use of stable and nontoxic materials for the construction of artificial reefs to minimize environmental risks
4). Appropriateness of artificial reefs pertaining to fish species
5). A long-term monitoring to identify the benthic process on the artificial reefs

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