The Scientific Justification for Practical Management in the Yellow Sea

About this publication:

This publication presents the results of 22 demonstration projects carried out during the first phase of the Yellow Sea Large Marine Ecosystem Project 2005-2010. The studies were commissioned in order to provide evidence of the effectiveness and usefulness of the management actions identified within the Project's Strategic Action Programme (UNDP/GEF 2009). The reports have been summarised by Helen Davies, Isao Endo and Yihang Jiang of the YSLME Project Management Office (PMO). Full versions of the reports including bibliographies can be found on the project website www.yslme.org and on CD.

The PMO would like to thank all those involved in the demonstration projects and their associated outputs. These collective efforts have helped progress the knowledge base for the Yellow Sea LME area considerably and cemented collaborative partnerships between scientists and practitioners within the member states and beyond.

Disclaimer:

For reference purposes, this report may be cited as:

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FOREWORD

By Yihang JIANG, Project Manager
UNDP/GEF Yellow Sea Large Marine Ecosystem Project

The Yellow Sea is one of the most productive sea areas in the world, its vast mudflats providing feeding grounds for huge flocks of waterbirds on their migration between Russia and Australia. Tens of thousands of people sustain their livelihoods from the Sea's rich coastal waters. But the Yellow Sea is showing signs of stress and over exploitation. Swarms of jellyfish and changes in the dominant fish species indicate that major changes are occurring in the Sea's natural functioning systems.

I first became involved in the Yellow Sea Large Marine Ecosystem Project in 2004 when the Governments of China and the Republic of Korea wanted to understand the causes of these problems in the marine environment. The UNDP and GEF provided support and financial assistance. Since then we have developed a substantial programme of work to identify the changes in the Yellows Sea's physical and biological make up. The Project's Transboundary Diagnostic Analysis (TDA) described the extent and nature of these changes, highlighting their root causes. The Strategic Action Programme (SAP) then set out a plan for tackling them. Both these documents were fully endorsed by the Countries bordering the Yellow Sea. Throughout the first phase the neighbouring countries have worked hard to establish a firm foundation for international collaboration and co-operation that will sustain efforts to resolve the Yellow Sea's current environmental problems long into the future.

The Yellow Sea Regional SAP takes the ecosystem-based approach to dealing with the problems in the marine environment and takes into account the carrying capacities of the system. The main objective of the SAP is to recover and/or maintain the Yellow Sea's ecosystems, enhancing their capacity in 'Providing, Regulating, Supporting and enabling Cultural Services, which can be accessed by millions of people who live alongside the Yellow Sea coast. The SAP is based on scientific findings and knowledge of marine science which have been applied to the design of the management actions. Demonstration projects and pilot projects have been implemented in order to understand the usefulness and effectiveness of these management actions. Their results have been very encouraging.

This publication presents a synthesis of the work of many scientists and Partners who, with the PMO's support, have carried out and reported on the demonstration projects. The full reports are available from the PMO.

As we look to the future, the ever growing demand for marine and coastal resources and competition for space and land along the coasts of the Yellow Sea, mean that the need for international co-operation and knowledge sharing is greater than ever. I hope this publication provides a source of information and inspiration to all those with an interest in and love of the Yellow Sea and of the many wonders contained within it.

Yihang JIANG

Assessing and Monitoring the Impacts of Climate Change on the Yellow Sea Ecosystem

Prepared by

The First Institute of Oceanography, China
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November 2009

Objectives and Methods

Climate change can have significant effects on the structure and functioning of marine ecosystems through complex physical, chemical and biological processes. Some climate-related problems were also experienced in the Yellow Sea, such as increases of temperature and salinity, decreases of pH, and rise of sea-level, etc.

This demonstration activity entitled "Assessing and Monitoring the Impacts of Climate Change on the Yellow Sea's Ecosystem" compiles existing data and knowledge on the assessment of climate change impacts on the YSLME, develops regional guidelines and establishes regional networks for monitoring the impacts. It also makes recommendations to governmental agencies in considering the effects of climate change in ocean management.

The Yellow Sea Cold Water Mass (YSCWM) is a bulk of cold water below the seasonal thermocline from spring through autumn which is a protruding phenomenon in the Yellow Sea. During winter, temperature of the whole water column of the Yellow Sea decreases to its lowest value of the year by surface cooling process. In spring, the surface water is heated while the bottom water remains cold. The existence of a strong themocline prevents the vertical circulation, so that the cold water can persist through the warm season. In late autumn, the themocline is broken by surface cooling and the YSCWM disappears. (Hu and Wang, 2004). The YSCWM is located in the deep layer of the central part of the Yellow Sea (Figure 1). Generally, water with a temperature less than 10°C (8°C, or 12°C in some references) during summer is regarded as "cold water".

Changes of YSCWM during 1930s-2007

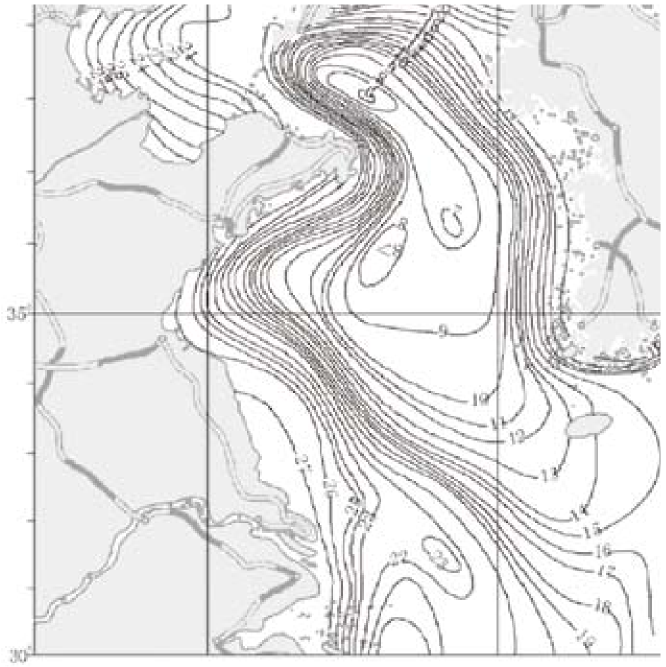


Figure 1 Average bottom temperature (℃) in August in the Yellow Sea

Changes of YSCWM during 1930s-2007

TheYSCWM was first discovered in the 1920s anf 1930s. The range of the YSCWM in 1935 was much smaller than that of 1936.

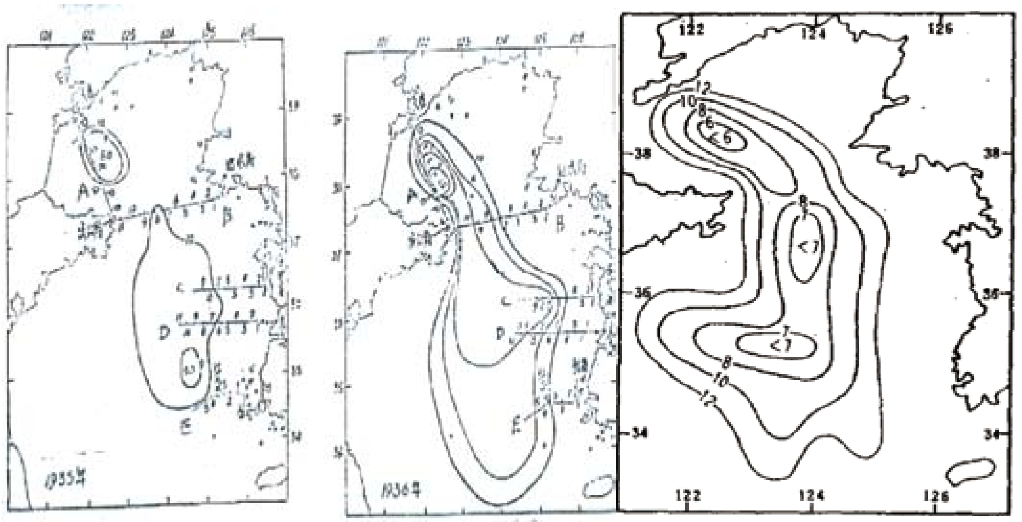


Figure 2 Bottom temperature (℃) in summer in 1935 and 1936 in the Yellow Sea (left) and average Bottom temperature (℃) in summer during 1930-1940 (right)

YSCWM in 2006

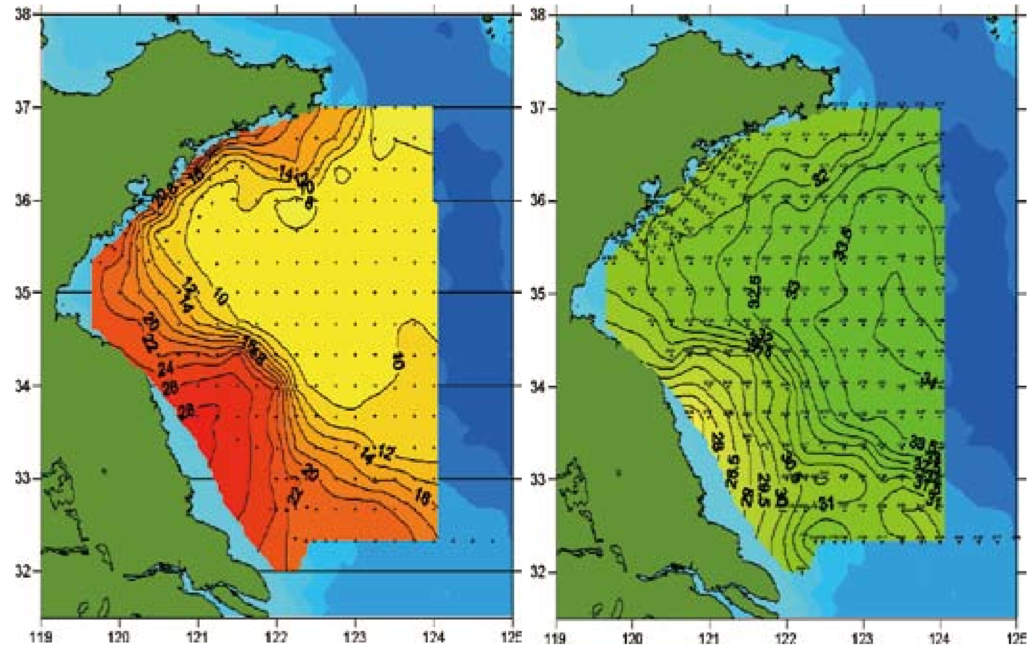
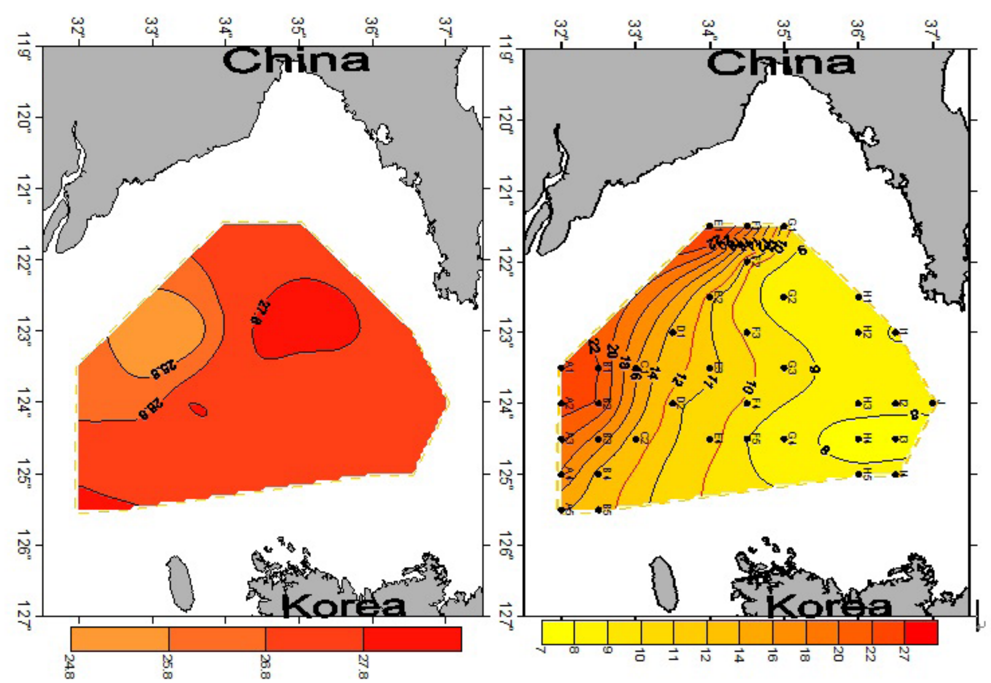


