YSLME
Regional Mariculture Conference

9-11 September 2008

Yellow Sea Fisheries Research Institute

Qingdao, China

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UNDP/GEF Project "Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem"

Regional Mariculture Conference

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Abstracts

Welcome Address of China

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Distinguished President Kim Yi Un, President Wang Qing yin, ladies and gentlemen:
Good morning! YSLME Regional Mariculture Conference is scheduled to start today. And I would like to avail myself and Chinese Academy of Fishery Sciences of this opportunity to express my heartfelt congratulations. Welcome to Qingdao!

This conference has 30 academic presentations, covering four topics, including environment protecting culturing techniques, disease control and the application of drugs and chemicals, economic benefit analysis of sustainable mariculture, etc. These presentations involve the status quo of aquaculture in both China and Korea, techniques for integrated multi-trophic aquaculture (IMTA), and diagnosis, prevention and treatment of disease, etc. which provides a good opportunity for academic exchanges between Chinese and Korean scientists, and will lay a good foundation for the successful execution of the YSLME project.

Ladies and gentlemen, Yellow Sea is not only one of the major mariculture sea areas of China and Korea, but also plays an important role world-wide in the field of mariculture. To reduce the pressure of aquaculture on the environment and to guarantee the sustainable development of aquaculture industry is the goal of Chinese mariculture and the research topic that we have always been engaged in. The Chinese government has designated Qingdao as the center for oceanology study, and has highlighted the future development of mariculture industry in Yellow Sea area. Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem, an international project of co-operation funded by UNDP, was launched in 2005 and has achieved remarkable results in the fields of collecting and analyzing mariculture data of Yellow Sea ecosystem, and summarizing common problems and their reasons. This conference is expected to be able to improve science of mariculture for both China and Korea, to enhance mutual understanding, and to contribute to the sustainable development of Chinese and Korean mariculture.

We wish the conference a great success! Wish you all a happy time in Qingdao!

Welcoming Remarks of Republic of Korea

Yi Un KIM

Director-General of West Sea Fisheries Research Institute, NFRDI, Republic of Korea

Good morning, Ladies and gentlemen!

It is a great honor for me to extend a warm welcome to all distinguished guests and participants to Yellow Sea Large Marine Ecosystem (YSLME) Regional Mariculture Conference. And, I also thank all of you who worked for successful initiation and organization of this conference.

The Yellow Sea is located between mainland of China and the Korean peninsula, and the line runs from the north bank of the estuary of the Yangtze River to the south side of Cheju Island. It covers an area of about four hundred thousand square kilometers (400,000 km^2). Among the 63 large marine ecosystems in the world, Yellow Sea Large Marine Ecosystem has been one of the most significantly affected by human activities.

Today the Yellow Sea faces serious environmental problems. The rapid increase of aquaculture farms around the Yellow Sea can be caused some problems including habitat degradation, disruption of trophic systems, depletion of natural seed stock, transmission of disease, and reproduction of genetic variability.

The main objective of this conference is to increase awareness and capability of mariculturists around the Yellow Sea and to foster exchange of information on methods for reducing chemical use to control pests, and economic benefits of sustainable mariculture. I think this conference will provide the proper frame work to the Strategic Action Plan of the YSLME Project through the exchange of expert views and innovative ideas. I am sure that this meeting will be an important step to accomplish the goals to prepare the Strategic Action Plan of the YSLME project.
For the 21ST century, one of the most important challenges of aquaculture industry around world would be “Environmentally Friendly and Sustainable Aquaculture”. And it has been established to the progressive and sustainable development of global aquaculture through promotion of excellence in science, technology, education, and information exchange.

Anyway, to solve and overcome the problems facing with unexpected and unsustainable aquaculture farming around the Yellow Sea, we need to exchange information in the field of sustainability of aquaculture. In this sense, I believe this conference will be a golden opportunity to share knowledge and experience on sustainable aquaculture between two countries, China and Korea.

Once again I would like to appreciate all of participants for joining this conference. I am sure that we can strengthen our cooperative research activities between Korea and China for the effective management of sustainable aquaculture in the Yellow Sea.

In conclusion, I hope that this conference will facilitate your work for better planning and implementation, strategies and successful outcomes.

Thank you for your kind attention.

Driving Sustainability in Yellow Sea Mariculture: The UNDP/GEF Yellow Sea Project

Mark Walton

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Dear Colleagues and Friends,

First of all, on behalf of the UNDP/GEF Yellow Sea LME project, I would like to warmly welcome all participants to the lovely city of Qingdao and thank them for participating in this important Regional Mariculture Conference where we will hear a variety of presentations on various methods to increase sustainability in mariculture production in the region. I wish to express our sincere thanks to the Yellow Sea Fisheries Institute for hosting this conference here at their Institute and also to Dr Fang Jianguang and Dr Zhang Jihong of YSFRI and Dr. Jang In Kwon of the West Sea Mariculture Research Center for helping us identify participants.

As some of you know, this project officially titled "UNDP/GEF Reducing environmental stress in the Yellow Sea" began back in 2005, and we spent the first 2 years identifying some of the critical transboundary problems affecting the Yellow Sea Ecosystem. Amongst the highlighted problems were unsustainable mariculture practices. The causes were common among most regions in the world and this included over-intensification of mariculture, variable natural food supplies, over-exploitation of natural habitats, the release of bacterial, viral and fecal material, nutrients and food and chemical residues from mariculture institutions.

However the problems we have seen in the mariculture industry that have resulted in decreasing productivity and increasing incidence of disease, are not only self inflicted. The environmental stress in the Yellow Sea has been increasing with the growth in population in the coastal region. Pollution, nutrient runoff, overfishing and climate change are driving changes in the ecosystem, effecting not only the rate of productivity but also the type of productivity. These can have profound affects on coastal mariculture.

So what are we going to do about it? Well as some of you know, we have spent the past year working closely with a number of experts from various marine science backgrounds, as well as government officials, NGOs and other stakeholders to develop the Strategic Action Programme for the Yellow Sea. In this document, we outline the changes that are needed to improve the Ecosystem Carrying Capacity, which we define as the sum of the ecosystem services that are used by mankind. So, all of these environmental concerns are tackled in this document, using specified targets. For example we are asking government to agree to a reduction of pollution from point sources by 10% every 5 years and fishing pressure is to be reduced by at least 25% by the year 2020. For mariculture the main emphasis is on increasing sustainability through the promotion of Integrated Multi-Trophic Aquaculture (IMTA) and Good Aquaculture Practice (GAP), reducing the release of nutrients and other substances from mariculture institutions and increasing the effectiveness of disease control.

Ladies and Gentlemen, we are in charge of one of the most important mariculture areas in the world and it is essential we work together to achieve these goals. So the management experiences we have gained can provide an example for the rest of the world. Sustainability and profitability are not mutually exclusive and are the only way to ensure the long term future of the industry. The YSLME project is helping promote some of the best examples of sustainable mariculture both here in Shandong province and in Korea. We hope that these projects will be the torch bearers in the drive to sustainability. Thank you.

Some consideration on the sustainable development of mariculture in China

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During the past few decades, a significant development in aquaculture has been seen worldwide which increased from less than 1 million tons before 1950s to 59 million tons in 2004. In 2004, Asia-Pacific region contributed 91.5% of world total aquaculture production, representing 80.5% of the total value; among which China's contribution was 69.6% and 51.2%, respectively. In 2006, aquaculture production in China was 35.9 million tons, which accounted for 68% of total fisheries output in the country. Mariculture, as one of the important parts of marine economy development, has contributed 24.6% of marine economic value which was over 2 trillion RMB and made up 10% of GDP in 2006 in China.

The growth of world population has put more demand on aquaculture for ever higher production. According to FAO expectations, world total mariculture production will reach 54~70 million tons in 2020 (FAO FIGIS), and in 2030, mariculture will replace fishing as the number one approach to produce seafood. The implication is that, mariculture production will increase from less than 19 million in 2005 to 35~51 million tons within 15 years.

There are quite a few obstacles for realizing these goals. Modern technologies still cannot support full control of the aquaculture process; an imbalance of aquaculture investment and output has impeded the healthy development of the industry; and a negative impact of aquaculture on the environment has, on the other hand, affected the growth of the industry. Additionally, local and international markets have put higher requirements on food quality; the incentives for organic food (or green food etc.) production is strong; and sustainable development has somehow become the only way to follow.

Some Considerations are put forward and discussed in this presentation.

1. Ecosystems and Ecosystem Approach to Aquaculture (EAA)

An ecosystem is a natural unit consisting of all plants, animals and micro-organisms (biotic factors) in an area functioning together with all of the non-living physical (abiotic) factors of the environment. Ecosystem Approach to Aquaculture (EAA) is a hot topic in recent years which involves society, economics and the environment; it encompasses the concepts of healthy aquaculture, ecological friendly, environmental friendly, aquatic animal welfare and sustainable development.

EAA is an approach that have integrated all “demands” and taken into consideration of sustainability. Demands include food security, market and quality, while sustainability includes resources, environment and ecology, etc. The logic is that, sustainable development is the only way to resolve the conflict between the ever growing demand on aquatic food by human beings and the carrying capacity of the ecosystem.

2. Major challenges and problems in mariculture in China

This conflict is reflected in the production of major mariculture species. Massive mortality of farming scallop, for example, occurred in 1998 resulted in heavy economic loss; although there were a significant expansion of culture areas, the increase of scallop yield in recent years was fairly limited, indicating a negative increase in productivity. On the contrary, shrimp culture production in China in recent years is more correlated with an increased productivity, as the enlargement of culture areas was insignificant. While for another major economic species, sea cucumbers, the productivity has been kept stable for the last few years.

Based on the above mentioned case investigations, it can be concluded that there is no necessarily positive correlation between mariculture scale and output, or mariculture production and economic benefits, or economic benefits and efforts.

3. EAA and sustainability

Natural laws keep a strict control over mariculture activities, and these laws also govern all ecosystems, and these are the laws human beings are hard to surpass. We need to understand, to abide by, and to conform to these laws so that may possibly achieve the maximum economic, social and ecological benefits in mariculture activities. For EAA, quality and sustainability are of the same importance. Quality refers to quality control of the culture process and the products; while sustainable mariculture, in the long run, must not harm or impose any cumulative effects on economic, social and ecological sustainability.

Developmental strategies for a sustainable mariculture are discussed as follows:

Scientific management of mariculture activities calls for improvement of technology. We need to learn more about carrying capacity, interactions between organisms and particularly the food web, relationships between organisms and their environment, impacts of human activities and social-economic aspects of mariculture.

In China, in particular, a strategic transformation of the targets, approaches and measures is needed for mariculture industry. We are especially in need of a shift from quantity-oriented fishery to quality-oriented fishery and responsible fishery. We call for a full-range application of modern bio-technology and engineering in mariculture, in order to accelerate the mariculture development.

Development strategies are emphasized in this presentation, including Protection Strategy, for protection and rational utilization of in-shore fisheries resource; Exploitation Strategy, for promoting stock enhancement and utilization of marine resources in the deep sea and the high-seas; High-tech Strategy, for upgrading technology in all sectors of mariculture.

State of Aquaculture in Republic of Korea

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Aquaculture has already become an important source of marine protein for Koreans. Because the capture fishing industry has peaked and is likely to decline as wild stocks are diminished, aquaculture will become an increasingly important source of seafood products. Already, a considerable percentage of all aquatic products consumed in Korea come from aquaculture and for some species, production is totally from aquaculture in the country. However, the aquaculture industry of Korea is not without problems and outbreaks of diseases and harmful algal blooms in the farming grounds occur annually. Efforts to overcome the problems are continuous, using environmentally sound aquaculture practices. Approaches from molecular biology and genetics are of recent interest in the practice of modern aquaculture.

Mariculture production in the Yellow Sea (YS) coast of Korea reaches 208 x 103, or 22.7% of total national mariculture production in 2004. Of these, seaweeds take a considerable part of total marine aquaculture. The yield of seaweed is 145.9 x 103 MT, or 70.1% of the total YS mariculture production. The farmed production of finfish, crustaceans, and molluscs occupy 3.9%, 0.5% and 25.5% respectively. Of the marine farmed production, shellfish are of interest in the Yellow Sea coast of Korea.