Figure 3 Bottom temperature (℃) and salinity (psu) in July 2006

YSCWM in 2008 (Cooperative Cruises of the YSLME project)



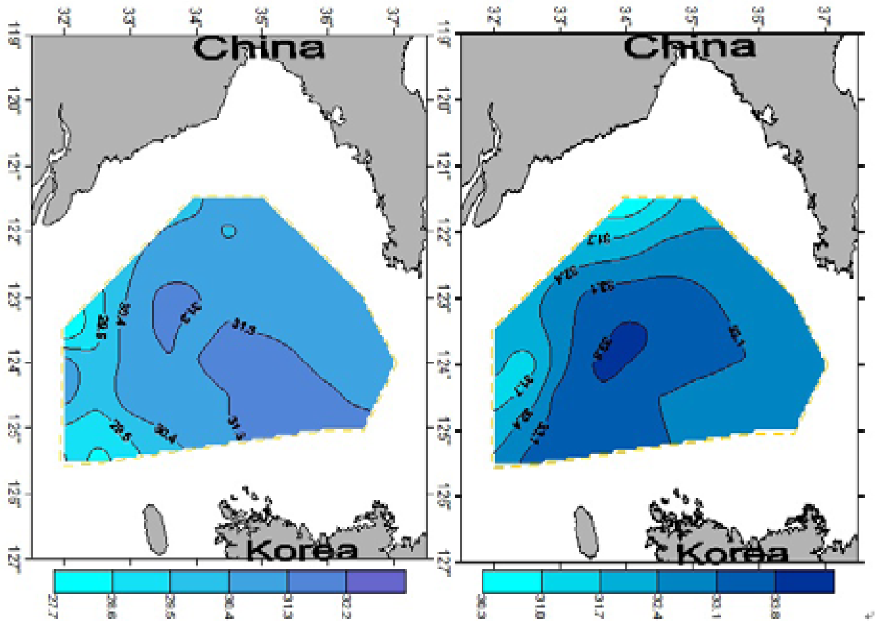


Figure 4 Temperature (℃) and salinity (psu) in Aug. 2008 (left: Surface; right: bottom)

Inter-annual variation of YSCWM

Using isothermal levels as indicators, Song *et al*. (2009) compared the range of YSCWM based on the ROMS model. The ranges of cold water (<12.5℃) at the 25 m layer are shown in Figure 4. The results showed the range of the YSCWM had obvious inter-annual changes with a 5 to 7 years cycle. There was a shift in the 1980s, after which the ranges of the YSCWM decreased to a lower level than that during 1960s to 1980s.

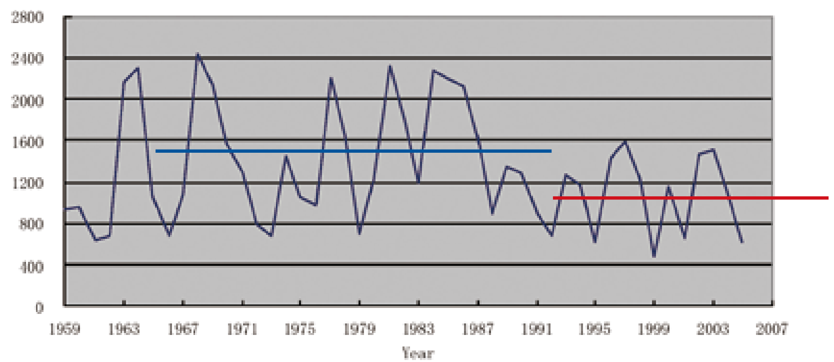


Figure 5 Ranges of YSCWM at 25 m layer during 1959 to 2005 (Redraw from Song *et al*, 2009)

Impacts of Climate Change on Phytoplankton in the Yellow Sea

Plankton are good indicators of climate change in marine environments because of their quick responses to physical and chemical environmental changes and lack of commercial exploitation (Hays *et al*, 2005). In this report, we analysed the impacts on phytoplankton and zooplankton in the Yellow Sea.

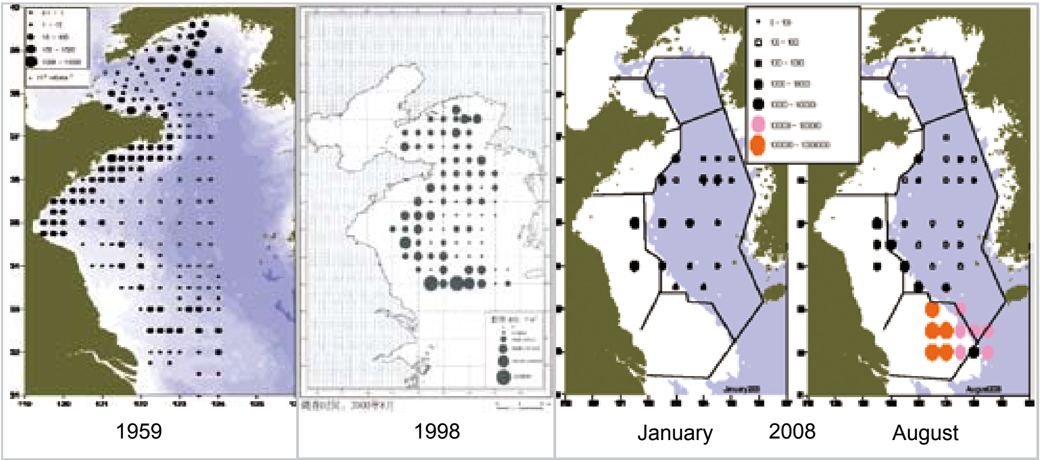


Figure 6 Plankton abundance

Besides the significant differences of phytoplankton abundance in different areas of the Yellow Sea, there were also great changes of phytoplankton abundance in different months. Generally, there were two phytoplankton peaks during one year: one in early spring from February to April, and the other in summer from July to September. In 2006 and 2008, the dominant species were both within the genus *Chaetoceros* and phytoplankton abundance also increased compared with that 50 years ago. This summer bloom was mainly attributed to the intrusion of the Changjiang Diluted Water (CDW), which brought sufficient nutrients and caused stratification in this area. The CDW was then controlled by precipitation in the Changjiang watershed, which was further influenced by broader climate phenomenon such as ENSO, Asia Monsoon, Pacific Oscillation, etc. But for the changes of phytoplankton species composition, human activities such as pollution, fishing and aquaculture are also important influential factors.

Long term changes of phytoplankton in the Yellow Sea

The average phytoplankton abundance is listed in the following table. It covered 4 order magnitudes, from 2.59 ×10^4 cells/m^3 in May to 63363 ×10^4 cells/m^3 in July 2006.

Table 1 Average phytoplankton abundance in the Yellow Sea (×10^4 cells/m^3).

Year	Spring	Summer	Autumn	Winter	Mean	Data source
1959	77.29	354.90	20.40	441.53	223.53	[15]
1984-1985	27.6	254.0	109.4	577	242	[24, 26]
1998-2000	7.96	20.17	2.24	18.24	12.94	[33, 34, 40]
2005-2006	1334.3 (March) 2027.66(April) 2.59 (May)					
2006-2007	271.79(Apr)	63363(Jul)	226(Oct)	90.44(Jan)		
2008		720.49(Aug)		8.29(Jan)		

Phytoplankton abundance changed so dramatically with both space and time. The results of four investigations a year only represented a snapshot of phytoplankton states at a specific point in time. The data points were not symmetrically arranged to represent the whole Yellow Sea, so no stable trend was obvious in the past 50 years of changing phytoplankton in the Yellow Sea.

Experimental study on the effects of Asia dust enrichment on phytoplankton

Asia dusts occur every spring and bring huge amounts of nutrients to the Yellow Sea. During 5 days from March 18 to March 22, 2002, the total sedimentation flux from air to the Yellow Sea exceeded 2000 mg/m^2.

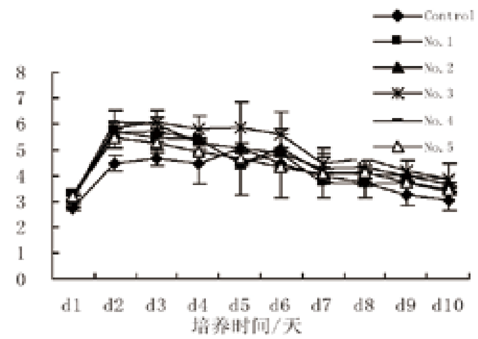


Figure 7 Effect of dust addition on *Prorocendrum donghaiense* growth with low nutrient treatments

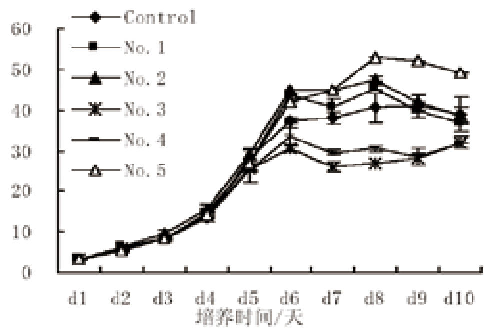


Figure 8 Effect of dust addition on *Prorocendrum donghaiense* growth with high nutrient treatments

The results from this project showed that, with lower initial nutrient concentrations (the incubation seawater was obtained from the open ocean, which we believed to have low nutrient concentrations), the growth rates of 3 species of microalgae *Chaetoceros curvisetus*, *Chaetoceros minutissimus* and *Prorocentrum donghaiense* were significantly stimulated after the addition of dust.

Conclusion

The spring bloom of phytoplankton occurs every spring in the central part of the Yellow Sea, however the timing and magnitude of the bloom changes inter-annually according to different climatic and environmental conditions. The most important influencing factor is the temperature of air and seawater which determines the timing of thermocline formation. Another important climate-related factor is the Asia Dust event, which occurs every spring and transports a huge amount of particles and nutrients from land into the Yellow Sea, which would supply phytoplankton production as an extra source. Our results suggested that with equal dust sedimentation flux to the ocean, the impacts on phytoplankton growth would be greater in the central Yellow Sea with lower nutrient concentrations than on the coasts of the Yellow Sea with higher nutrient concentrations.

Changes of the volume and intensity of YSCWM are said to be the results of climate change which can exert great influences on biological communities in the central part of the Yellow Sea. Cold bottom water and warm surface water forms a strong thermocline between them, which could be an obstacle for upward transport of nutrients from deep to surface. In the “warmer” years of YSCWM, the thermocline is getting weaker and nutrient concentrations are higher than those in the “colder” years, so that phytoplankton would have a higher abundance. For zooplankton, temperature and food environment are the two most important factors affecting their population dynamics, so their physiology, vertical migration, feeding and survival will all be affected.

Better ocean management is needed to cope with climate change. Ecosystem-based management and adaptive management have been recognised and emphasised by oceanic managers. Since the impact of climate change on marine ecosystem is such a huge question, oceanic managers or governmental oceanic administrators, should support long-term time-series monitoring and organise scientists of various subjects to work together to investgate a the whole scheme of the changes of climate and marine ecosystems. Oceanic managers should also keep in mind that the marine ecosystem itself is dynamic and is affected by various factors. The impact of climate change is not evenly distributed in oceans,so any change in marine ecosystem should be studied and managed specifically.

Monitoring Jellyfish Blooms in the Yellow Sea

Prepared by

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November 2009

Introduction

Since the 1960's, global warming, environmental pollution, marine construction and the over-exploitation of fishery resources, have caused mass occurrences of jellyfish and resulted in socio-economic problems around the world, with the Yellow Sea being no exception (Arai, 2001; Graham, 2001; Parsons and Lalli, 2002; Uye and Ueta, 2004; Yasuda, 2004). Korea and China, the neighbouring countries of the Yellow Sea, have experienced rapid industrial development and high levels of fishing since 1970s which has resulted in the degradation of marine environmental quality. The main drivers of change have been identified as increasing populations in coastal areas, the production of pollutants, and a decrease of natural habitats including the basin's huge tidal flats. This has attracted international attention, the environment is becoming so degraded that The Yellow Sea is now considered to be one of the 7 most polluted regional seas of the world (World Watch, 1995).

Jellyfish have asexual and sexual reproduction phases within their life cycle and can proliferate exponentially if conditions are appropriate for their reproduction (Arai, 1997). For example, the polyps, which undertake asexual reproduction to produce the medusae, are well known for their ability of tolerating extremely low concentrations of dissolved oxygen which would normally be fatal for other marine organisms if they were not able to move to more favourable conditions (MOMAF, 2007). Bearing in mind recent reports in the expansion of dead zones, characterised by very low dissolved oxygen concentrations (Diaz and Rosenberg, 2008), jellyfish populations could continue to appear in large numbers (Purcell et al., 2001; Brodeur et al., 2002; Johnson et al., 2005; Purcell, 2005; Xian et al., 2005; Purcell et al., 2007). The mass appearance of jellyfish, venomous or not, could lead marine ecosystems and fisheries to an even more perilous position in which biodiversity and fisheries remain at low levels and plankton numbers are severely depleted. (Feigenbaum and Kelly, 1984; Verity and Smetacek, 1996; Arai, 1997; Schneider and Behrends, 1998; Jankowski et al., 2005; Lynam et al., 2005; Uye and Shimauchi, 2005). Swarms of jellyfish have been reported in Korea, Japan, China, USA, the Mediterranean, Great Britain, and Australia where it has at times, become a national socio economic problem.

In order to examine target 8 of the Yellow Sea SAP 'Better understanding and prediction of ecosystem changes for adaptive management', the authors concentrated on the following activities;

1. The development of national/regional methodologies for monitoring jellyfish blooms
2. Monitoring jellyfish blooms in the Yellow Sea and co-ordinating with other monitoring events such the summer co-operative cruises scheduled for August 2008 and 2009
3. Developing and using commercial shipping in monitoring activities
4. The establishment of an international monitoring network for jellyfish in the Yellow Sea.

Methods

Firstly, different methods of estimating the timing, abundance and distribution of giant jellyfish were compared. 3 different methods were trialed to look for jellyfish throughout the water column which included visual counting and echo counting using underwater acoustics. These were supplemented by the use of an underwater camera and in some cases, midwater trawls.

Secondly, 12 surveys were conducted in the Yellow Sea and 5 in the northern East China Sea using the Oceanographic and the Fisheries Monitoring Program of the National Fisheries Research and Development Institute. From this it was discovered that human sightings varied according to the time of the observation, and large diurnal variations were also found due to the vertical migration of the jellyfish.

Thirdly, an unmanned ship-based monitoring system was deployed in the Yellow Sea. It consisted of camcorders, a camera angle controller, mobile DVR Board, image treating unit, power controller and an external hard-disk. The camcorders recorded the images, stored them on hard drive and then sent them, via wireless internet, to the office. The instrument was installed on a research vessel and a field test was made in the Yellow Sea. Images were clear during testing on board but the images of jelly fish in the water were not clear due to the reflection of sunlight from the sea surface. This resulted in blurred images.

In the fourth part of the project, international co-operation in jellyfish monitoring was attempted with China, Japan, France, Italy and East Asian countries using scientific, administrative and diplomatic methods. A Memorandum of Understanding between Korea, China and Japan enabled data to be exchanged and a symposium and workshop held with invited experts. Through these activities it soon became apparent that the participation of China was essential in understanding the distribution and ecology of these unusual creatures. Access was sought from the Chinese Government via a high level regular meeting (Meeting of The Joint Committee on Environmental Co-operation between the Government of the Republic of Korea and The Government of the People's Republic of China). This was successful in securing a co-operative jellyfish research project. Collaboration with France and Italy was also agreed in the implementation of a common scientific project focusing on comparisons of jellyfish abundances between the Yellow Sea and the Mediterranean Sea. Through a workshop of COBSEA (Co-ordinating Body on the Seas of East Asia), the establishment of a jellyfish monitoring programme was discussed and verbally agreed by each country.

Figure 1 A sample picture of *N. Nomurai* jellyfish moved by current.

Results

From the results of the visual counting methods, the maximum density of jellyfish distributed in the surface area was 10.06 (inds./ 1000m^3), and the average value was 1.03 (inds./1000m^3). The standard deviation of density estimation can be higher using the continuous VC method which will be higher in densely populated areas of jellyfish.

Underwater acoustics showed a maximum density of jellyfish, distributed in depth from 10 – 40m depth, was 0.31 (inds./1000m^3), and the average was 0.05 (inds./1000m^3).

The towed underwater camera system showed, the maximum density of jellyfish which distributed in the surface area was 0.95 (inds./ 1000m^3), and the average value was 0.05 (inds./ 1000m^3).

3 kinds of monitoring survey were compared and analysed during bottom trawl sampling on the basis of vessel logs.

- For visual counting method, the maximum distributed density of N. Nomurai jellyfish was estimated as 2,656.6 (10^3·inds./m) at station. 249, and the average density was estimated as 523.7 (10^3·inds./m).
- For underwater acoustics, the maximum distributed density of N. Nomurai jellyfish was estimated as 74.0 (10^3·inds./m) at station. 249, and the average density was estimated as 41.0 (10^3·inds./m). The underwater acoustic method verified that the jellyfish was intensively and vertically distributed around 93% in the range from surface to 40m depth. This result also showed that the jellyfish individuals were mainly distributed in surface and pelagic areas and moved by currents (Figure 2).

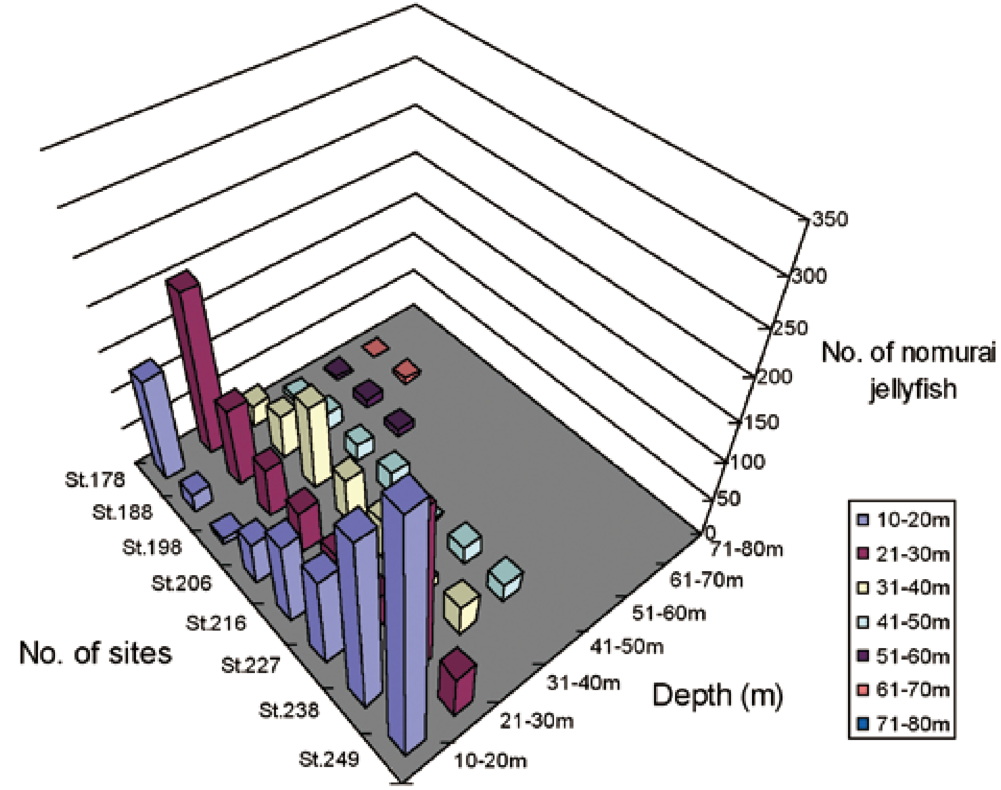

Figure 2 Vertical distribution of *N. Nomurai* jellyfish using underwater acoustics.

Additionally, the maximum distributed density of N. Nomurai jellyfish for bottom trawl sampling (averaged sweep area; 0.103 km^2) was estimated as 57.7 (10^3·inds./m) at St. 238, and the average density was estimated to be 15.6 (10^3·inds./m). As the density estimates by pelagic trawl sampling was over maximum 15 times higher than that by bottom trawl sampling, so sampled jellyfish might have been caught in the process of rolling up the net. Moreover, the sampling data showed that the average bell size of jellyfish at 10 stations was 60.5±9.5 cms.

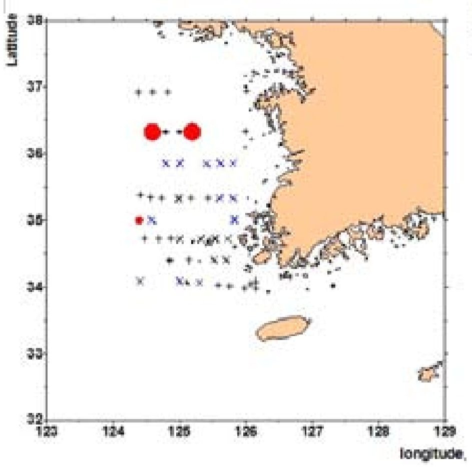

Figure 3 *Nemopilema nomurai* in the eastern Yellow Sea in August 2008. The abundance of the jellyfish was always less than 10 inds/10000m^2.

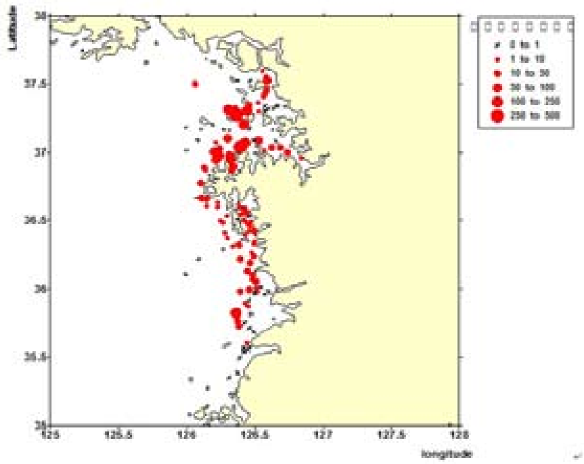

Figure 4 Jellyfish monitoring stations visited in August 2009.Observations were made at 213 stations and found them at 128 stations (Figure 4). Their mean abundance was 28 and maximum 403 inds / 10000m^2.

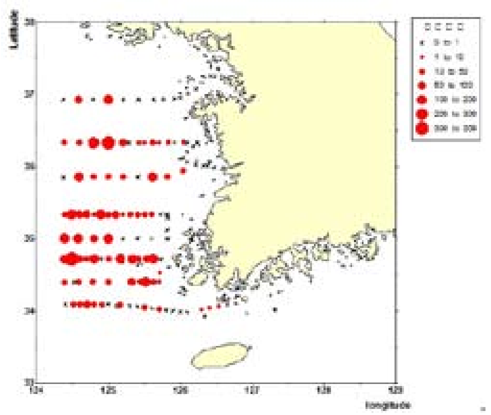

Figure 5 *Nemopilema nomurai* in the eastern Yellow Sea in October 2009.One hundred and twenty two stations were visited and found the giant jellyfish at 70 stations (Figure 5).

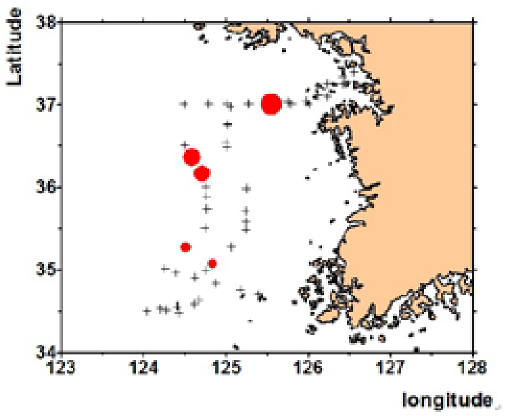

Figure 6 *Nemopilema nomurai* in the eastern Yellow Sea in September 2008. The abundance of the jellyfish was always less than 5 inds / 10000m^2.