Production of shellfish in the YS coast in 2004 reached 53 x 103 MT, making up 27.2% of the national shellfish production. Two shellfish species, Pacific oyster and Manila clam have been major bivalves in YS mariculture industry. Production of these two species occupied 91.7% of the total YS shellfish production.

The total farmed finfish production in YS coast reached 8,049 MT in 2004 and occupied comparatively small parts of total mariculture production in the west coast of Korea. Two marine finfish, olive flounder and black rockfish, dominate all the finfish species farmed in Korea. Production of these two species consists of 76.1% of total finfish production. Other minor farmed species are sea bass (*Lateolabrax japonicus*), mullet (*Mugil cephalus*), black sea bream (*Acanthopagrus schlegeli*) and parrot fish (*Oplegnathus faciatus*).

Seaweeds have long history of aquaculture and have been important aquatic products in Korea. The two species, laver (*Porphyra*) and sea mustard (*Undaria*) occupied 92.5% of the total seaweed production. Other minor cultured species are kelp (*Laminaria*), fusiforme (*Hijikia fusiforme*), and green algae (*Enteromopha*).

Crustacean culture in Korea is primarily of penaeid shrimps. Two penaeid shrimps, fleshy prawn (*Fenneropenaeus chinensis*) and Kuruma prawn (*Penaeus japonicus*), have been cultured for decades in western and southern coasts of Korean peninsula. In 2003, Pacific white shrimp (*Litopenaeus vannamei*) was introduced from U.S.A. and by 2006 occupied about 70% of total farmed shrimp production in Korea. More than 90% of shrimp farms are located in the western coast and the rest are along the southern coast.

Key words: Yellow Sea, South Korea, aquaculture

Development of Integrated Multi Trophic Aquaculture in open sea

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The crises in global marine fisheries are well documented and accepted by most stakeholders. Scientific evidence indicate that more than 70% of the world's commercial marine fish stocks are either: fully exploited, overfished, or recovering from overfishing. Mariculture, although having the potential to alleviate mankind's pressure on marine ecosystems, is not without its own problems such as encroachment of crucial coastal habitats, release of pollutants and fishing down the food chain.

China is one of the world's biggest mariculture producing countries. The scale of China's mariculture industry is unmatchable. The sustainable development of China's mariculture is confronting many challenges. Perhaps the biggest challenge is how to increase the production capacity of an existing site without exceeding the ecosystem capacity. One of the possible practices is to increase the resource utilization maximally by adding functionally different species to the cultivation system. One of the innovative solutions being proposed for environmental sustainability, economic diversification and social acceptability, is integrated multi-trophic aquaculture (IMTA).

Generally speaking, there are two variations of the IMTA approach have been developed in China: suspended multi-species aquaculture, and multi-species large scale sea ranching in more offshore and deeper waters (Fig.1 and Fig.2).

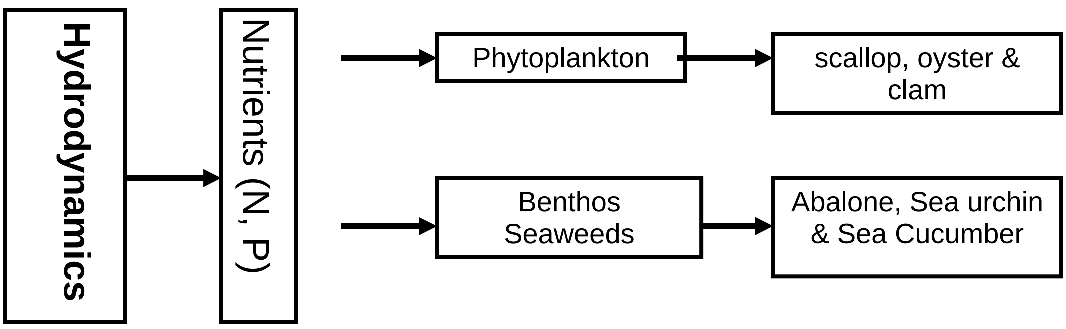

Fig.1: IMTA practiced for Sea Ranching in China

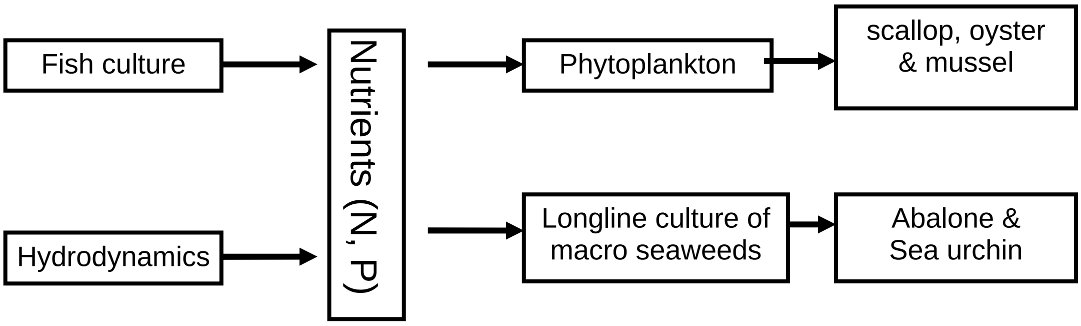

Fig. 2: IMTA Practiced for Suspending Mariculture in China

Nowadays, offshore IMTA has mainly developed in northern China, especially in Shandong and Liaoning Provinces. An example of suspended multi-species aquaculture is being well developed in Sungo Bay, which is located in the East of the Shandong Peninsula, China, with a total area of 13,300 ha. Sungo Bay has an annual production of 2,100 tonnes of scallop *Chlamys farreri* in fresh weight, 110,000 tonnes of oysters *Crassostrea gigas* in fresh weight, 80,000 tonnes of kelp *Laminaria japonica* in dry weight, and about 100 tonnes of finfish respectively, and is becoming the one of most famous IMTA areas in the world. The co-cultivation of abalone *Haliotis discus hannai* with L. japonica is also being developed, with abalones kept in lantern nets hanging vertically from the long lines, while kelps are grown on ropes maintained horizontally between long lines so that the abalones can feed on the kelps by manual feeding. Once the kelps have been harvested, the abalones are fed with dried kelps.

In recent years, some experiments of IMTA has conducted in the bay, such as co-culture of sea cucumber with abalone in the abalone nets, co-culture sea urchin with scallop in lantern nets in the offshore. The preliminary results showed these experiments have great potential to be the new IMTA.

An example of multi-species large scale sea ranching is taking place near Zhangzidao Island, 40 miles offshore in the northern Yellow Sea (water depth from 20 to 40 m). Sea ranching is usually practiced for the enhancement of natural stocks such as Japanese Scallop, Sea cucumber, abalone, sea urchin. The Zhangzidao Fishery Group Co., Ltd., is authorized to farm up to approximately 60,000 ha, and presently cultivates 40,000 ha of the scallop, *Patinopecten yessoensis*, 3,000 ha of the arkshell, *Scapharca broughtonii*, 1,000 ha of the sea cucumber, Apostichopus japonicus, 1,000ha of the abalone *Haliotis discus hannai*, and 1,000ha of sea urchin *Strongylocentrotus nudus*. The annual productions of scallop, sea cucumber, ark shell, abalone and sea urchin are 20,000 ton, 400 ton, 500ton 100 ton and 300 ton respectively. To improve ecological conditions and the sustainability of the operation, the company is now thinking of developing seaweed cultivation and the construction of artificial reefs in more offshore environments. To date, about 2,000 ha of sea bed have been optimized in this way.

Besides the development of demonstration and applied research to clearly show farmers and regulators the benefits of IMTA, basic research to make the IMTA approach more commercially attractive has been also carried out in recent years in China. For example, the environmental requirements for the growth of seaweeds and shellfish to enable efficient nutrient recycling with the culture conditions (depths, relative position with respect to the fish cages in relation to the prevailing currents, distance from the cages and culture density), how to use the seaweed and shellfish as both a highly efficient biofilters and to increase biomass production capacity

Key words: Mariculture, IMTA, Sungo Bay, Inshore, Offshore, Seaweeds, Shellfish.

Marine Ranching Project in Yellow sea coastal, Korea

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Korean coastal fisheries catch sharply increased between 1950s and 1070s due to the increase of vessel power, use of synthetic fabric mesh, and development and automatization of fishing gears. The increase of fishing power resulted in overfishing and was followed by a sharp decrease of fisheries catch from 1990s with the retardation of fisheries development while aquaculture techniques have developed rapidly in terms of the fish culture from 1980s to 1990s. However, the current aquaculture industry is confronted by a serious crisis due to the increase of imported aquatic products and costs, decrease of market price, and coastal pollution. Moreover, international agreements such as Korea-Japan and Korea-China Fisheries Agreement, WTO and FTA have further increased the pressure on the aquaculture industry in Korea.

Many coastal nations have put their efforts into the recovery of coastal fisheries resources by promoting the sustainable use of resources since 1970s. Especially, Japan, USA, Canada, England and Norway etc are the leading countries in the coastal fisheries resource recovery.

Korea has also tried to protect and encourage recovery of coastal fisheries resources by deployment of artificial reefs and restocking beginning in 1970s and peaking in 1990s. Preliminary marine ranching started from 1977 and the first site was constructed in Tongyeong in 1988. Five more candidate sites in East Sea (Uljin County, Gyoungbuk Province), West Sea (Taean County, Chungnam Province), South Sea (Yeosu City, Jeonnam Province), Jeju Island etc were designated in 2004 and these marine ranching projects are scheduled to be completed by 2010. About 50 small scale marine ranching projects will also have been initiated by local governments by 2014 and 500 ranching projects by 2030.

The marine ranching site in the west coast is located in mud tidal flat of Taean County in Chungnam Province, covering about 8,500ha (6,500ha for ranch, 1,500 for mud flat, 500ha for others) and was developed as a "mud flat type". The target species are fishes (Black rockfish, Olive flounder, Greenling) and crustaceans (Swimming crab, Chinese shrimp), shellfishes in tidal flats (Shortneck clam, Hard clam) etc. Artificial reef deployment and restocking of various species are planned to continue for the foreseeable future and also environmental status and resources are monitored regularly.

Marine ranching in the west coast of Korea will be developed to conserve the ecosystem. By these approaches we can protect the natural mud tidal flats and produce sustainable shellfish products. Also, the ranches will be used for education, eco-tourism and good example of sustainable use for future generations.

In terms of the local scale, four ranching sites are planned to be constructed within the next 5 years with a budget of 5,000,000,000 Won with 50% coming from central government and 50% from local government in Ongjin County of Incheon City, Boryong City and Seocheon City in Chungnam Province, and Gunsan City in Jeonbuk Province. The ranch in Ongjin County of Incheon City was already started in 2008 and will be constructed to overcome the decrease and ageing of fishermen population that has led to a decrease of manpower in the area. Moreover, four ranches neighbouring the demonstration site in Taean County of Chungnam Province will be developed to achieve the sustainable production of fisheries resources in the west coast of Korea.

Super-intensive shrimp culture under limited water exchange

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Shrimp culture is one of the most important mariculture industries in the west coast of Korea. The most Korean shrimp farms are semi-intensive and conducted in earthen ponds in which stocking density is 25-30 PL/m2 and productivity is about 0.25-0.3 kg/m2. Water quality is controlled by autotrophic phytoplankton with high water exchange in these culture systems.

The rapid increase of semi-intensive shrimp farms has caused some problems. The possible introduction with the incoming water of harmful pathogens such as white spot syndrome virus (WSSV), and the release of nutrient rich effluent into receiving seas is both issues of particular concern. In the near future the shrimp farming industry will be required to meet tougher standards for effluent water releases. These issues will force the industry to seek out more sustainable management practices.

Limited water-exchange shrimp culture system is an option that can reduce both disease introduction and the negative environmental impact created by conventional shrimp farms under semi-intensive culture systems. Heterotrophic bacterial conditions can be induced in shrimp culture systems with limited water exchange and high shrimp density, and may be more stable and effective in controlling water quality than autotrophic phytoplankton system. Water quality is one of the most important environmental factors affecting the health of the cultured shrimp.

A 42 days nursery trial was conducted in two 13 m2 and two 18 m2 raceways under limited water exchange. Juveniles of Pacific white shrimp (PL40), *Litopenaeus vannamei* were stocked at a density of 3,000~5,625 inds./m3. The average body weight at harvest ranged from 1.45 to 2.03 g and yields per unit area were 2.49~4.2 kg/m3 from four tanks. The yield was as much as ten times higher than conventional nursery production. The current study showed the potential of this nursery system in reducing both the culture period and the risk of pathogen introduction from incoming water.