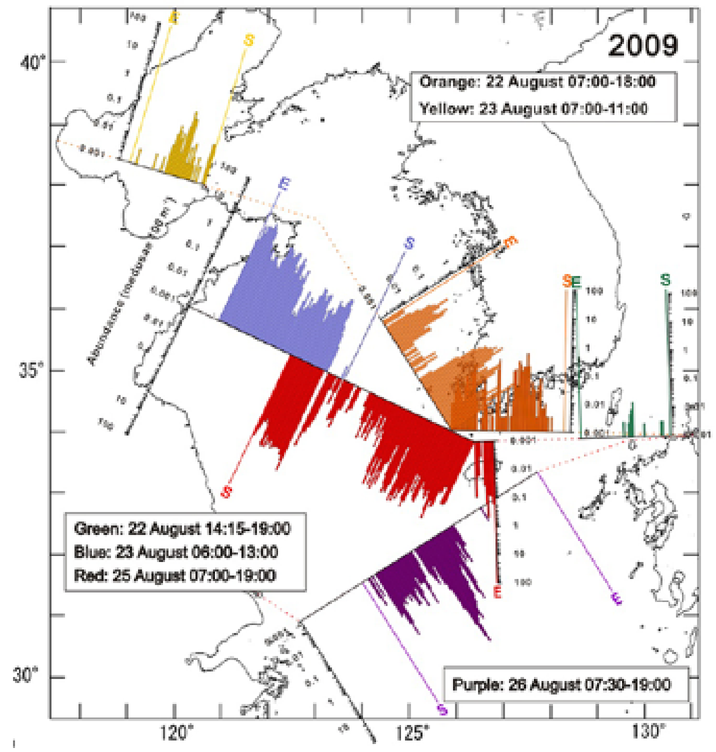

Figure 7 Abundance of the giant jellyfish in August 2009, using international ferry boat lines from Japan to Korea (Busan) and China (Shanghai, Qingdao, Tianjin).

Discussion

The distribution of the jelly fish is largely driven by wind and shelf currents. Without wind, dispersal may be limited (Moon 2005). Since 2003, the East China Sea (ECS), Yellow Sea (YS) and East Sea of Korea (ESK) have experienced large scale appearances of the giant jellyfish, *Nomepilema nomurai*. This jellyfish is the largest local jellyfish and the most widespread endemic species to inhabit Korean waters. Since 2003, a population explosion of N. nomurai has occurred (Yasuda, 2004; Kawahara et al., 2006), resulting in serious damage to local fisheries. According to the field observations since 2005, the jellyfish are mainly distributed in the northern ECS in July and in August appearing off the west coasts of Korea and Japan. After that period, the abundance decreased and they disappeared in December from the ECS, YS, and ESK (NFRDI, 2008). In the eastern ESK along the Japanese coast however, they remained en masse until December. From January to February, they were found in the western Pacific Japanese coast, after having passed through the Tsugaru Strait.

Although the origin of this giant jellyfish is still being debated, it is generally believed that the coastal area between the Changjiang Estuary and the Shandong Peninsula is one possible source (Yoon *et al*., 2008). Kawahara *et al*. (2006) It is suspected the influence of the Changjiang's diluted water (CDW) was having an effect on the distribution of *N. nomurai*. Yoon et al. (2008) found a close relationship between the spatial distribution of *N. nomurai* and the CDW, and further surmised that the polyps of the giant jellyfish overwinter somewhere between the Changjiang Estuary and the Shandong Peninsula. They suggest that juveniles are transported to an area near the Changjiang Estuary and northern ECS during winter–spring. Thereafter, the *N. nomurai* population drifts east-northeastward along the CDW and enters the ESK.

Figure 8 Jelly fish can occupy a high proportion of the catch at certain times of the year

Mass appearances of jellyfish have caused damage to fisheries worldwide (Shimomura, 1959; Yasuda, 1988) for example in the Mexican Bay area where it amounts to several million dollars (Graham, 2003). The giant jellyfish in Korean waters also has serious effects on fisheries and tourism (due to the stinging effects of contact with the jellyfish), and on power station security when intake pipes become blocked. These effects are estimated to cost somewhere in the region 76.3-229 million, 17 million, and 58.8 million US dollars every year (MLTM, 2009).

Assessing the Impacts of the N:P:Si Ratio Change on the Yellow Sea's Ecosystem

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November 2009

Objectives and Methods

The classic Redfield ratio of C106:N16:P1 is a cornerstone of aquatic biogeochemistry (Sterner et al., 2008; Geider et al., 2002). This concept refers to the relationship between organism compositions and water chemistry. The Redfield ratio was later extended to incorporate also silica, i.e. C106:N16:P1:Si16 (Harrison et al., 1977). Deviations in pelagic nutrient concentrations from these proportions have been used as indicators of primary production limitation. The marine environment is often assumed to be nitrogen limited (Nixon et al., 1996), while freshwaters are mainly thought as phosphorus limited (Correll, 1998; Schindler, 1974).

This demonstration project "Assessing impacts of N:P:Si ratio changes on the Yellow Sea ecosystem" was designated to address the regional target of "better understanding and prediction of ecosystem changes for adaptive management". It harmonises historical data and information (including the long-term monitoring programmes), the data from the joint cruise surveys of YSLME and experimental data from the project. This enables scientists to quantify the impacts of N:P:Si ratio change on the Yellow Sea ecosystem, based on Chlorophyll-a, primary production, phytoplankton abundance, biodiversity, community structure and the occurrence of HABs. Understanding the nutrient sources and human modifications to nutrient dynamics will serve well the management policies in the Yellow Sea.

Three different analyses were carried in this demonstration project:

1. Cruises data
2. In situ MESOCOSM experiments
3. Lab Experiments

Results from Cruise Data

Two recent important marine investigation projects were carried out in southern Yellow Sea: one was the UNDP/GEF Yellow Sea Project's Co-operative Study Cruises conducted in the winter and summer of 2008, and another was the National Comprehensive Marine Investigation Project, conducted seasonally during 2006-2007. The results of nutrient levels and distributions and N:P:Si ratios obtained from the two projects are presented in this paper to provide evidence as to the nutrient status of the waters in this area.

UNDP/GEF Yellow Sea Project's Co-operative Study Cruises 2008

In the winter cruise, the N/P ratios at the surface layer were in the range of 6.77-13.37 (averaged 9.11) and decreased from the northwest part of the surveyed area to the southeast part (Figure 1). The Si/N ratios were in the range of 0.59-1.85 and averaged 1.10. Except in station H3 (Si/N=1.85), the Si/N ratios were around 1.0. The nutrient structure was relatively balanced in the winter season.

Table 1 N:P:Si ratios at the surface water of Southern Yellow Sea during winter and summer of 2008

	N/P	Si/N	Si/P
Winter	5.27-22.80	0.59-1.85	4.80-28.95
(n=10)	(14.91)	(1.10)	(16.35)
Summer	8.19-272.23	0-31.81	0.26-331.02
(n=37)	(64.45)	(2.64)	(80.30)

In the summer cruise, the N/P ratios in the surface layer were in the range of 8.19-272.23 and averaged 64.45 which were much higher than that in winter. High values of N/P were mainly observed along the coast of Jiangsu Province of China especially in the Yangtze River mouth which indicated the eutrophication status of the coastal region. The Si/N ratios were in the range of 0.00-31.81 and averaged 2.64. Except in station F5 (Si/N=31.81), the Si/N ratios in most of the other stations were <5.

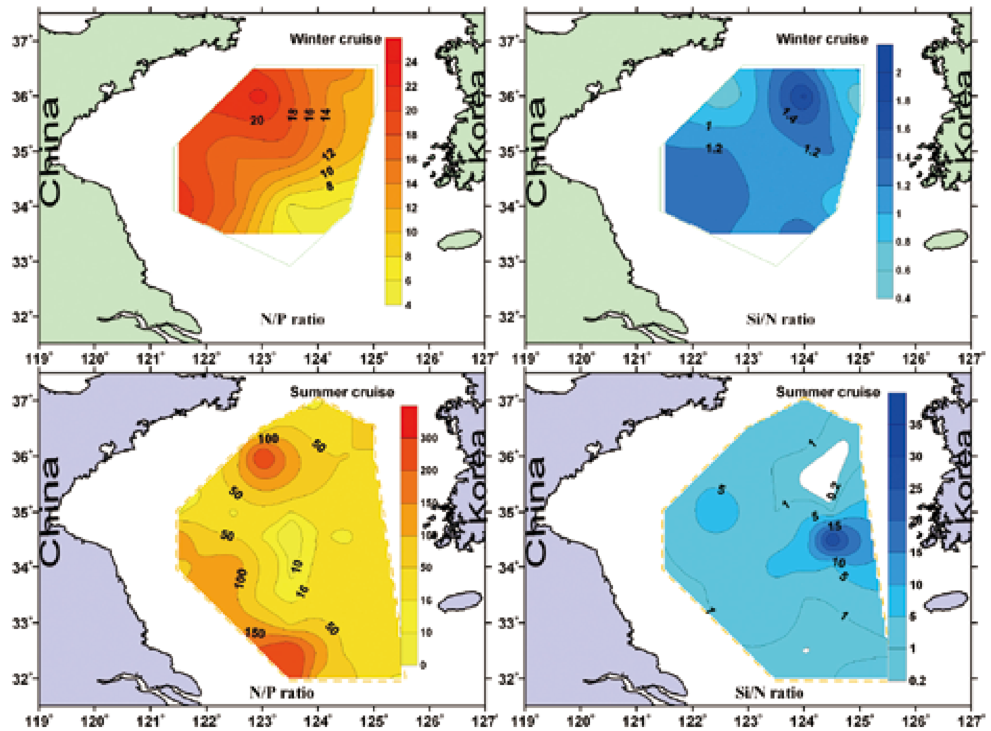

Figure1 Distribution of N/P ratios in the surface water of Yellow Sea during winter and summer 2008 (YSLME joint cruises)

National Comprehensive Marine Investigation Project of China（*2006-2007*）

The variation range and average N:P:Si ratios in the surface water of the Southern Yellow Sea during 2006-2007 are listed in Table 2. The N/P ratios in spring and winter cruise were relatively balanced, while in summer and autumn, were significantly higher than the Redfield ratio. The average Si/N ratios were around 1-2 in the four cruises.

Table 2 N:P:Si ratios in the surface water of the western part of Southern Yellow Sea during 2006-2007

		spring	summer	autumn	winter
Atomic ratios in surface layer					
DIN:P	ranges mean	1.4-117.3 19.9	0.8-1832.6 104.8	12.3-16130 676.5	4.1-177.6 23.2
Si:DIN	ranges mean	0.1-12.6 1.7	0-21.7 1.9	0.2-3.1 1.0	0.3-8.2 1.3
Si:P	ranges mean	2.1-74.4 23.0	0-579.1 41.1	17.5-5876.6 648.7	4.6-68.2 25.8

Long-term variations of nutrient level and N:P:Si ratios

Lin *et al*. (2005) studied the changes in the environmental features of the Yellow Sea during the last 25 years of the 20th century using a set of seasonally monitored data along a transect (at 36°N). The results from this study suggest changes in environmental parameters in the Yellow Sea which might deviate from the trends revealed by Lin *et al*. Further evaluations of environmental changes and the responses of the ecosystems of the Yellow Sea are necessary.

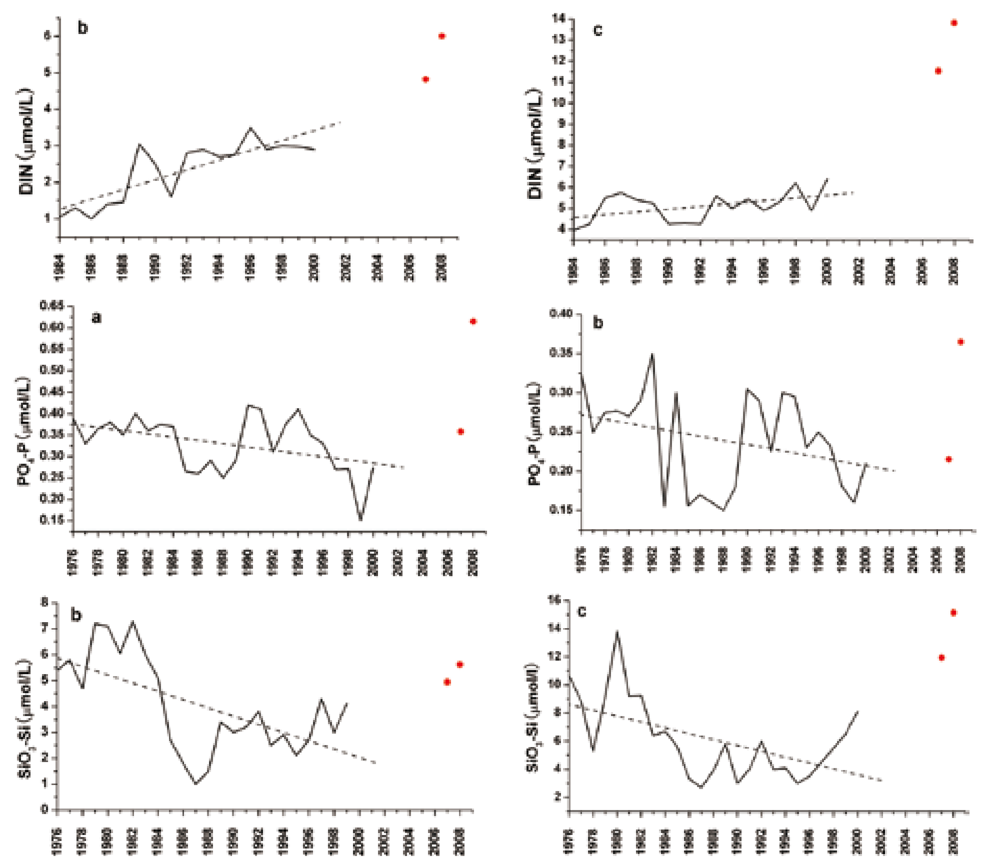

Figure 2 Variation of temperature and DIN, PO_4^{3-} SiO_3^{2-} concentrations along 36°N transect (a. average; b. surface; c. bottom) (1976-2000: Lin *et al*., 2005; 2007: Red dot: National Comprehensive Marine Investigation Project; 2008: YSLME joint-cruises)

Results from the Mesocosm experiment

Variations in nutrients

The concentration of DIN, phosphate and silicate varied during the experiment, i.e. the concentration declined quickly in the first three days, except for phosphates in M2, nutrients levels in other mesocosms decreased below the initial concentrations after four days due to the consumption of phytoplankton（Figure 3）.

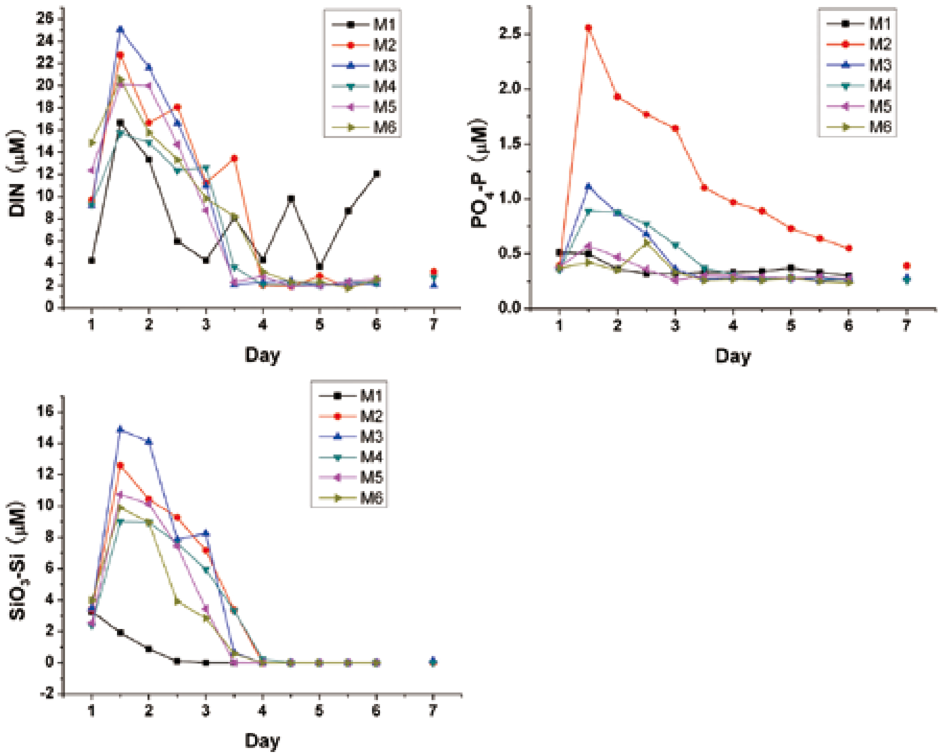

Figure 3 Variations of DIN, phosphate and silicate concentrations in the mesocosms

Based on these results, the growth of natural phytoplankton in the mesocosm system seemed to be influence by the combined effects of nutrient concentrations and N:P:Si ratios.

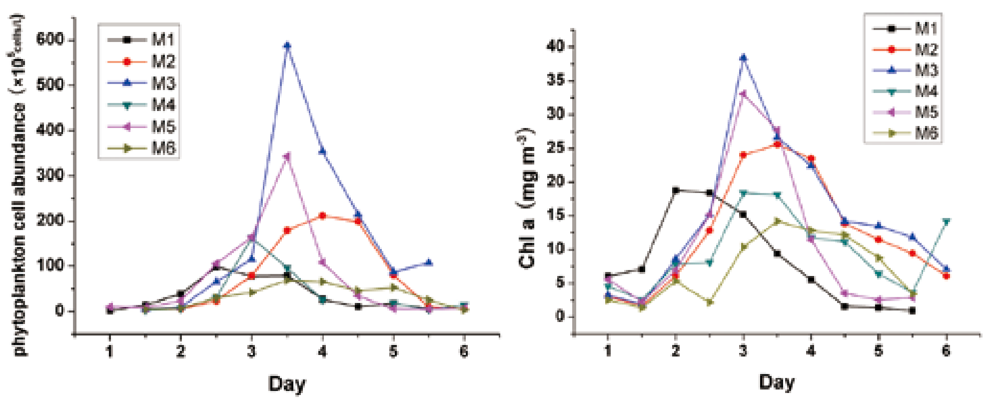

Figure 4 Variations of chlorophyll a and phytoplankton cell abundance in the mesocosms

Dominant phytoplankton species

The variations of dominant phytoplankton species cell abundance and their contributions in the six mesocosms are presented in Figure 5. Diatoms dominated throughout the experiment period, and *Thalassiosira nordenskiold* was the predominant species in almost all the mesocosms. In M4, another species of diatom *Amphiprora* sp., assumed dominance from day 4.

No significant impact of N:P:Si ratios were found on the phytoplankton species composition and dominance.

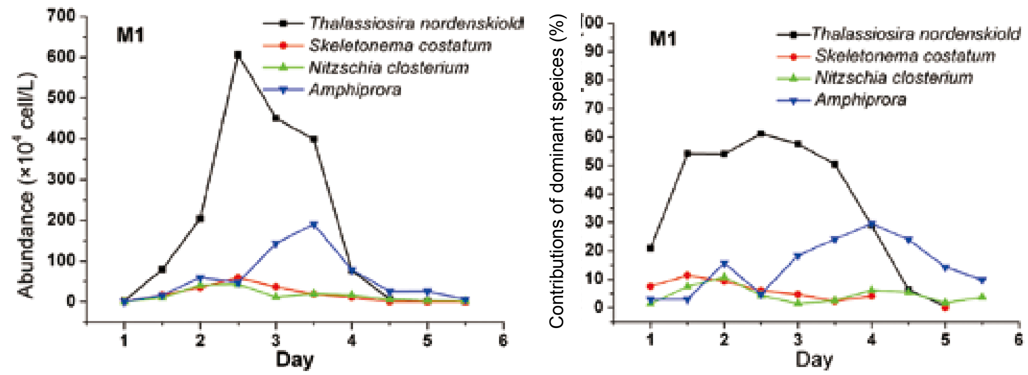

Figure 5 Variations of dominant phytoplankton species cell abundance

Results from Laboratory Experiments

Two sets of laboratory experiments were conducted on the impacts of different N/P ratios on the growth and interspecific competition of key algal species in the Yellow Sea. One was between diatom and dinoflagellate, and another was between dinoflagellate and dinoflagellate. The purposes of the experiments were to study the impacts of different nutrient concentrations and N/P ratios on the phytoplankton population growth rates and the interspecific competition between different species.

In the case of single-species culture, both *S. costatum* and *P. dentatum* showed similar growth curves under different nutrient environments and no obvious differences were observed between N-limitation and P-limitation conditions (Figure 6). But at the final equilibrium state, both algal cell densities were slightly higher in the P-limitation treatment than in the N-limitation treatment. These results indicated that N:P ratios may not be the major influencing factor for the growth of the two target algae and that algal cell density was mainly influenced by the absolute concentrations of the potential limiting nutrients.

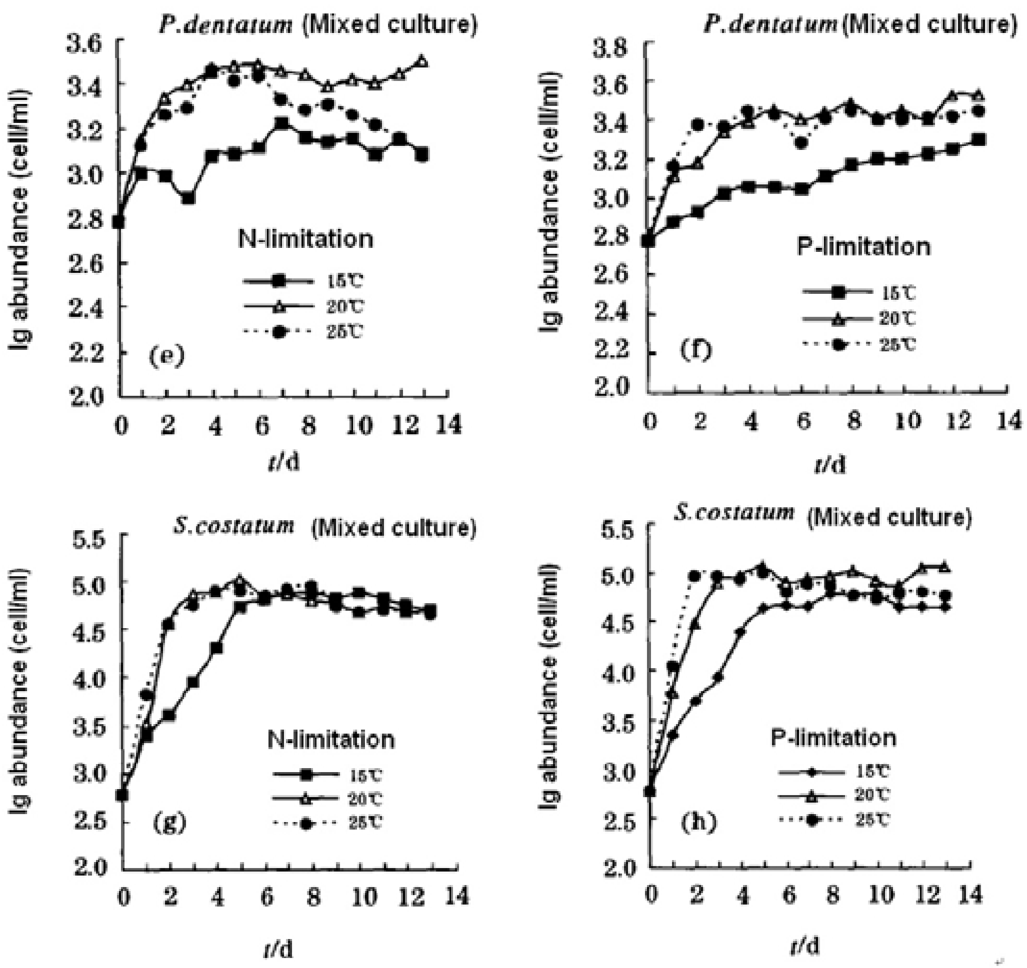

Figure 6 Variation processes of algal cell densities under different culture conditions

Conclusion

The results showed the nutrient concentrations and N:P:Si ratios revealed great annual fluctuations during the last 10 years and no clear patterns were observed in the whole region. Yet in the coastal region, significant increases of DIN level and N/P ratio were observed such as in Jiaozhou Bay and Sanggou Bay. Many pelagic ecosystem changes have been strongly related to the changes of the inorganic nutrients, such as the changes in phytoplankton abundance, Chl-a concentrations and primary production, increases in eutrophication, and the occurrence of HABs.