In addition, two growout trials were also performed to evaluate the potential for heterotrophic shrimp culture. The first was conducted in two HDPE-lined outdoor ponds

(500 m2). Each pond was stocked with Pacific white shrimp (PL15) of 300 inds./m2 in density. After a culture period of 91 day, the production per unit area(m^2) were 2.7kg/m^2 and 2.56kg/m^2 respectively. These results were as much as ten times compared with yields of the other semi-intensive farms. The second grow-out trial was conducted in four green-house raceways (68.5m^2). Each raceway stocked juvenile Pacific white shrimp (1.25±0.17 g) with a density of 530 inds./m3. This study shows that shrimp can be produced with high yield as 7.92~9.29kg/ m3 after a 94 day culture period.

These studies were conducted to develop the super-intensive shrimp culture method for the Pacific white shrimp operated with limited water exchange. Research has indicated that better shrimp production can be achieved under limited water exchange and especially for indoor shrimp culture, high biosecurity can be maintained minimizing the risk of the introduction of viral infection from environment.

Key words : Shrimp culture, Limited water exchange, Pacific white shrimp, Biosecurity, *Litopenaeus vannamei*

Facility & Technology of Water Recirculating Aquaculture

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The developmental process of facility fishery mostly includes six stages: pond culture, natural flowing water culture, flowing water with controlled temperature culture, high density still water with increased oxygen culture, enclosed recirculating fish culture, automatic fish culture. Following with the development of technology, yield of per unit area increases from several kilogram /m^3 to hundreds kilograms /m^3 and culture species are also increased.

In developed countries, industrial aquaculture techniques become more popularization, maximization and industrialization day by day, many aquaculture industry have already been in the stage of "enclosed recirculating fish culture" and "automatic fish culture". While in China, although industrial aquaculture technique developed rapidly in recent years and techniques beginning to be transformed from "imitate & follow" stage into "independent innovation" stage step by step, present status of industrial aquaculture are still at primary stage, only very few projects reach to "enclosed recirculating culture" stage.

Enclosed recirculating culture system builds a controllable ecosystem through utilizing high-tech to control the main factors of aquaculture environment (including water temperature, water quality, feed, sterilization and water treatment). With this system, many methods such as high density, strange area culture, whole year culture and reverse season culture can be come into reality. The water treatment system and the circulating system are the core technique. The enclosed recirculating culture system is not only enhance the larval density but also meet to recycle use the seawater, reduce energy consume and waste water emission, which satisfies the national demand on energy saving and environmental protection.

Different organisms need for different culture facility, professional culture technology is clustering the different aquatic animals into several large-scale types based on their ecological habit first, and then designs suitable facilities for each type to earn maximum economic benefit. At present, many professional facilities have been exploited, such as photo-reactor used for microalgae and photobacteria, fluidising kettle used for larvae and zooplankton, multilayer tridimensional tank used for zoobenthos, complete cycle pond used for small swimming animal and seed transition, channel plus cage complete cycle pond used for large swimming animals. Following with the development of the technology, it is expected that more and more advanced facilities will be exploited in the future.

Fish protein hydrolysate vs. fish meal in compound diets for tongue sole *Cynoglossus semilaevis* Günther post-larvae

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The consistently high demand for and value of sole *Cynoglossus semilaevis* make it one of the most attractive candidates for fish farming in China**.** During transfer from natural to artificial diets: transfer was consistently associated with high mortality and poor growth. As very young larvae exhibit high peptidase capacity, it assumed that the protein hydrolysate would be efficiently used by the early developmental stages. The aim of the study was to determine whether sole larvae fed compound diets incorporating different levels of fish protein hydrolysate(FPH) could normally develop their digestive system. Four groups of tongue sole post-larvae were fed for 28 days with four isoenergetic and isonitrogenous(60%) compound diets differing only by the incorporation level of fish protein hydrolysate（FPH）. In diet control（FM）, the protein fraction was fish meal. In diets FPH-20, FPH-40 and FPH-60, 30.7%, 60.8% and 88.1% of whole protein in the diet was replaced by FPH, respectively. The four compound diets sustained larval growth throughout the experiment. The results showed the highest SGR was obtained in the group fed FPH-20 (2.84±0.06) %/d, FPH-20＞FPH-40＞FM. No significant differences in SGR between FM and FPH-60 were observed（P>0.05）. The highest survival was obtained in the group fed FPH-20（78.88±0.96）%. The tongue sole larvae showed a tendency: FPH-20＞FPH-40＞control＞FPH-60 in survival. The tongue sole larvae showed a tendency: FPH-20＞FPH-40＞control＞FPH-60 in alkaline phosphatase relative activities. Effect of FPH on digestive enzymes relative activities (lipase, amylase, acid and alkaline protease) in tongue fish post-larvae was shown in Fig 1 and Fig 2. By using light microscopes, it was detected that the fish fed with FPH-20 was best, worst when fed with FPH-60 on intestinal tract development (Fig 3).

The compound diet containing 20% FPH can not only improve growth and survival rate of tongue sole post-larvae, but also enhance the development of intestinal tract of tongue sole post-larvae.

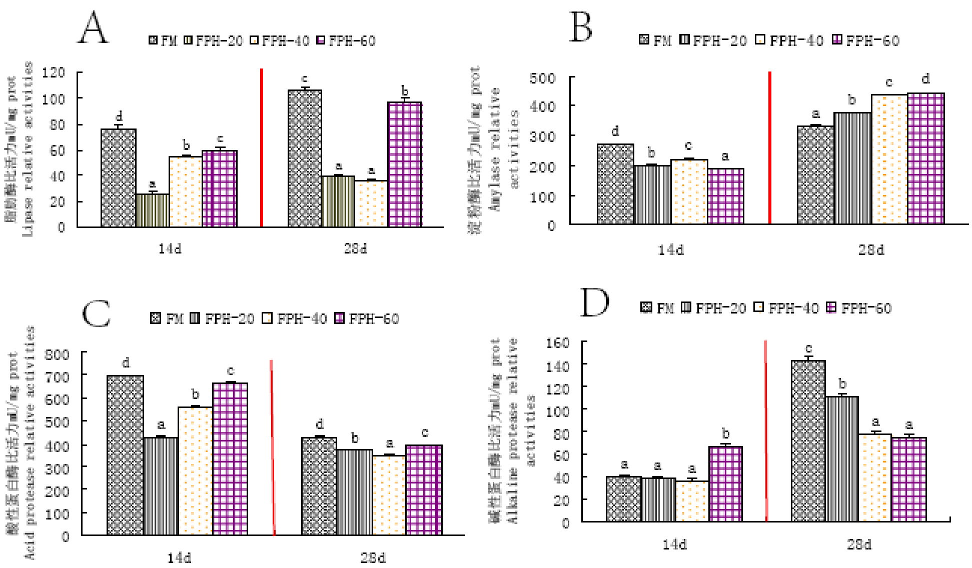

Fig.1: Effect of FPH on digestive enzymes relative activities: (A)Lipase; (B) Amylase; (C) Acid protease; (D) Alkaline protease

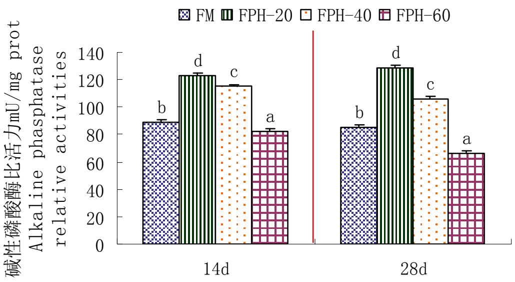

Fig.2: Effect of FPH on alkaline phosphatase relative activities.

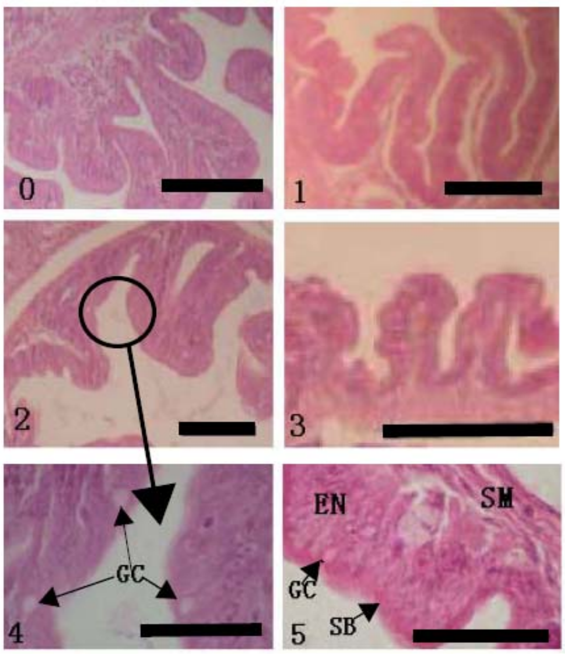

Fig.3: Effect of FPH on intestine structure in tongue fish post-larvae(Bar=100μm)

Growth, body composition and nutrient loadings of juvenile olive flounder (*Paralichthys olivaceus*) fed diets with different physical types under on-farm conditions

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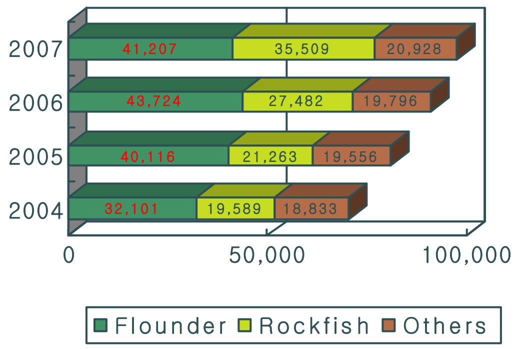
Like other industrial activities, fish farming practices also results in the environmental pollution. The pollution by fish culture mainly comes from feeding system, which includes unconsumed feeds, urine, feces, drugs, and dead fish. Korean seawater fish culture production tremendously increased from 1,290 tons in 1988 to 97,644 tons in 2007 (Fig. 1). Moist pellet composed of trash fish and mash feed is, however, still employed for the fish production (Fig. 2), which is known to be a main pollution source. Growth, whole body and eye-side muscle composition and excretion of nitrogen and phosphorus were investigated for olive flounder (*Paralichthys olivaceus*) fed diets with extruded pellet (EP), moist pellet (MP) based on raw fish and semi-moist pellet (SMP) under on-farm conditions. Three diets, EP, MP based on raw fish and SMP made of formulated powder feed with water, were fed to apparent satiation twice a day except Sunday by hand during 8 weeks. A total of 3,000 fish with an average initial weight of 123 g were randomly allotted to each (500 fish/tank) of 6 concrete tanks (2 tanks/treatment). Filtered sea water was supplied to each tank with a flow rate of 150 l/min. Water temperature ranged from 16 to 18 ℃ during the experimental period. Final weight of fish varied from 193 g (MP) to 233 g (SMP), Weight gains showed a significant difference ($p<0.05$) among fish groups, being 111 g, 104 g and 69 g for fish fed SMP, EP and MP, respectively. Dry feed intake was significantly different ($p<0.05$) among fish groups, ranging from 65 g to 91 g for fish fed MP and SMP, respectively. Fish groups fed EP showed the lowest feed conversion (0.75), while the highest value of 0.94 was found in fish groups fed MP. The best protein efficiency ratio was obtained in fish fed EP (2.41), which was significantly higher than those in fish fed MP (1.95) or SMP (1.93).



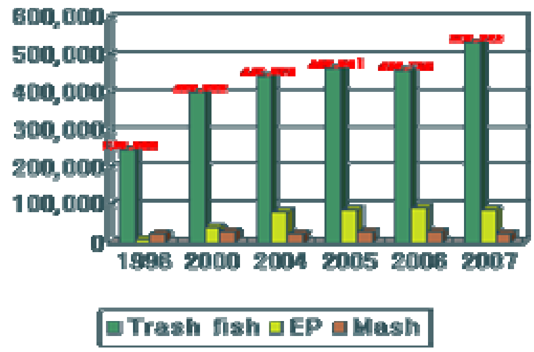


Fig.1. Marine culture fish production in Korea (unit: MT)

Fig.2. Feeds used for marine fish farming (unit: MT)

Protein was lowest while lipid was highest ($P<0.05$) in whole body of fish groups fed MP though the levels in all groups maintained relatively constant from 17.5% (MP) to 18.0% (EP) and from 3.2% (SMP) to 3.8% (MP) for protein and lipid, respectively. Moisture in dorsal part of eye-side muscle was highest in MP groups, lipid was, however, not significantly different among treatments. Moisture and lipid in ventral part of eye-side muscle were not significantly different among treatments, while protein was lowest ($P<0.05$) in fish fed MP.

Table 1. Utilization of nitrogen (N) and phosphorus (P) by olive flounder fed the different diets[1]

Diet	EP		MP		SMP	
	N	P	N	P	N	P
Intake, g/fish	6.91 ± 0.03^{b}	1.05 ± 0.00^{b}	5.65 ± 0.20^{c}	0.72 ± 0.03^{c}	9.20 ± 0.18^{a}	1.38 ± 0.03^{a}
Gain, g/fish	2.96 ± 0.12^{a}	0.36 ± 0.01^{a}	1.80 ± 0.05^{b}	0.14 ± 0.01^{b}	3.11 ± 0.07^{a}	0.33 ± 0.02^{a}
RE, %[2]	42.9 ± 1.56^{a}	34.2 ± 1.57^{a}	32.0 ± 0.18^{c}	19.9 ± 0.77^{c}	33.8 ± 0.15^{b}	23.6 ± 1.10^{b}
Excretion[3]	38.1 ± 2.24^{b}	6.65 ± 0.05^{c}	55.8 ± 1.75^{a}	8.42 ± 0.16^{b}	54.8 ± 1.18^{a}	9.51 ± 0.09^{a}

[1]Values (means±SE of two replicate groups) in the same row sharing a common superscript were not significantly different ($P>0.05$). [2]Retention efficiency= N or P gain/N or P intake x 100. [3]g/kg wt. gain.

Table 1 shows the intake and gain of nitrogen (N) and phosphorus (P) by fish fed the diets. Retention efficiencies (%) and excretions of N and P were calculated using the data. Gain of nitrogen (N) and phosphorus (P) of fish fed EP was not significantly different ($p>0.05$) from that of fish fed SMP, although fish fed MP showed the lowest gain. The highest retention of N (42.9%) and P (34.2%) was obtained in fish fed EP, which, in turn, resulted in the lowest excretion of N (38.1 g) and P (6.7 g) among treatments. The results showed that dry pellet EP was much more advantageous than MP or SMP in terms of feed utilization and excretions of nitrogen and phosphorus for olive flounder. The present status of Korean marine fish farming, nutrient loadings from flounder farming and how to reduce them by feeding practice will be discussed.

Key word: *Paralichthys olivaceus*, Extruded pellet, Moist pellet, semi-moist pellet, Growth, Body and muscle composition, Excretion, Nitrogen, Phosphorus.

Technological developments of offshore longline mariculture

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Aquaculture is presently one of the fastest growing aquatic food production sectors in the world due to the rapidly increasing demand and declining global fishery yields. Overlapping use of coastal habitats adds to the increasing pollution of coastal waters and gives rise to spatial conflicts, thus leaving little space for the expansion of modern coastal aquaculture systems. This problem has triggered the movement to offshore areas, where little spatial regulations have been established so far and clean water can be expected (Krause et al., 2003). In this paper, the concept, progress status of offshore longline mariculture were outlined and the farming methods and potential of scallop *Chlamys farreri*, Japanese scallop in offshore areas in Yellow Sea were studied.

For the scallop *Chlamys farreri*, experimental sites were set up in Sungo Bay from May 2007 to April 2008. The effects of seed density and lantern size on the growth rate of scallop *Chlamys farreri* at inshore and offshore area were studied. 10 groups of different lantern nets and initial density were designed. The shell height, dry tissue weight and dry shell weight of the scallops, and environmental parameters were measure monthly. For the Japanese scallop, new mariculture equipment was designed and the culture efficiency was measured from May 2008.

The monitoring results showed that the concentration of chlorophyll a was higher inshore, but the concentration of inshore POM was lower than offshore. The water flow velocity at inshore and offshore is quite different. On the survival rate, offshore and inshore groups were 90.1% and 84.9%, respectively. The initial seeding density had negative correlated with dry tissue weight growth. Student–Newman–Kuels procedure showed: significant different for the shell height and dry tissue weight between group of OL-60 and IL-60 at April 2008 ($p<0.05$).

The results showed the scallop *Chlamys. farreri* could be cultured in offshore areas.

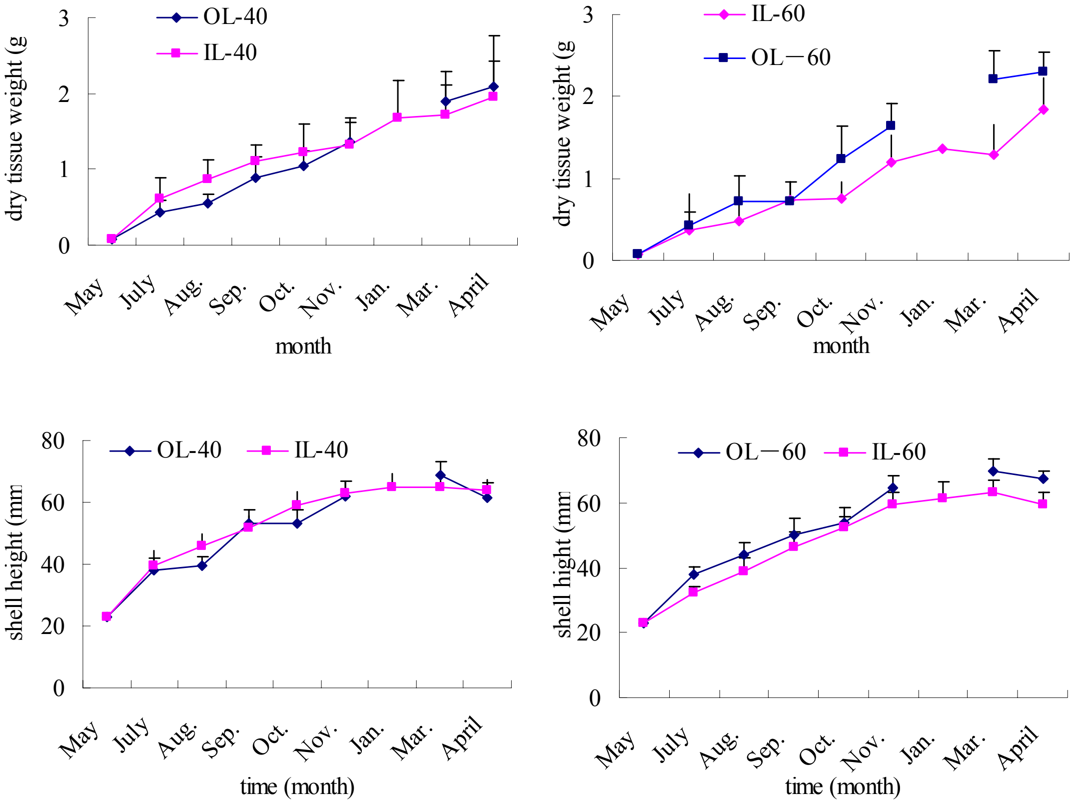

Figure 1: The scallop dry tissue weight and shell height for each experimental treatment

Key words: scallop; *Chlamys farreri;* offshore culture; growth rate

Korean Offshore Aquaculture, the Past, the Present, and the Future

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Recently, the aquaculture industry in Korea has been facing serious difficulties not only from water pollution, typhoons and red tides but also from the opening of the fisheries market under agreements with the World Trade Organization (WTO). Integrated aquaculture management is an alternative plan to overcome these problems. Under integrated aquaculture management, the scope of aquaculture ground extends to open areas which have never before been included until recently. These aquaculture grounds are divided into 3 subdivisions: the areas for land-based aquaculture, polytrophic aquaculture, and offshore aquaculture.

Offshore aquaculture is most advanced method for finfish and shellfish culture. One of the biggest problems obstructing the successful introduction of offshore aquaculture is how to overcome the high surface energy which can physically damage cages in the open environment. Submerged cages lessen the likelihood that the cage will be damaged by the physical energy, even during typhoons. Moreover, putting the cages underwater can eliminate visual impact coming from deployment of cages in the coastal waters. However the most outstanding advantage of offshore aquaculture is that these waters having higher carrying capacities than inshore waters and therefore higher stocking densities can be attained.

In an attempt to persuade Korean aquaculture businesses to move to offshore cages culture from the traditional inshore cages, the National Fisheries Research and Development Institute (NFRDI) launched a pilot study, the Korean Offshore Aquaculture Project (KOAP) in 2005. After several surveys, six offshore cages were installed in the south coastal water off Jeju Island from 2005 to 2006, and four cages of SeaStation were deployed off Geomundo island in 2007. All cages are SeaStation™ (OceanSparLLC) of United States. Installation sites were selected on the basis of oceanographic and environmental characters. The sites were 45 to 50 m in depth, and the cages were installed in middle layer in the water column. On the basis of technological and economic characters, parrot fish (*Oplegnathus fasciatus*) and seven-band grouper (*Epinephelus septemfasciatus*) were selected as main culture fishes.

Periodically monitoring of environmental parameters in the water mass and bottom sediment around the cages detected no noticeable change. The current velocities at the culture sites were recorded at 30 to 120 cm per second depending on the direction of the tidal currents, and several typhoons directly hit the culture sites. So far the cage safety has been confirmed against strong currents and typhoons. And early results suggest that offshore aquaculture has strong competitiveness over inshore and on-land aquacultures.

However, as offshore aquaculture just started in Korea, many challenges are still unresolved and new problems are expected to emerge in the future. During KOAP the best offshore aquaculture techniques such as under-water fish cultivation, feeding, monitoring of cages and culture fish, sorting, will be developed. The results from KOAP will help farmers when the Korean government gives permission for actual offshore aquaculture businesses to fish farmers and companies starting in year 2010.

Research on Characteristics of Flow Field around Artificial Reef Based on CFD Numerical Method

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Artificial reefs are men-constructed objects in waters to make the habitat environment better for aquatic organisms and to provide fish a ground for feeding, reproduction and growing up so as to protect and enhance fishery resources and improve the quality of catches. The effect and functions of artificial reefs have been verified in practices in many countries and regions of the world and the engineering of artificial reefs has become an important measure for costal countries to meliorate the environment of fishing grounds and to carry through conservation and enhancement of fish

Fig.1 Artificial reef of star shape

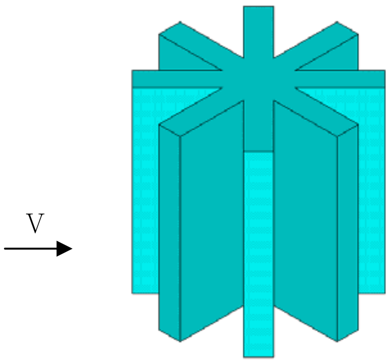

Fig.2: Axes perpendicular to the current

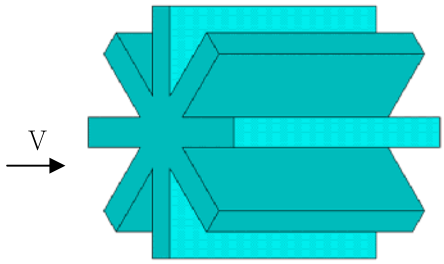

Fig.3: Axes parallels the current

stocks. Current field formed around artificial reefs plays important roles in the formation of feed organisms and conglomeration of fishes. So it is important to design and construct artificial reefs based on the prediction of the characteristics of flow field around reefs. Therefore, a CFD method was employed to determine the features of flow field around reefs and the flow field around star reefs was simulated. According to the investigation results in the artificial reef area of Lingshan island (Fig.1), the current speed and water depth in reef areas is 0.5m/s and 6m respectively. It is supposed that the axes be perpendicular to the current and in parallel with the current as shown in figure 2 and figure 3. It can be seen from the simulation results that a so called “deceleration area” can be formed around the reef. The current speed at upriver area is smaller at about 0.3m/s, and the current speed at side face of reef is about 0.4m/s. The range of the eddy behind reef is in a strip area and the speed there is the smallest. The influence range of the upwelling field is one and a half times as large as the height of the reef, and the largest current speed is almost 0.64m/s (Fig.4 to 5). The results of numerical modeling show that the characteristics of flow field around reefs are better when the axes of the reef are perpendicular to the current. Because it is difficult to make model experiment or view on the sea spot, the simulation method can replace the flume tank test and spot observation. The simulation method can economize the test costs, shorten the designing time and obtain much data, so it is a convenient and economic tool for the artificial reef designs. It is expected that some measures or methods to optimize the shape of the artificial reefs can be found by numerical simulation instead of the model test in flume tank and the field trials in the sea.