Managing Pollution in Critical Habitats around the Yellow Sea

Prepared by

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December 2009

Introduction

The Ganghwa Southern Tidal Flat (GSTF) is located on the Han River Estuary (Figure 1) and designated as the demonstration site for this study through the 1st year of the YSLME biodiversity project. GSTF is the largest unit of mud flat and also the only tidal flat connected to the naturally well conserved river estuary in South Korea. By these reasons, GSTF was designated as one of the three critical habitats in terms of the biodiversity in the west coast and also designated as the YSEPP (Yellow Sea Ecoregion Planning Program) #16 (Han River Estuary and Gyeonggi Bay). Tidal flat is the most common habitat type in the west coast of Korea, encompassing 83% (1,980km^2) of total tidal flat in the Korean peninsula (Noh and Lee, 2006). In particular, Ganghwa Southern Tidal Flat is well known for migratory bird stop-over sites and used by black faced spoon bills, Chinese egrets, Saunder's gull, and black-winged stilts.

In terms of the economy it is a very productive area in the west coast. The macroeconomic contribution of the Ganghwa tidal flat to the Korean economy was estimated as 31.9 million won per hectare annually (Kang, 2001). However, there are lots of environmental issues in the tidal flat such as the increase of pollution loading through the Han River and its vicinity, developmental plans such as tidal power plants and reclamations for land use etc. These made the GSTF the most pressurised habitats in terms of anthropogenic activity, pollution and habitat loss in the west coast of Korea. Major objectives of this study were to estimate the current status of pollution and pollution loadings, the biodiversity-pollution relationship, and finally, draw environmental management actions for future implementation to conserve this important habitat on the west coast of Korea.

Figure 1 Locations of demonstration sites and natural views

Materials and Methods

Microcosm study

The microcosm study was initiated on June 5, 2009 on the tidal flats located in Yeocha-ri, near the Ganghwa Tidal Flat Center. Sediment sub-samples for chemical analysis were collected every three weeks as follows ; June 5, June 25, July 16, August 4, August 27, and September 18, 2009. The study was designed to test that inorganic/organic pollution in the tidal flat which negatively affects benthic communities e.g. decreased biodiversity and abundance and proliferation of species indicative of pollution. The microcosms (total of 21) were made of round PVC tubes with both ends open (50 cm in diameter and 30 cm in depth, with several holes in the bottom section of the PVC tube). The microcosms were installed during a low tide on the tidal flat with the top 10 cm remaining above the sediment, and the rest (20 cm) buried in the sediment (Figure 2). As a source of organic pollutant, granule type-organic fertilizer (diameter 50mm) and compost (debris) were used to increase the organic concentration in the sediment. Natural sediment was collected in the same site for the microcosm study and frozen for at least 24 hours to remove all the live benthic animals and thawed before use. Final concentrations of organic concentration as ignition loss (%) were 4% (background level as control), 7%, 14% and 21% with three replicates for each treatment group. Sediment COD and ignition loss (IL) were analysed every three weeks from the initiation, and total sulphur in the last three samples. On the last sampling day, the whole sediment in the microcosm was sieved with 1mm pore sized sieve for macrobenthos analysis.

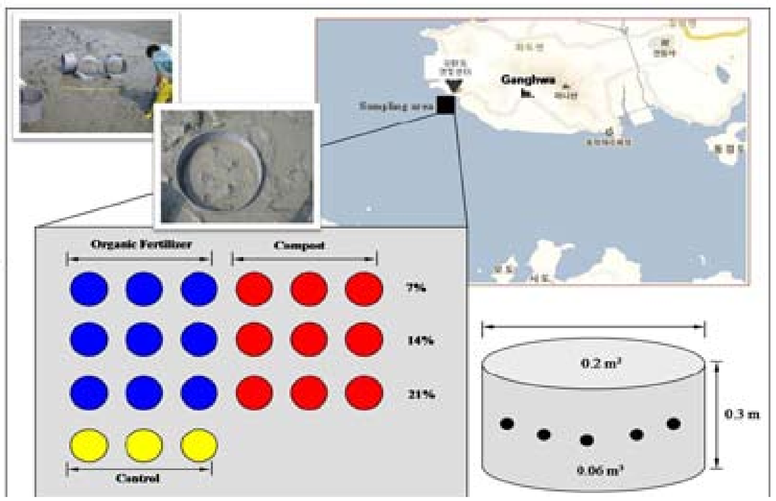

Figure 2 Experiment schemes in the microcosm study

Estimation of pollution loading

Pollution loads (produced loads and discharge loads) into the habitat and nearby Geoynggi Bay from the three watershed regions were assessed using pollution source data collected from the survey of local government agencies. The relationship between produced loads and discharged loads was quantified by comparing monitoring data and river water flux data. Produced and discharged loads were computed for the three constituents of biological oxygen demand (BOD), total nitrogen (TN), and total phosphorus (TP), which were indicative of organic pollution. BOD values were expressed as those of chemical oxygen demand (COD) using the BOD-COD conversion factor. The data from the pollution source survey and river water flux were produced in 2006.

The discharged loads into the GSTF and nearby Gyeonggi Bay were assessed with the technical pollution management manual. The loads from point sources and non-point sources were calculated separately. The loads from the population were calculated by dividing into waste water treatment areas and non-treatment areas, The loads from poultry farming were assessed using the raising class and dividing it into manure and urine. The loads from industry were calculated considering individual factory and public treatment plants, respectively. The loads from fish farms were assessed by species and farming types. The loads from landfills were calculated using the treatment of leaching water.

Results

1. General environmental conditions of the GSTF

Based on the August 2008 biodiversity survey, water depths of the GSTF were between 0.5 and 15m. Surface water temperature ranged from 22.8 to 28.0ºC, increasing towards the south of the Island. Surface salinity steadily increased from the east (Yumha Channel) to the west (Sukmo Channel), reflecting the influence of freshwater discharges from the Han River which flows down through both channels around Ganghwa Island. Average salinity was 21.4 ± 5.4 psu in 2003 and 19.4± 6.8 psu in 2008. DO was usually higher in the middle part, but DO concentration was saturated or oversaturated in all sampling sites.

2. Pollution loadings

Pollution loadings in the Han River Estuary and the GSTF were highest in the west coast of Korea in terms of COD, TN and TP discharges (personal communication with E&Wiz). This suggests the habitat quality of the Ganghwa tidal flat is heavily influenced most prominently by the discharge from the Han River. Estimations of pollution loadings in the GSTF were based on the source data from the Han River, Gimpo City, Incheon City (East, West and Central regions of Incheon), Ongjin County and Ganghwa County. The results of discharge loads in the GSTF and the estuary region of the Han River are shown in Figure 3 and 4. The discharge loads of COD, TN, and TP are much higher in the estuary region of the Han River than in the GSTF. In terms of the COD, TN and TP, discharge to the GSTF input through the Han River, contributed 95% of total pollutant loadings and only 5% from Ganghwa County and its vicinity. Major pollution sources in the Han River were land, population and industries and land and population in the GSTF and its vicinity. Therefore, populations in Seoul and Incheon, 50% of the South Korean population, were major contributiors of high pollution loadings in the GSTF, followed by industries.

3. Current status of pollution in the critical habitat

COD and nutrients concentrations in the GSTF (station 1) were highest among the 18 stations in the Gyeonggi Bay and almost 50% higher than those in other stations (Figure 3). In terms of the COD and nutrients, water quality in the GSTF was within the Korean Seawater Quality Criteria II out of three classes. Annual trends showed increasing patterns, with sharp increases since 2002. NP ratios were extremely high in the Han River Estuary exceeding 100, normally N/P=16, in the open ocean. This indicated that the relative nitrogen input was more significant than phosphorus input (Figure 4). KORDI (2008) also monitors other components such as heavy metals and organic pollutants (PCBs, PAHs), but their concentrations were found to be very low, so, those components were not analysed.

In terms of the sediment quality, the organic contents were higher on both the eastern and western part of the tidal flat, with the center being slightly lower. Sediment granulometry showed that gravels were restricted mostly to the south-west region, with a minor presence around the mouth of the Yumha Channel. A higher mud content was observed at both western and eastern parts with generally a lower percentage of mud in the middle parts, the pattern of mud distribution being substantially different from that in 2003. Overall the sediment environment of the study area was a mud dominated system (61.5% on average), showing little change of the composition from the previous survey made in 2003 (mud content of 60.4% on average). Average ignition loss in this study was 3.3±0.2% (mean±95% CL), slightly higher but not significantly different from the level surveyed in 2003 (3.1± 0.5%, mean ± 95% CL; MOMAF, 2003 and YSLME, 2008).

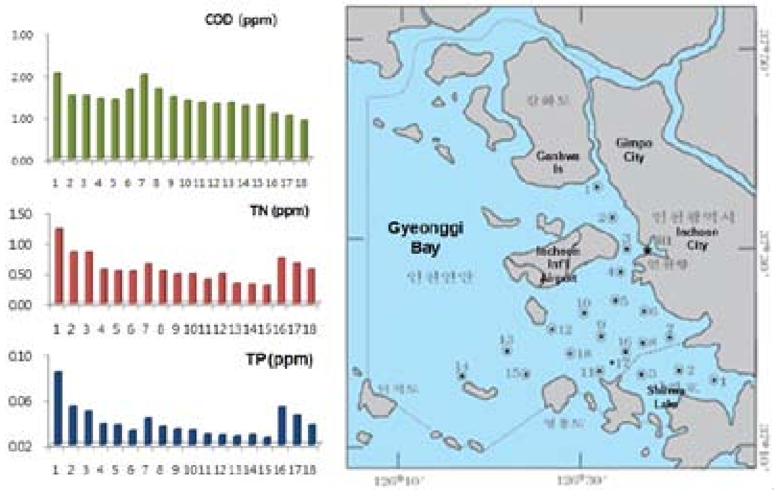

Figure 3 Water quality in the GSTF and its vicinity. Numbers indicate stations in the Gyeonggi Bay, Incheon. Station 1 is located in GSTF

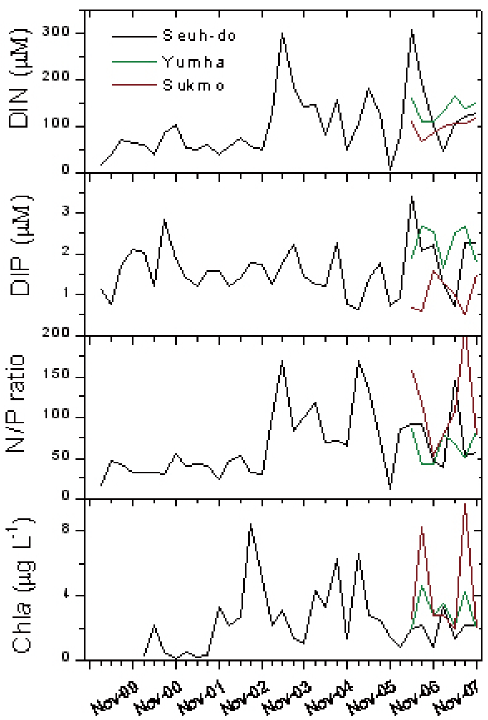

Figure 4 Long-term trends in surface water quality in the southern Ganghwa tidal flat quarterly measurement (February, May, August, and November, sample size (n) =1 for each time point) from 1999 to 2007 of the concentration of dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP), N/P molar ratio, and chlorophyll a. Data from NFRDI long-term monitoring program. Yumha and Sukmo Channels; quarterly measurements (February, May, August, and November, mean values) from 2006 to 2007. Data from KORDI (2008).

4. Organic pollution – biodiversity

Sediment is a major influence for benthic organisms and its composition and status are important factors for benthic biodiversity. Various pollutants in sediment can affect the benthic species composition and biodiversity. In this study existing benthic species composition and organic concentration data were analysed to identify the relationship between organic pollution as ignition loss (%) and benthic biodiversity because nutrient and organic pollutions are major concerns in the GSTF. Using the monitoring data from over 40 stations, ignition loss and benthic macrobenthos diversity data were plotted to identify the relationships. There was a distinctive parabolic relationship between ignition loss and macrobenthic biodiversity in the GSTF (Figure 5). Based on this observation, there is a strong possibility that increased organic pollution can reduce the benthic biodiversity. It is almost certain that the peak concentration is 3% in ignition loss and if values are over the concentration, there will be a decrease in benthic biodiversity. Current sediment ignition loss in the GSTF has been observed at an average of 3.3±0.2 % (± 95 % CL) in the 2008 survey from 43 stations. Therefore, organic concentration in GSTF is on the critical point for benthic biodiversity conservation.

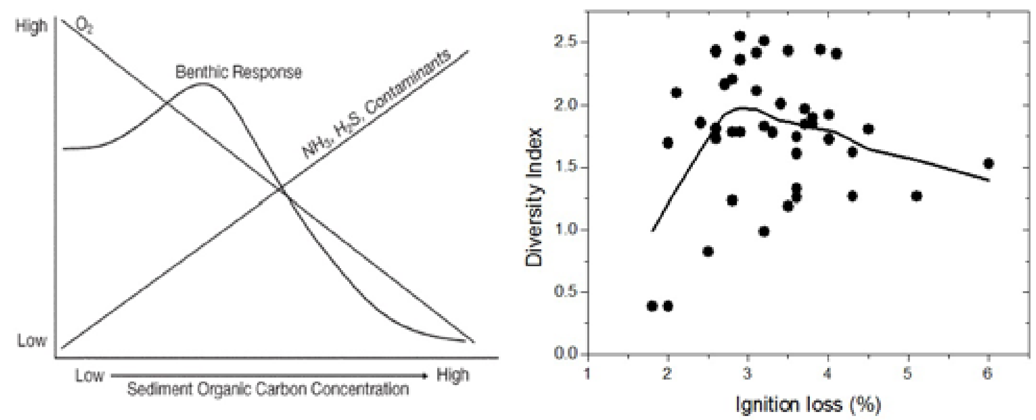

Figure 5 Diversity indices (Shannon–Wiener species diversity index (H')) as a function of organic contents only in which the effects of the grain size and depth on diversity were removed, with locally weighted regression line

Microcosm study

Sediment chemistry in the microcosms was analysed to identify the changes of sediment COD, total sulphur and ignition loss by time, and also the macrobenthic species number and biomass were estimated. Sediment COD of treatment groups was 1.5 -2.0 times higher than the control as averages during the study periods. Decreases in COD concentrations in the organic fertiliser treated groups by exposed time, was significant during the first 3 weeks and then fell to the background level (control level) thereafter.

Compost treated groups however, showed a relatively slow decrease of COD concentrations during the exposure time which indicated less decomposition or dilution within the microcosms. Ignition loss and total sulphur concentrations also showed similar patterns with sediment COD trends. By this experiment, initial dilution and continuous decomposition of introduced organic matter within sediment, was significant for both of organic fertiliser and compost, even with slower rates for compost treated groups.

A total of 8 taxa and 16 macrobenthic species were identified in the microcosm during 15 weeks exposure. Polychaetes were the most dominated group including 6 species followed by 4 brachyura, 3 bivalvia and 2 fish species. However, benthic amphipods were the most abundant taxon, representing 70% of total individuals.

Benthic species compositions and abundances, however, were significant between treatment groups. The number of species found at each treatment group showed positive dose-response relationships; highest was at the control (15 species) and the lowest was at the high concentration of treatment (21% compost and fertilizer treated groups)(8 species respectively) and ecological indices such as species richness, evenness and species diversity were also decreased with the increased pollutant treatment.

Total numbers of individuals however, were significantly different between treatment groups. Compost treated groups showed much higher macrobenthos density than control and fertiliser treated groups due to the sharp increase of amphipod density. Within fertiliser treated groups, macrura (shrimp) species sharply increased with the increased organic treatment and amphipods dominated with the increased compost concentration groups. Polychaetes, gastropods and oligochaetes showed a significant negative correlation with the increased organic concentration, with the highest sensitivity for polychaete species (Figure 6).

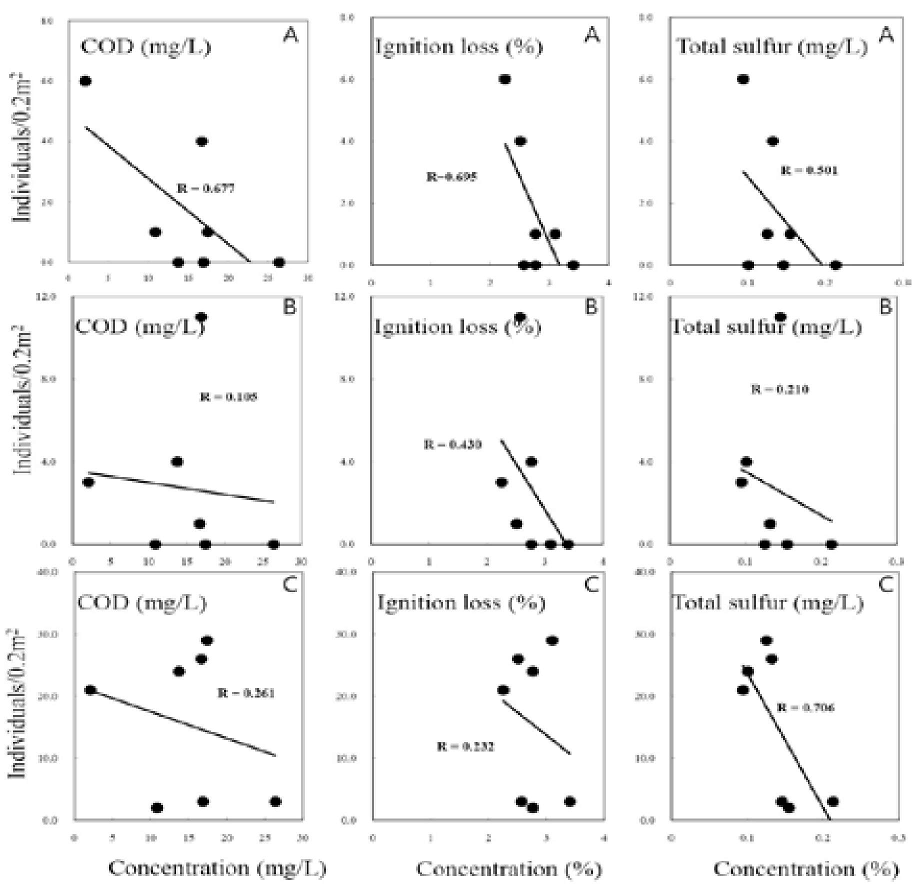

Figure 6 Relationships between increased organic pollution and macrobenthos density. Polychaeta (A), Oligocheata (B) and Brachyura (C)

Polychaetes were the most vulnerable species by increasing organic pollution. There was a significant negative correlation between polychaete density and increased organic pollution from the microcosm study. Types of organic pollution sources were also very critical factors for benthic community changes. Dissolved organic pollution using organic fertiliser significantly contributed to the decrease of polychaete density and increase of macrura species. Solid organic pollution using compost as debris however, represented a significant increase of amphipod density. From this observation it is very obvious that both the increase of organic pollution and types of organic pollutants can change the community structure and benthic biodiversity significantly.

Monitoring programme in/around the habitat

Based on the pollution loadings and pollution status we recommend that it is essential to monitor the environmental status of the GSTF, especially dissolved nitrogen, organic contents and solid wastes introduced through the Han River, Ganghwa Island, Gimpo City and West/East Incheon City.

Biodiversity monitoring is also an essential factor to identify changes in the biological resources of the GSTF. Macrobenthic species such as large crustaceans and shellfishes and water birds, are major targets for biodiversity monitoring. Scientists need to establish a transect line from Dongmak Beach, passing the subtidal zone, to Young Jong Island (Incheon Int'l Airport), and to monitor the macrobenthos diversity, water depth and grain size changes. Monitoring objectives should track the sedimentation of the tidal flat using external sources such as waterway changes and benthos/bird community changes, which are critical biological components of the GSTF. The proposed monitoring parameters are water depth during high tide, grain size, macrobenthos and water birds in August (summer) and February (winter). The station locations must be decided from the preliminary survey using the proposed transect line to identify the homogeneity in sediment structure and qualities.

This 8km transect line covers the central area of the GSTF and subtidal areas within the shortest distance. In addition to the above monitoring factors, it is strongly recommend to monitor the water bird population changes because the GSTF is the important breeding site for migratory birds including the endangered species black faced spoon bill.

Management action plans

Based on the estimation of pollution loadings in the GSTF, freshwater discharges from the Han River contributed about 95% of COD, TN and TP loadings. The remaining 5% was from Ganghwa Island and its vicinity. Major sources were from large populations of Seoul and its satellite cities and industries, and land use from Ganghwa Island and Gimpo City. In order to reduce nutrient pollution loads in the GSTF, the different management practices should be applied to urban and rural areas. For urban areas, it is more efficient to construct domestic and industrial treatment systems and expand sanitary sewer systems which are the most general and material methods for reducing pollution from population and industries. On the other hand, it is more desirable to apply the non-point pollution management practices in the rural areas such as Ganghwa County and its vicinity. Among the non-point pollution management practices, targeting specific treatment systems depending on the vegetation types (farm or forest etc) in the drainage basin, is more effective in pollution reduction in this area. Therefore, it is proposed to establish a basin working group (BWG) for the GSTF to reduce the pollution input in the GSTF with the following members;

- Seoul City and its satellite cities located in the Han River basins
- Gyeonggi Province

- Ganghwa County and its related departments of pollution and coastal management
- Gimpo city
- Incheon City
- Ministry of Land, Transport and Maritime Affairs (MLTM)
- Ministry of Environment
- Han River Basin Administration Office
- Ganghwa Tidal Flat Center
- Ganghwa People's Network
- Anyang University and research institutes

Water quality improvement programs and local partnerships must be built to reduce the pollution input through Han River and Ganghwa Island and its vicinity. Central and local governments, community groups, and local agencies have to commit to the implementation.

These include
- Identification of specific potential sources of nutrients and organic matter;
- Assignment or allocation of loadings to sources;
- Funding and timeline for projects;
- Monitoring (water quality) plans for follow-up and implementation;
- Tracking of projects;
- Controlling loadings from future growth; and
- Commitment to plan implementation by local partners.

The management actions cover a wide variety of pollutant sources and are categorised as follows:
- Wastewater Infrastructure Management
- Restoration and Water Quality Improvements
- Basic Stormwater Management Programs
- Education and Outreach Efforts
- Agricultural Best Management Practices
- Regulations, Ordinances, and Guidelines
- Special Studies, Planning, Monitoring, and Assessments.

The Economic Justification for the Conservation and Improved Management of Korean Tidal Mudflats

Prepared by

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July 2009

Introduction

The southern tidal flat of Ganghwa Island, located on the mid-western coast of Korean Peninsula, provides a number of ecosystem services (Figure 1). This is the largest tidal flat (approximately 130 km^2) on the west coast of South Korea (Choi et al., 2010). People benefit from a variety of seafood and recreational opportunities, including various creatures, like the last remaining populations of black-faced spoonbill, which inhabit the area in and around the tidal flat.

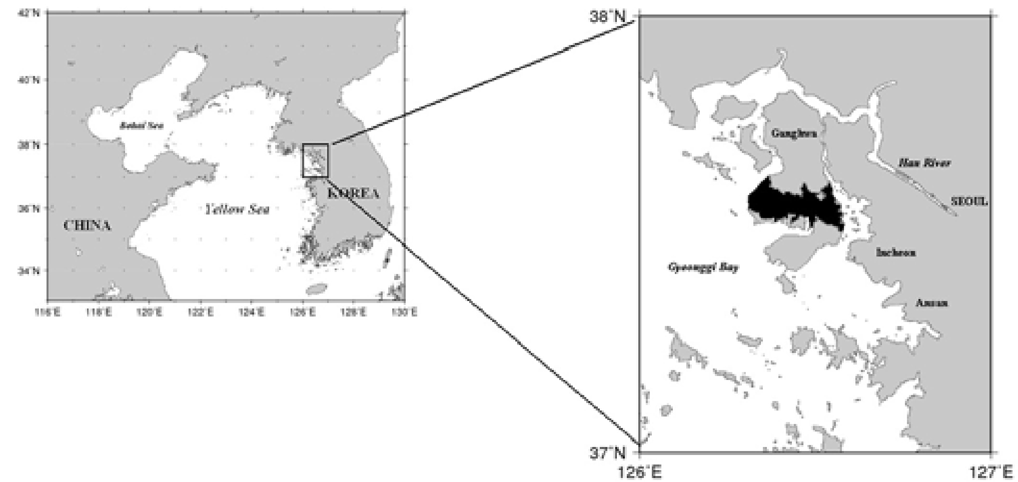


Figure 1 The Yellow Sea (left) and the mid-western coast of Korean Peninsula (right). The darker-shaded area illustrates the southern tidal flat of Ganghwa Island.