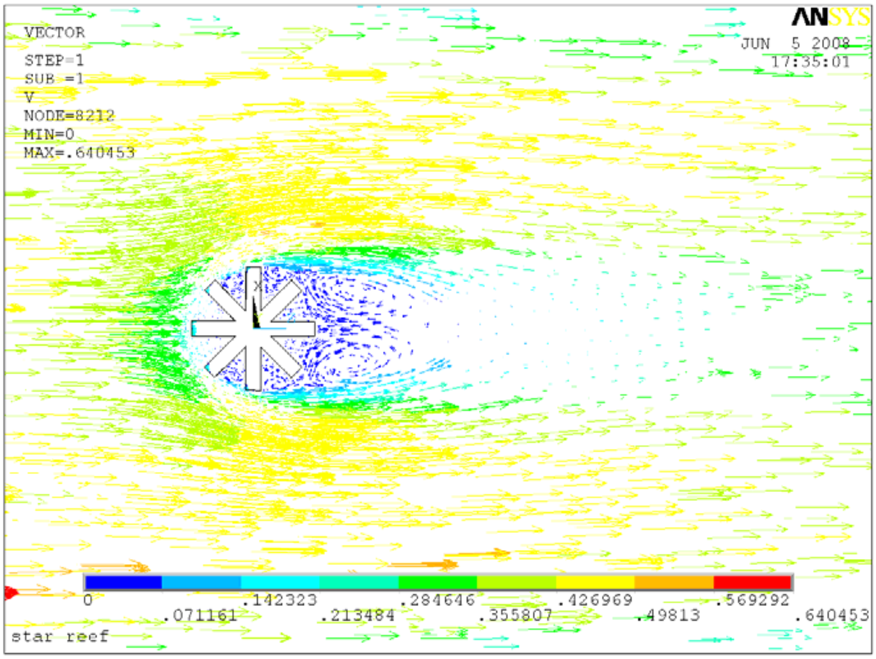

Fig.4: Vector plot of current in condition 1 (axes perpendicular to the current)

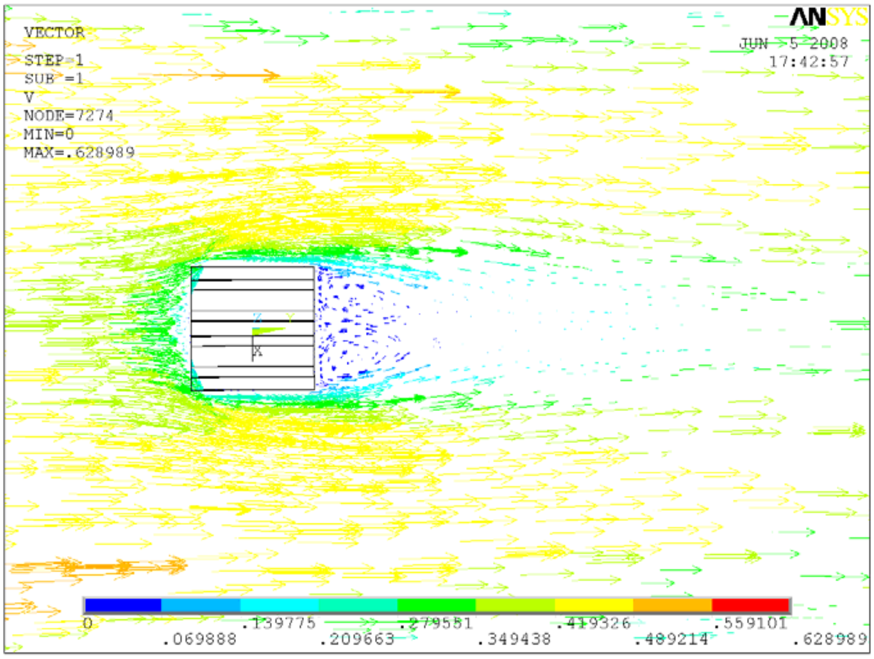

Fig.5: Vector plot of current in condition 2 (axes in parallel with the current)

Key words: CFD method; artificial reef; characteristics of flow field; numerical modeling

Effectiveness of artificial reefs in the western coastal waters of Korea

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This study describes the effectiveness of artificial reefs in the western coastal waters of Korea. Korea has been installing artificial reefs since 1971 for the enhancement of coastal fisheries productivity. Through 2006, national funding has increased every year, totaling approximately $676 million (U.S.), and the total installation area amounts to approximately 191 thousand hectors (ha). Of this area, 41621 ha were created in the western coastal waters of Korea. 42 reef designs are used in Korea, 26 reef designs are for finfish, and the other for shellfish and seaweed.

Reef materials used in Korea are mainly concrete and steel. Concrete reefs are chiefly placed for attracting benthic or residential fishes, and steel reefs for pelagic or migratory fishes. In order to sustain the performance of reefs for the service life of more than 30 years, the post-placement management of artificial reefs must be conducted. The management comprises four steps: survey of the state of the reef installations; removal of derelict fishing gear from the reefs; evaluation of the reefs' functions; and incorporating the surveyed data into a database. Of them, the survey for evaluation of the reefs' functions is made to assess whether the existing reefs fulfill their requirements, including the durability of the reef structures, enhancement of the fishery harvest, and increase in biomass.

In Korea, investigation into the effectiveness of reefs has been carried out since 1975, five of six reef sites including yellow sea are monitored every year. Effectiveness is mainly estimated by the observations of fish species through SCUBA diving and fish catch through fishing gears such as trammel gill net, hooks and etc. Statistics indicate the catch volume per reef was 2.2 to 2.9 times greater in artificial reefs than in non-artificial reef. There were 104 fish species caught at reef areas, out of some 800 fish species that live in the Korean coastal waters. The results mean that artificial reef is one of the important tools for the enhancement of coastal fisheries productivity.

Design and Performance of Super-intensive Shrimp Culture System

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*Presented

Culture of *Litopenaeus vannamei* in a super-intensive system is a kind of effective technology in aquaculture. It can use water resource efficiently, reduce the waste water discharged to environment, and it can also greatly enhance output.

The paper is divided into two parts. The first part aims at design of super-intensive culture systems, the changing rule and infecting factor of water quality. The result indicated that culture density had no significant effect on water quality in culture tank (NH_4-N, NO_2^--N and COD_{Mn}). Residual feed is the key factor which leading to bad water quality, while dead shrimp body has a little influence on water quality as compared with feed remnant, excrement effects. The data showed that the residual food remaining in pond should be removed as soon as possible and thoroughly, so as to meet to keep water quality for shrimp growth in high intensive cultivation aquaculture and to meet the environment standard. The change rule of water in 24hrs was that NH_4-N had slim increasing after feeding and kept stable in night. The concentration of COD also increased slimly after feeding and then decreased fluctuantly and kept stable in night.

Another part is aim at the budgets of important elements in Super-intensive Shrimp Culture System.The budgets of carbon, nitrogen, phosphorus and energy in 6 shrimp super-intensive culture systems were deal with in this paper. The material is *Litopenaeus vannamei* with initial body weight of 0.098±0.013g. The stocking rate is 700 ind./m^3 and 1250 ind./m^3 both with three repeats. The experiment was finished in 94d and only formatted feed was used. Only 1.10% of the total water volume was replaced by fresh seawater every other day during experiment period. The means of survival rates and ultimate body weight is 81.12±4.94% and 2.33±0.08g, respectively. The production is 1.75±0.17kg/ m^3. The feed coefficient is 2.04±0.10. Main results according to 6 SSICS as follows:

1. The budgets of carbon

1.1 The equation of carbon budgets as follows: Feed (100%) = Shrimp assimilated (30.60%) + System filtered (36.77%) + System transformed (10.91%) + Accumulated in water (1.02) + Pipe consumed (20.70%).

1.2 The average ratio of carbon shrimp eaten to total feed carbon used (narrow sense food taken rates, nFTR) is 54.39%. And the carbon assimilated by shrimp is 30.60% of total feed carbon used (TFC). The carbon accumulated in harvested shrimp (the ratio of growth carbon, RGC) is 13.60% of TFC. The RGC is observably bigger than that of in shrimp culture in nature pond and the Lindeman's efficiency. In another word, the carbon utilized efficiency in SSICS was improved.

1.3 Carbon transformed in system (including respiration of corallite, microbe ball and water) is 10.91% of TFC. When experiment finished, the concentrations of dissolved organic carbon (DOC) and particulate organic carbon (POC) was only 8.80mgC/L and 2.38mgC/L. So water treatment parts run well and the quality of system water was limpidity. In a word, basing on the budgets of carbon, SSICS is feasible and promising.

2. The budgets of nitrogen

2.1 The equation of nitrogen budgets as follows: Feed (100%) = Shrimp growth(22.27%) + System filtered(47.22%) + System transformed(15.39%) + Accumulated in water(3.99%) + Pipe consumed(11.13%).

2.2 The average ratio of nitrogen shrimp eaten to total feed nitrogen used (narrow sense food taken rates, nFTR) is 62.23%. And the nitrogen assimilated by shrimp is 40.55% of total feed carbon used (TFN). The nitrogen accumulated in harvested shrimp (the ratio of growth nitrogen, RGN) is 22.27% of TFN. The RGN is observably bigger than that of in shrimp culture in nature pond and the Lindeman's efficiency. In another word, the nitrogen utilized efficiency in SSICS was improved. 3.3 In SSICS, nitrogen filtered (including excess food, feces, molted shells and waste water) is 47.22% of TFN, so the function of filtering part is very important.

2.3 The ammonification in system (including corallite, microbe ball and water) is 14.90% of TFN. The nitrification in system (including corallite, microbe ball and water) is 21.80% of TFN. When experiment finished, the concentrations of ammonium and nitrite was only 0.183mgN/L and 0.329mgN/L. So water treatment parts run well and the quality of system water was stable. In a word, basing on the budgets of nitrogen, SSICS is feasible and promising.

3. The budgets of phosphorus

3.1 The equation of phosphorus budgets as follows: Feed(100%) = Shrimp growth(9.79%) + System filtered (54.677%) + Accumulated in water(3.40) + Phosphate sediment(32.15).

3.2 The average ratio of phosphorus shrimp eaten to total feed phosphorus used (narrow sense food taken rates, nFTR) is 64.62%. And the phosphorus assimilated by shrimp is 21.68% of total feed phosphorus used (TFP). The phosphorus accumulated in harvested shrimp (the ratio of growth phosphorus, RGP) is 9.79% of TFP. The RGP is observably bigger than that of in shrimp culture in nature pond and can be compared with the Lindeman's efficiency (10%). In another word, the phosphorus utilized efficiency in SSICS was improved.

3.3 In SSICS, phosphorus filtered (including excess food, feces, molted shells and waste water) is 54.67% of TFP, so the function of filtering part is very important.

3.4 As the cycle of phosphorus is a sedimentary cycle in nature, 32.15% of TFP was phosphate sediment in SSICS. When experiment finished, the concentrations of phosphate and organic phosphorus was only 0.63mgP/L and 0.22mgP/L. In a word, basing on the budgets of phosphorus, SSICS is feasible and promising.

Solids Wastes Control in an Intensive Semi-Recirculating Rainbow Trout Farm
고밀도 반 순환여과식 무지개송어 양식장의 고형물질 제거

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Solid wastes in the effluent water of intensive aquaculture systems affect the natural body of water. Therefore, management of solid wastes in the intensive culture system is not only one of the key factors for managing the health of fish but also for the protection of natural body of water to which effluent from the system is discharged. Various methods or equipments of solids removal strategies such as swirl separator, drum and disc screen filters, and sedimentation chambers, have been employed in the aquaculture industry. Recently, biofilter in the Intensive Bio-production Korean (IBK) system showed not only effective in nitrification process but also effective in solids removal from the water. Therefore, the efficiencies of suspended solids removal of the biofilter in the IBK system at an intensive semi-recirculating rainbow trout farm (Fig. 1) were evaluated.

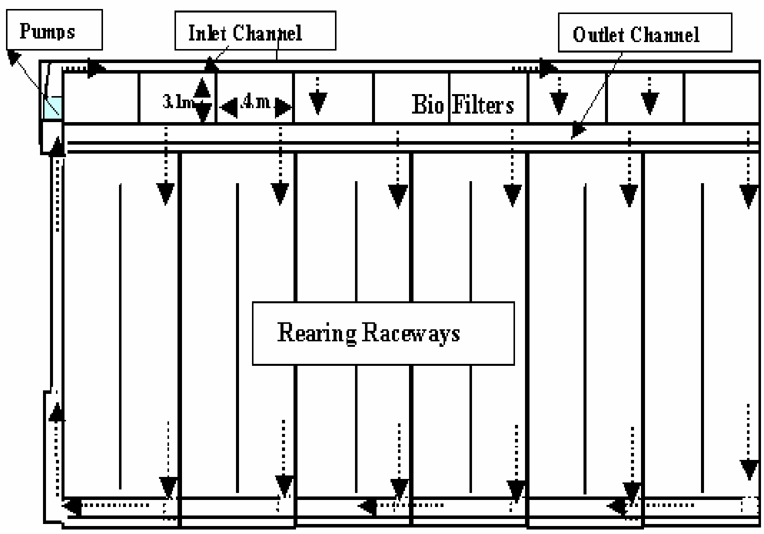

Figure 1: Schematic drawing of raceways and biofilters in the tested semi-recirculating rainbow trout farm

The biofilter in the IBK system in the rainbow trout farm was effective to reduce total suspended solids (TSS) with average removal efficiencies of 74.5% (Table 1).

Corrugated plastic plates (Fig. 2), the filter material used in the IBK system, were very effective to trap TSS. This is because of the high specific surface area (237.8 m^2/m^3) and high upward surface area of biofilter material for sedimentation (40 times floor area of the biofilter) and slow water velocity through the biofilter. This biofilter showed high possibility to control solid wastes in the effluent water of intensive finfish culture farms.

Table 1: Removal efficiencies of TSS and SS in the IBK system biofilter

	Before	After
Average TSS (mg/L)	3.64	0.928
SD(±)	0.645	0.188
Average SS (mg/L)	1.53	0.928
SD(±)	0.13	0.188
Removal efficiency of TSS (%)	**74.51**	
Removal efficiency of SS (%)	**39.20**	
Removal (kg/d) of TSS	32.50	
Removal (kg/d) of SS	7.20	
Removal ($g/m^2/d$) of TSS	0.72	

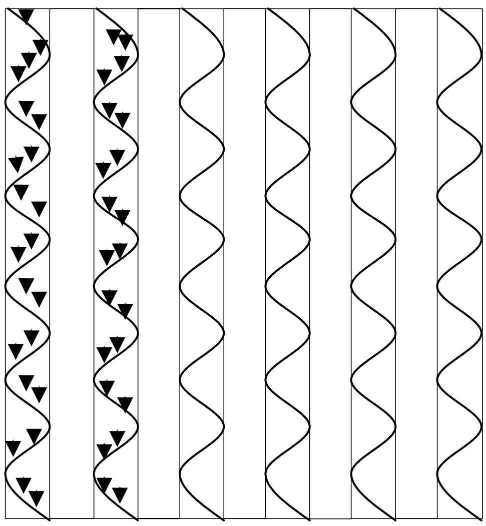

Figure 2. Schematic drawing of corrugated plastic plates arranged in the IBK system biofilter

* Short distance of SS settling
* Settling area 40 x more of floor space
* Specific surface area, 237.8m^2/m^3 (302 m^2/m^2 of floor)
* 1600 corrugated plastic plates per each IBK system biofilter of 4.0 x 3.1 x 1.7 m (D)

IMTA Proposition in Yeosu Expo. 2012.

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There are two important standpoints of Yeosu EXPO, 2012.
The first is that after the EXPO being held in Japan and China, the whole world's attention and concern will be attracted to the North-east Asia by the EXPO which will be held in Korea.
The second is that the Yeosu EXPO will be the first EXPO in the theme of the marine and environment, the slogan of Yeosu EXPO is "The Living Ocean and Coast", and many events about various fields of ocean and coast will take place.

In these events, IMTA is very important event in the relationship of marine environment and industries. Not only the IMTA, the other projects such as promoting of marine forest and the complex of reducing CO_2 are also promoted. IMTA is the event which will take industrial effects in profile directly.

The IMTA of Yeosu coast will be showed as follow.
Remove the pollution source caused by cage-aquafarms and underwater shellfish aquafarms in Yeosu coast, the methods of make use of marine algae are necessary in order to ensure the environmental feed source for the abalone culture. Especially, after the culture methods of industrially important brown algae such as *Ecklonia cava*, *Eisenia bicyclis*, *Sargassum*. sp, *Laminaria japonica*, *Undaria pinnatifida* are improved, the methods of make use of these brown algae will be developed.
Upon the benefits of marine algae such as releasing oxygen, absorption the source of eutrophication, diffusion of floating matters and excretions, and the environment of aquafarms will be purified. The yield of marine algae also can be applied to the fishermen who culturing abalone, so the burden of them will be reduced. There will be many economical benefits if the regular marine aquaculture can be changed to composite order, the fishermen's income source will be created and the cause of aquaculture will also be reduced.
국문제목 : 2012 여수 EXPO 에서 IMTA 제안

Immunity and Biological Methods of Disease Prevention and Control

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World aquaculture has grown significantly during the past half-century, and contributed enormously to global supplies of protein and food continues. The aquaculture of marine animals concerns all parts of the world but this activity significantly contributes to the economical development of China. Of the world total, the production from China is reported to account for about 70 percent of the total quantity and 51.2 percent of the total value of aquaculture production. However, it is now commonly agreed that the sustainability of aquaculture at the world scale greatly depends on the control of disease problems that affect regularly the production. The difficulties to control diseases in aquaculture come from the differences in susceptibility of the animals (from vertebrates to invertebrates) and the diversity of pathogens (bacteria, viruses, fungi or protozoans). To overcome such problems, the common practise in aquaculture was based on the intensive use of antibiotics and chemicals which have fostered the development of drug-resistant bacteria. Moreover, the abuse of antibiotics and chemicals has the incontrovertible harmful consequence for environment. The etiological diversity of pathogens and the repeated appearance of new diseases that affect the cultured species led to develop new approaches for the control of diseases. These approaches can be based firstly, on the development of new preventive and curative treatments of pathogens, and secondly, on the selection of animals with non-specific resistance to pathogens.

The immunity of marine animals and its application in disease prevention and control such as vaccine and immunostimulants are discussed, and the preliminary progress in the study of scallop immunity and the potential immunity-based approaches to control disease are also included in the presentation.

Examples for disease prevention in Korea; bacteriophage, antibiotics

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Bacteriophages have an effect on a considerable influence on controlling environmental bacterial populations. These phenomena are of considerable potential importance because of the prominent role of bacteria as mineralizing and chemical transforming agents within the environment. The virulent bacteriophage can specifically infect the host bacteria and lyses its host within one or several hours. Therefore, the bacteriophage can serve the purpose of specific biological control of fish diseases. We have studied on the possibility of the bacteriophage as a biological control agent for lactococcal infection in yellowtail. Yellowtail was injected intraperitoneally with a *Lactococcus garvieae* strain and the bacteriophage was also intraperitoneally injected simultaneously, 1h after or 24 h after the bacterial challenge. As a result, survival rates following experimental infection with *L. garvieae* were significantly higher in the yellowtail treated with bacteriophage than that of control fish administered with TSB. The higher protective effects were observed in the earlier treated groups with bacteriophage preparation.

It is well known that marine vibrios cause serious diseases and high mortality during the larval stage of oyster in the summer, bringing huge economic loss to oyster farmers. Once oyster larvae were infected by vibrios, more than 90% of them were killed within 24 hours, becoming one of the most serious problems in oyster industry in Japan, Europe, and U. S. Among vibrios, *V. tubiashii, V. alginolyticus, V. anguillarum, V. splendidus* are known to cause the serious vibriosis in oyster larvae. The symptoms mainly appeared in the mantle such as appearance of bacterial colonies, loss of pili, and destruction, called 'Bacillary necrosis'. We have recently identified a new species of *Vibrio sp.* from oyster larvae in Korea showing the typical symptoms of bacillary necrosis and the efficient prevention method using antibiotics. Oyster larvae were immersed in sea water containing vibrios such as *Vibrio sp., V. splendidus, V. angullarum*, *V. cholerae* and *V. vulnificus*, assessed the mortality of larvae, viability and concentration of vibrios every 4 hour. Once the larvae started to die, added different doses of oxytetracycline to test its efficiency to control bacillary necrosis occurred in oyster lavae. In the experiment to test pathogenicity of *Vibrio sp.*, the mortality was first shown after 8 hours and all were killed after 24 hours, indicating high pathogenicity of

Vibrio sp.. Comparing to the high pathogenicity of *Vibrio sp.* other experimented vibrios including *V. angullarum*, *V. vulnificus*, *V. cholerae* except *V. splendidus* seem to have lower pathogenicity as showed mortality of less than 20 %. Oxytetracycline treatment was shown to be an efficient method to control Bacillary necrosis caused by vibrios since the mortality was reduced to 25.5%, 12.38%, 35.3% in Oxytetracycline treated group at the doses of 25ppm, 50ppm, 100ppm, respectively. This study demonstrates that the large casuality recently occurred in oyster larvae hatchery with unknown reason was caused by vibriosis and the mortality can be reduced by oxytetracycline treatment.

Inhibit *Procambarus clarkii* from the infection of WSSV by WSSV reconstructed viral attachment protein 1 (rVAP1)

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The potential for injection of WSSV envelope protein against white spot syndrome virus was investigated. The protein rVAP1 (Viral Attachment Protein one) constructed according to WSSV envelope protein VP281 was expressed in *Pichia pastoris*. A cellulose nitrate membrane was laid on top of the plate in order to quickly screen high-expressing clone. High-expressing reconstructed WSSV rVAP1 clone was selected and expressed successfully. rVAP1 expressed by the screened clone was identified by SDS-PAGE ,Western-blot and the binding capability of rVAP1 to shrimp membrane proteins. *Procambarus clarkii* were infected with WSSV to study the viral titer (median lethal dose). The inhibiting effect of rVAP1 was studied through infecting crayfish with mixtures of different dilutions of rVAP1 and WSSV for 16 days. The results of infection trials showed that rVAP1 which was infected 1.6μg per crayfish could inhibit the infectivity of WSSV which was diluted under the viral titer of 6.81 LD_{50} and delay the death time of crayfish (Table 1). Our study lay a foundation for deeper explanation of pathogenic mechanism of WSSV. It provides a new approach of exploiting antiviral drugs and feeds, furthermore, offers a useful reference to the disease control and the interrelated research.

Table 1. Viral titers (LD_{50}) of different experimental groups

Group	Median lethal dose (LD_{50})
rVAP1 16μg per crayfish	$1.37x10^4$ LD_{50}/ml
rVAP1 1.6μg per crayfish	$1.73x10^4$ LD_{50}/ml
rVAP1 0.16μg per crayfish	3.16×10^4 LD_{50}/ml
X-33 16μg per crayfish	2.46×10^4 LD_{50}/ml
X-33 1.6μg per crayfish	4.58×10^4 LD_{50}/ml
X-33 0.16μg per crayfish	LD_{50} was lower than the most dilution
WSSV stock	1×10^5 LD_{50}/ml

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Physical, Environmental and Chemical Methods on Disease Prevention and Control in China

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The marine production has been renovated time after time from 777,500t in 1980 to 13,848,000t in 2005. However, it is apparent that disease problems play an important role in the development of mariculture industry. According to a national report, the loss from disease impact is about 2.8 billion USD every year in China.

Based on research and practice, there are several methods to prevent and control diseases in Chinese recipes. As the first category, the physical method is usually applied in hatcheries and farms, which includes filters, UV light and ozone (O_3) in order to remove organic matters or kill the bed microorganisms from the water body. Secondly, environmental factors are also important way to prevent and control diseases. For instance, low down salinity even freshwater could decrease the occurrence of white spot syndrome (WSS) in shrimp and parasitic diseases in marine fishes. Reversely, marine fishes are shortly immersed in freshwater will be a useful treatment for parasitic infections, e.g. trichdiniasis, cryptocaryoniosis. Meanwhile, temperature is an important factor can be changed in the practice of disease prevention. In which, heating or adding cold water usually operated in indoor farms or hatcheries. Comparatively, chemical methods are more complicated in the disease treatment. The used chemicals include disinfectants, antibiotics, pesticides, herbals, biotranimated products (immunostimulant, vaccine, microecological modulator, diagnostic reagent etc.) as well as vitamins, minerals. In recent years, use of antibiotics is much reduced, replaced by herbals and microecological modulator (especially probiotics and prebiotics). Several vaccines are available for certain diseases, but the commercial products need to be approved urgently. In recent years, food safety is concerned as the very important event in aquaculture industry. As such, physical, environmental methods are required to pay more attention, rather than chemical methods. For drugs, the products must be chosen before use, it is clear that those drugs should have high efficiency, but with no harm and residues. In addition, it is believed that Chinese herbals have a good prospect in mariculture as they have played an important role in freshwater industry.

A study of the summer mortality of rockfish (*Sebastes schlegeli*) in South Korea

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The rockfish (*Sebastes schlegeli*) is ovoviviparous species that inhabits the waters around the Korean peninsula, south of Hotkaido in Japan, and in the northern coastal area of China. In Korea, the fish has been targeted as a suitable fish species for aquaculture since middle of 1980s after the National Fisheries Research and Development Institute (NFRDI) established a seed production technique. The species shows sedentary behaviour characteristics.

The optimum growth temperature of the rockfish has been identified as 18 - 22°C. When the water temperature rises above 23°C, the feed consumption amount decreases, and at more than 25°C physiological activity declines rapidly. During periods of elevated water temperature this fish species is more sensitive characteristics to other environmental factors such as freshness of fish feed, cage changing, size sorting or fish farm moving .

In Korea the mortality rate during culture caused by disease was about 5.3% in 2004. The diseases of this species include Vibriosis, Flavobacterial disease, Streptococcosis and Gill monogenean parasite. The mortality caused by Streptococcosis has mostly increased during summer season. Gill monogenean parasite can cause anaemia and may induce death in young fish but in adult fish it is not fatal.

In this study, the cause of mass mortality of rockfish that broke out at the fish farms in Tongyeong City and Geoje City regions between late August and early September in 2006 were investigated. Pathological examination of 52 fish revealed no external disease symptoms, with the exception of ulcers or blood spots found on the skin of a few fish. From internal observations and diagnosis results, some yellowish brown liver, intestine bleeding, atrophy and congestion of the abdominal cavity were found. Also in the gill, a swelling phenomenon was noted that may be induced by foreign material accumulation and secretion of mucus also observed. However, the main cause of the mass mortality of rockfish in Tongyeong City and Geoje City region during summer season in 2006 may be due to physiological weakness induced by the abrupt water temperature increase of 3.0 - 6.4□. This sudden temperature rise in a short time period may be induced by the break down of the thermocline caused by typhoon Wookong that occurred during the investigation period.

Screening and Developing of Probiotic Bacteria from the Environment of Culture Shrimps

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In recent years, shrimp culture suffered great damage from viral and bacterial diseases, so its sustainable development was serious constrained. Recognizing the negative effect of antibiotics, emphasis was transferred to stimulate the immune system of shrimp. Immunological capability and health of shrimp is highly correlated to each other, fortunately, immunostimulants can enhance the immunocompetence of animal, which can contribute to health of animal, making them more immune to many kinds of diseases. So how to screen immunostimulants of shrimp became the focus of research.

112 native bacteria strains were isolated from the intestine of different-aged shrimps *Penaeus chinensis* & *Litopenaeus vannamei* and shrimp culture water, in order to screen for probiotic bacteria and to develop micro-ecological agents or immuno-stimulants for cultured shrimp. Twenty-nine stains had been classified and identified by 16S rDNA sequence, API 20E and BIOLOG. Among of them, 24 stains were classified but 4 were identified to genus only.

The intestinal flora of *P. chinensis* in various growth stages were analyzed next. The results show that the quantity of intestinal flora of *P. chinensis* increased unceasingly from egg to brood shrimp in 3×10^7-4×10^8 cfu/g. The category of intestinal flora of *P. chinensis* also increased unceasingly. The major bacteria in intestinal flora from egg to postlarvae were *Bacillus*. Only *Bacillus* contained from egg to nauplius. The bacteria category increased until zoea, *Vibrio parahaemolyticus* and *Vibrio alginolyticus* contained. *Pseudoalteromonas* and *Flexibacter maritimus* contained until mysid. *Root nodule bacteria* and *Vibrio harveyi* contained until postlarvae. The major bacteria in intestinal flora in adult shrimp and brood shrimp were *Vibriol* and *Bacillus*. *Vibrio campbellii*, *Pseudoalteromonas*, *Photobacterium*, *Exiguobacterium Collins* and

Sphingomonas paucimobilis were found in these stages.

The biotic function of intestinal bacteria, isolated from *P. chinensis,* was determined by challenge examination. Ten tested bacteria (PC070460, PC070461, PC070462, PC070463, PC070368, PC070370, PC070373, PC070374, PC070375 and PC070376) were injected to *Penaeus chinensis*, low dosage was 10^4 cells and high dosage was 10^8 cells per shrimp, and *Vibrio anguillarum* was pathogenic bacteria. The result shown that the higher dose of PC070461 and PC070374 were pathogenic to *P. chinensis* ($P<0.05$), however the lower dose reduced the cumulative mortality of *P. chinensis*, and played a protective role to *P. chinensis*. The bacterial strains PC070462 and PC070373 also played a protective role to *P. chinensis*, and increased the survival rate of *P. chinensis* obviously ($P<0.05$). The lower dose of bacterial strain PC070463 played a protective to *P. chinensis* ($P<0.05$), while the higher dose has no protective effect to *P. chinensis*. The bacterial strain PC070376 was a weak pathogenic bacterium, and it was pathogenic to *P. chinensis* to a certain extent.

There are four stains which were isolated from the intestine of *Litopenaeus vannamei* showing antagonism against three pathogenic indicator vibrios, *Vibrio anguillarum*, *V. harveyi*, and *V. parahaemolyticus*. Their inhibitory activities were tested by solid diffusion assay and liquid blend assay. And these 4 stains didn't show pathogenicity to artificially infected shrimp. The 16S rRNA of strains were sequenced and compared with those of relative strains. Strains LV060806, LV060808 were identified as *V. natriegens*, and LV060810, LV060815 as *V. alginolyticus* in physiology and biochemistry shown molecular phylogenetic dendrogram.

The optimum culture medium of 6 stains (LV060810, LV060806, PC070477, PC070568, PC070573, PC070460) were detected at last, by Single-factor test and uniform design. Estimated optimum medium composition include Sucrose, Tryptone, Beef Extract, Yeast Extract, Trisodium Citrate Dihydrate, K_2HPO_4, $MgSO_4$, inoculum size and appropriate pH. Next, our research work will focus on screening live bacteria, killed bacteria or component of bacteria in order to develop micro-ecological agent or immunostimulants for shrimp culture.

Sanitary characteristics of *Vibrio parahaemolyticus* in Korean farming area

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To ensure that shellfish is safe for human use, the Republic of Korea operates the Korean Shellfish Sanitation Program (KSSP). Since 1970s, the KSSP is performed by the National Fisheries Research & Development Institute (NFRDI) which surveys shellfish growing areas to secure public health and to ensure the food safety of shellfish products shipped to foreign countries (e.g. United States, EU and Japan). The Sanitary Survey includes indicative bacteria (coliform group, fecal coliform etc.), human pathogens (*V. parahaemolyticus*, *Shigella* spp. and *Salmonella* spp. etc), and chemical and physical elements

Generally, *Vibrio parahaemolyticus* is thought to be most important causative microorganism in bacterial food poisoning through seafood consumption. Every summer *V. parahaemolyticus* related food poisoning is a common problem and has a detrimental influence on the seafood market. Therefore the risk of *V. parahaemolyticus* should be given careful reconsideration.

To investigate the importance of *V. parahaemolyticusin* in the contamination of shellfish and seawater from farms; samples were examined for the total count of *V. parahaemolyticus* and the presence of tdh and trh positive *V. parahaemolyticus* from 2005 to 2007.

The average detection rate of *V. parahaemolyticus* from 644 samples was 29.7% and the detection rate was highest during periods of higher water temperature, from July to September. The range of *V. parahaemolyticus* total count in samples of farmed oyster was <30~11,000MPN/100g. and tdh(or trh) gene was detected from 19 isolates. It was found that tdh and trh positive *V. parahaemolyticus* was not common in the Korean marine environment.

Bioremediation of mariculture environment: A case study in a marine cage fish farm in Daya Bay*

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Self-induced environmental deterioration around marine cage fish farms has been widespread in South China Sea coast since marine cage fish farming first began in Guangdong coastal waters of China at the end of 1970s. To mitigate the adverse impacts caused by marine cage fish farming and sustain future development of marine cage fish farming industry, a integrated bioremediation model of fish-mussels-seaweeds polyculture, probiotics using and land-based seawater-resistant vegetable planting was established in a marine cage fish farm in Daya Bay, China. It showed that pacific oyster and seaweed (*Graciaria lemaneaformis*) culture and harvest could remove lots of nutrients from seawater, reduce eutrophication. Integrating seaweed in to fish cage could also bring mutual benefits to co-cultured organisms. In laboratory test, probiotics (photosynthetic bacteria, PSB) using could restrain the growth of SRB isolated from sediment in cage fish farm effectively. Land-based seawater-resistant vegetable (*Calicornia biglovii*) planting test showed that polluted sediment from cage fish farm can be used as plant food for *Calicornia biglovii* growing.

Key words: integrated bioremediation; cage fish farm environment; Daya Bay

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Toxicity of heavy metals on survival and physiological responses of three bivalve mollusks, *Crassostrea gigas*, *Tegillarca granosa* and *Ruditapes philippinarum*.

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Heavy metal pollution caused by development of the industrial society is becoming an important ecological issue. Various heavy metals, which are discharged into natural environment, are directly and indirectly absorbed into organisms having undergone various changes in state. Accordingly, as harmful heavy metals are discharged into coastal sea regions, they are slowly accumulated in aquatic organisms. Eventually, accumulation levels can impart serious hazard to health of humans as they are concentrated through food chain. In the marine environment, heavy metals and chemical substances impart affects on the existence and growth of shellfish as well as causing functional disorders by inducing a diverse range of physiological changes. The majority of shellfish farms are located along seashores, thereby increasing the possibility of exposure to various pollutants including heavy metals. From a long-term perspective, such an exposure may eventually reduce the production of shellfish.

This study examined the accumulation of heavy metals in shellfish sampled from the coastal areas around industrial estates located in the South Sea regions of Korea. In addition, through laboratory experiments, the toxic effects of Cu and Pb on survival, respiration, reproduction as well as the internal structure of these shellfish, has been investigated.

This study is part of the continuous management of heavy metal pollutants around shellfish farms.

Effects of Mass of Artificial Fouling Added to the Upper Valve on the Growth and Survival of Two Scallops *Chlamys farreri* and *Patinopecten yessoesis* Cultured in Sanggou Bay, China

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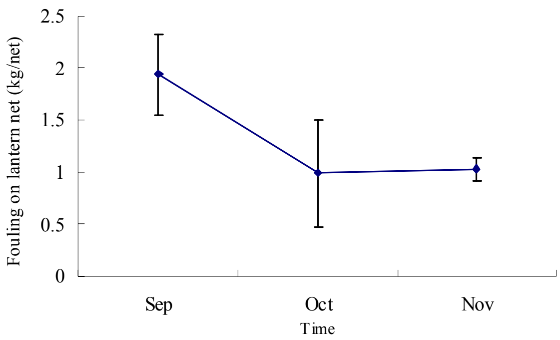
Chlamys farreri and *Patinopecten yessoesis* are the major species cultivated in Sanggou Bay which is one of the most important mariculture coastal waters in northern China. Fouling organisms affect scallop culture in various ways. Firstly, the biomass of fouling organisms on the lantern nets and on the scallops was quantified, from September to November 2007. Secondly, the effects of the mass of fouling on two scallops *C. farreri* and *P. yessoesis* were investigated by added artificial fouling (cement) weighing 0.5, 1, 2 and 3 fold the mass of the upper valve to the upper valves of *C. farreri* and *P. yessoesis*. Scallops with no artificial fouling added serviced as control. After 60-d longline cultivation the increases of shell length, dry mass of muscle and remaining soft tissue and the survival of the scallops were examined. Wet weight of fouling on lantern nets was greatest in September and lowest in October, ranging from 0.99kg to 1.94 kg (Fig. 1). The mass of shell fouling was maximum in November and minimum in October, ranged from 0.49g to 2.09 g (Fig. 2). The mass of fouling organisms on lantern net was almost equal to the weight of the lantern net. The mass of fouling may cause cultivation facilities failure or even sinking. Because fouling cleaning operation induce prolonged aerial exposure which reduces the growth and survival of cultivated scallops. It is suggested to deploy mechanical methods to keep the longline and cultivation nets in proper depth. There were no significant differences of the growth and survival between the treatment and control groups (Fig. 3, 4, 5, 6). The results indicated that the mass of artificial fouling added to the shell of did not impose detrimental effects on the two scallops. In Sanggou Bay, even in summer seasons when the fouling was heaviest, the mass of natural fouling that developed on scallop shells was much lower than the experimental levels. Thus, it may be unnecessary to frequently clean the scallop shells. The aerial exposure and handling of scallops which were induced by the operation of cultivation nets changing or cleaning should be as less as possible.



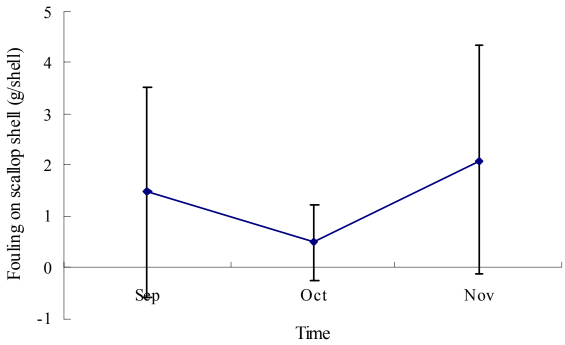


Fig 1. Mass of fouling organisms on scallop *C. farreri* lantern nets. Vertical lines represent standard errors

Fig 2. Mass of fouling organisms on scallop *C. farreri* shell. Vertical lines represent standard errors.

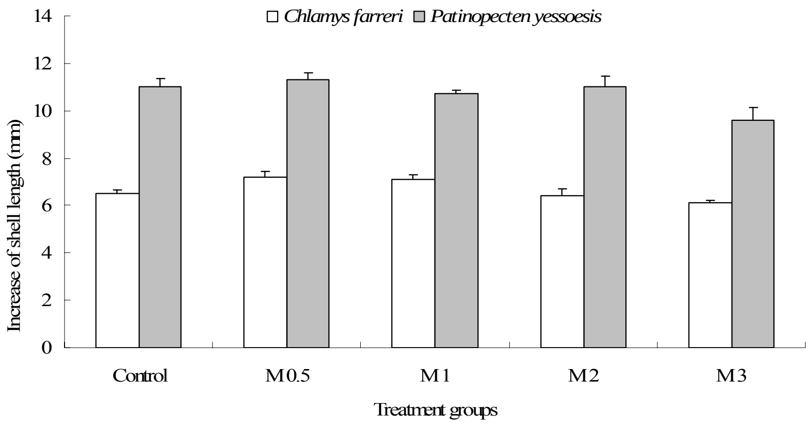


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Figure 3. Effect of mass of artificial fouling added to the upper valve of *C. farreri* and *P. yessoesis* on the increase of shell length. Vertical lines represent standard errors.

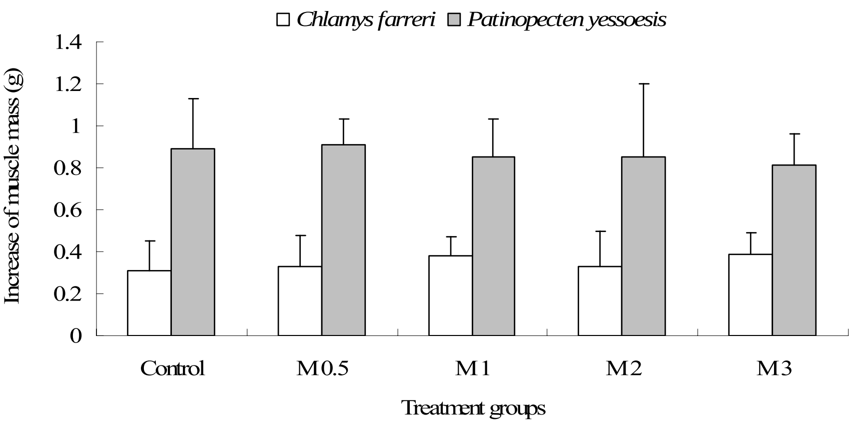

Figure 4. Effect of mass of artificial fouling added to the upper valve of *C. farreri* and *P. yessoesis* on the increase of dry mass of muscle. Vertical lines represent standard errors.

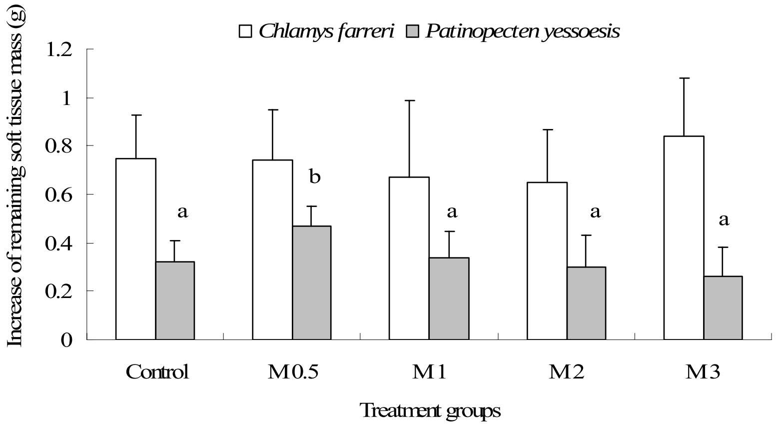

Figure 5. Effect of mass of artificial fouling added to the upper valve of *Chlamys farreri* and *Patinopecten yessoesis* on the increase of remaining soft tissue. Vertical lines represent standard errors.

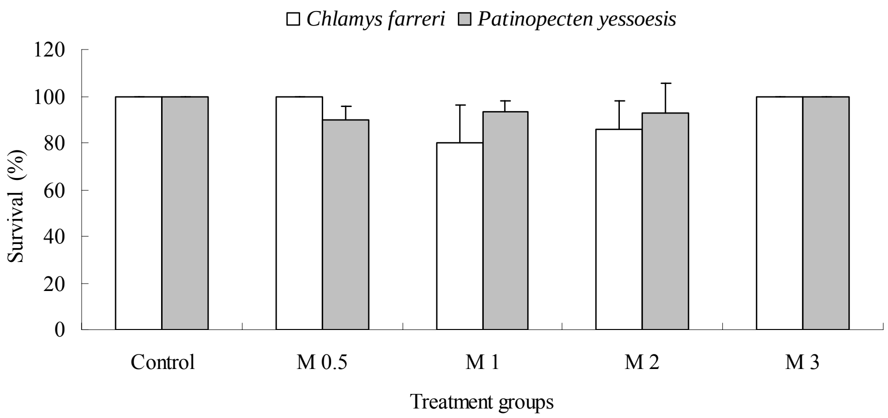

Figure 6. Effect of mass of artificial fouling added to the upper valve of *Chlamys farreri* and *Patinopecten yessoesis* on the survival. Vertical lines represent standard errors.

Natural Precious Seafood, Standard Process Management-Shellfish Ecological Aquaculture and Safety Control in the North of Yellow Sea

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Dalian Zhangzidao Fishery Group Co., Ltd, a fishery group originating from Yellow Sea, now has developed to be the “National Key Flagship Enterprise in Agricultural Industrialization” and a public company. I would like to share the following experience with you, which is crucial for our development

First, we have groped out an ecological aquaculture method, which fits the sea condition, is characterized by large-scale production of shellfish and sea bottom multiplication. Second, we take it as our responsibility to produce the high-quality, safe precious seafood, paying attention to the management of processing quality from the origin of products to the market. Our aim is “To be the manufacturer of high-quality, safe and healthy choice aquatic products across the world”, for which we have been making unremitting efforts. In the present, it contents:

1. Developing Zhangzidao Fishery Group
    - The mariculture area Condition;
    - The mariculture Industry;
    - The Management system of the Group;
2. The Ecological Bottom Multiplication Method for Large-scale Shellfish Aquaculture
    - The Ecological Sea Bottom Multiplication Method
    - General Introduction of Proliferation
    - Bottom culture method
    - Harvest technique
3. Quality Control for Food Safety from the Origin of Products to the Market
    - HACCP management system in Zhangzidao Island;
    - The Control of Seawater Environment;
    - Management for the Breeding progress;
    - Temporary Maintenance for Equipment and Purification Treatment;
    - Products processing management

Best management practices for sustainable mariculture; Korean oyster aquaculture industry as a case

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Oysters are considered to be the most important shellfish in the aquaculture industry of the Republic of Korea; the industry produced 251 706 tonnes of oysters in 2005. In Korea Rep., the Pacific oyster, *Crassostrea gigas*, is widely cultured along the southern coast where a number of small, shallow bays (mostly <10 m in depth) are protected by numerous islands. Oysters are intensively cultured in these bays with a long-line suspended culture system. The Korean oyster industry uses oyster spat collected from mid-summer to early fall as seed. Oyster spat that settle on the strings undergo 7–9 months of hardening in intertidal areas. After the hardening period, the oysters are relocated to a grow-out field in the middle of the bay. Oysters are then harvested during late winter and mid-spring, 9–11 months after grow-out. Approximately 3 400 families are engaged in the oyster long-line culture industry on the southern coast, with 22 000 full-time employees in 2005. Inter-annual variation in oyster landing has been observed and this is in part associated with environmental contamination as well as some problems involved in the management.

Benefit evaluation of IMTA based on ecosystem service.

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IMTA is an advanced aquaculture systems approach which combines the cultivation of fed aquaculture species with organic extractive aquaculture species and inorganic extractive aquaculture species to create balanced systems for environmental sustainability, economic stability and social acceptability. As a life-supporting system, IMTA aquaculture system provides various services for human being. Based on ecosystem services, the market income and benefits of shellfish and seaweed co-culture ecosystem were calculated and evaluated in Sanggou Bay, one of the most environmentally scrutinized and regulated regions in the China, even in the world, taking an active role in assessing the socio-economic and environmental benefits of IMTA. The results show that IMTA is a sustainable ecological aquaculture system approach, and introduction of IMTA has greater contributions to the local social economy, environmental regulation and social culture.

Economic analysis of offshore aquaculture in Korea: a financial evaluation based on rock bream (*Oplegnathus fasciatus*) production

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Interest is growing in offshore aquaculture as a means of overcoming environmental concerns that plague onshore and coastal aquaculture production. However, these environmental gains may be offset by higher investment costs, higher operating expenses, and greater risk. As with any new production process, there are little data available about the economic performance until a sufficient-size industry develops from which to gather data. In this paper, we based an economic analysis of rock bream, *Oplegnathus fasciatus*, culture in the offshore waters of Jeju Island, Korea, on the actual performance of a privately owned and operated aquaculture enterprise.

Financial performance of the offshore system was evaluated using stochastic simulation model (Monte Carlo simulation model) to project the necessary conditions for long-term success for similar offshore operations. To compare performance, it is focused on the 10-yr internal rate of return (IRR) and net present value based on different assumptions regarding fish survival rate and market prices.

The baseline model that used the observed survival rate and market prices has an IRR of 18.6%. Financial performance became a lot riskier when survival rates decrease and costs such as fingerling and feed increase. In addition, if prices fall from the initial baseline level in the early year of production, then the operation has little chance of surviving.

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for

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