Water quality around the tidal flat has declined over the years because of human induced pollution. According to national standards (http://www.nfrdi.re.kr), the current water quality is poor due to the excess nutrients and is now classified as level III, the lowest level, which is suitable only for industrial use, but not for swimming or recreation (Park, 2009b). Additional threats come from the proposed construction of two tidal power plants around the tidal flat that will impact its already a stressed fragile ecosystem (Park, 2009b).

In co-operation with the UNDP/GEF YSLME Project, Anyang University has developed a management plan to improve the water quality in the tidal flat. Various management actions are proposed by the plan, the most important of which is the introduction of two sewage-treatment plants to reduce the pollution loadings (Park, 2009b). These actions aim to remove organic and nutrient pollution in the Han River that is the major source of pollution to the tidal flat. The costs of improving the water quality in the tidal flat by introducing the treatment plants are estimated to be approximately 370 million South Korean won (KRW) per year.

The objective of this study is to estimate the benefits of improving the water quality in terms of recreational opportunities, and to examine whether it is justifiable to invest in the treatment plants. The study, the first trial of its kind in the area, computes the benefits of reducing organic and nutrient pollution in the tidal flat and compares them with the costs of constructing and operating the treatment plants.

Material and methods

The study employed a contingent behaviour analysis, one of the approaches of the travel cost method where data collected from questionnaire surveys was analysed with Poisson and negative binomial regression models, to estimate the values of the tidal flat according to its water quality.

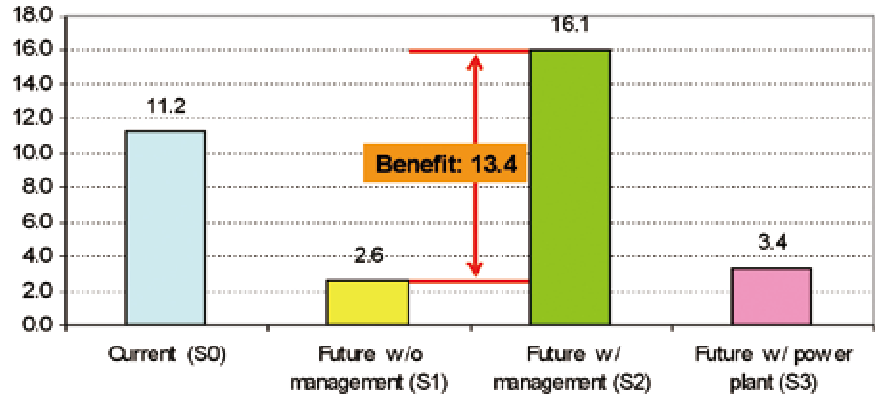
On-site and face-to-face questionnaire surveys were conducted in the summer and autumn of 2009 (Figure 2). The number of samples to be collected in each season was decided in proportion to the total number of visitors expected at a particular time of year. The dates and time of the surveys included not only weekdays and weekends, but also mornings and afternoons, to collect samples such that they represented the population of visitors to the site. The trained enumerators who were experienced eco-tour guides, interviewed visitors to the Centre and the Dongmak Beach. The interviewees were Koreans with the age of 18 years or older, who were randomly selected on site. Non-Korean visitors were not targeted because the percentage of them accounting for the total number of visitors to the site was negligible. A total of 403 samples were collected: 300 samples in August and 103 samples in November.

Figure 2 Questionnaire survey conducted with visitors to the Ganghwa Tidal Flat

Results

Most visitors to the site were from nearby cities in the province of Gyeonggi (40.2%) as well as Seoul (32.0%) and Incheon (23.0%). The number of people coming from other places was small, although the visitors did originate from almost all over the country. Most visitors (92.1%) used cars, including chartered buses to travel to the site, while a small number of people used route buses (7.1%) or other transportation such as bicycles (0.8%). The average tourist was 40 years old with a university diploma and an annual salary of KRW 34 million. He travelled 70 km and spent one hour forty minutes each way. The average travel cost was approximately KRW 37,000 per person per trip. The average tourist visited the site twice a year. He would raise the number of his visits to almost three times a year if the water quality of the site increased (Scenario 2); however, he would decrease the visits to less than one time a year if the water quality declined (Scenarios 1 and 3).

The values of the tidal flat vary widely from KRW 2.6 billion to 16.1 billion per year depending on the water quality (Figure 3). The estimated value of the tidal flat in its present condition was approximately KRW 11.2 billion per year. The value would decrease significantly by as much as KRW 9.0 billion per year if the water quality degraded under the hypothetical Scenarios 1 and 3. However, the value would increase up to KRW 16.1 billion per year if the water quality improved with the management actions were implemented under Scenario 2. The difference in the estimated values between Scenarios 1 and 2 can be considered as the annual benefits of improving the water quality which is approximately KRW 13.4 billion per year.



Note: Unit: KRW billion per year. S1, 2, & 3 denote Scenario 1, 2, & 3, respectively.

Figure 3 Value of Ganghwa tidal flat according to different scenarios

Discussion and conclusions

There is a strong economic justification for investing in the proposed treatment plants to improve the water quality in the tidal flat. This study, applying the contingent behaviour approach, estimated the total value of the recreational opportunities offered by the tidal flat in its current state of water quality as approximately KRW 11.2 billion per year (US$ 1 = KRW 1,100; mean 2008 rate). The survey suggested that the recreational value would decrease by KRW 9.0 billion if the water quality continued to degrade as a result of a lack of implementation of management actions. However, the annual value could increase to KRW 16.1 billion if the management actions were implemented so that the water quality was improved. The benefits of improving the water quality are estimated as approximately KRW 13.4 billion per year. Compared to these benefits, the costs of improving the water quality (i.e., the costs of the treatment plants worth KRW 0.37 billion per year) were relatively insignificant. The costs account for less than three percent of the benefits (0.37 / 13.4 = 0.028). These findings could be useful for policymakers and managers when considering public spending on tidal flat conservation, ensuring that decision-making at a policy level is efficient and justifiable.

Improving the Management of Critical Habitats: The Rongcheng Seagrass Beds in China

Prepared by

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January 2010

Introduction

Seagrass beds are a critical habitat and host a high diversity of marine life, providing valuable services to human society. In the western Yellow Sea, there were many seagrass beds along the coast (Yang 1979). However, as was the case with many other areas of the world (Waycott et al. 2009), the seagrass beds in this region have largely disappeared in recent decades as a result of heavy pressure from human exploitation activities and environmental changes (Zhang et al. in press). The situation is so severe that the current distribution of seagrass beds is limited to the coastal shallow water of Rongcheng City, Shandong Province, China (Figure 1) which has not been established as a marine protected area nor been under dedicated and efficient management and protection.

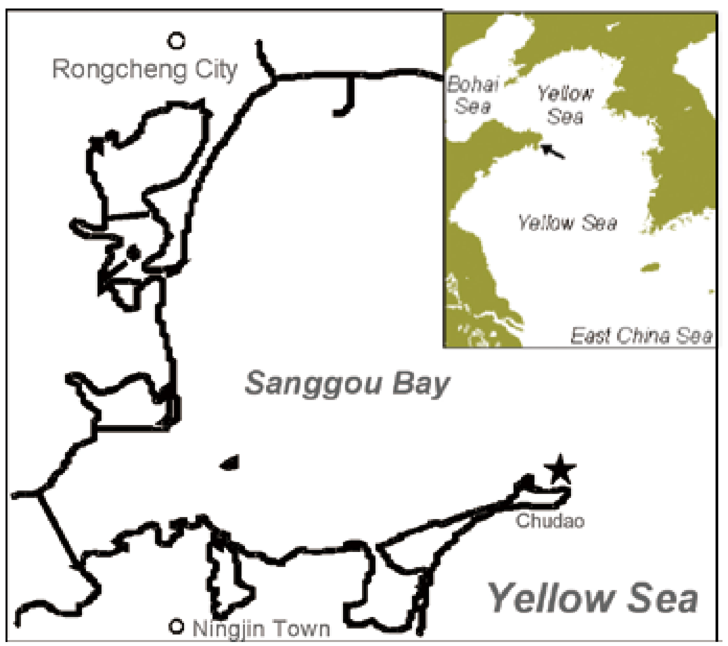

Figure 1 Location of the target area. The insert shows the location in the region.

In recent studies funded by the YSLME project, the seagrass beds off Rongcheng have been identified as the best example of seagrass habitat along the west coast of the Yellow Sea. As it is one of the last remaining seagrass areas it is considered a critical habitat with high biodiversity value that is in need of protection and improved management to ensure the sustainable provision of ecological services to the stakeholders. The center of the critical area has been identified as the seagrass bed near Chudao of Ningjin Town.

The project aims to address one of the regional targets of the YSLME project, "Maintenance of habitats according to standards and regulations of 2007" and its management action "Develop regional guidelines for coastal habitat management" by improving the management of the remaining seagrass habitat with full co-operation of stakeholders.

Methods

Major problems affecting the seagrass habitats and their causes were first identified through a literature review and follow-up consultancy meeting with nine experts from local institutes and the First Institute of Oceanography, SOA, P.R. China. The environmental, management and public awareness targets to restore and sustain seagrass bed health were identified through causal chain analysis which was assisted by two technical meetings to introduce expertise from outside the contract team and ensure efficiency.

As there were no marine protected areas for seagrass in the region, a consultation meeting was held in April for ideas and comments and then a proposal was submitted to establish the waters around Chudao as a protected area for seagrass and algae. This was in response to a call for proposals by the provincial government of Shandong. The proposal was approved in June and a new improved management plan prepared. The proposal was finally accepted by the Provincial Government in October.

The new plan was developed through a series of activities that included: i) a review of current management plans; ii) an assessment of the impact/effectiveness of the current management plans through stakeholder surveys, a meeting with local representatives and consultations with experts (if no management was in place) iii) gaps between the current management plans and the design of new management actions to fill those gaps iv) stakeholder agreement of the new plan.

Results

1. Major problems affecting the selected habitat and the causes

The major problems affecting the habitats were identified as; improper use of the sea area and a lack of protection and restorative action. The major causes included the lack of recognition by the users of the importance of the seagrass beds, both to the sea and local livelihoods and the lack an effective mechanism to protect the seagrass beds.

2. Environmental, management and public awareness targets to restore and sustain seagrass bed health

The key targets were identified as:

(1) Physical environment: keep seawater clarity to a depth of 2m so that critical light can reach the depth where seagrass normally grows in the region (Zhang et al. in press), maintain the natural hydrodynamics, sediment morphology and type (preferable sandy-mud) to allow normal growth of the seagrass;

(2) For management: set up a specific mechanism to protect the seagrass beds and develop/launch action programs to restore the seagrass beds

(3) For public awareness: ensure all sea users have awareness of the seagrass beds' value and the serious consequences of improper uses, raise the willingness of the general public to support seagrass bed protection and restoration, ensure their involvement in monitoring the sea use and reporting any improper use.

Development of the new integrated management plan

Current management plans

Reviews of different management plans by various sectors revealed very few to be in existence. They were a) one by the Mashan Group who tried to restore the declined seagrass in the Swan Lake area by clearing off the artificial bank and b) the Weihai Yihe Fishery Company who used the existing seagrass in Shuangdao Bay to protect sea cucumbers, thus indirectly protecting the seagrass as well. However neither of these two plans addressed major problems affecting the habitat and could not deliver targets to restore and sustain seagrass bed health.

Impact/effectiveness of the current management plans

Surveys revealed that a large proportion of local stakeholders are for the management and protection of seagrass and wish to continue receiving the ecological benefits of such actions. The survey also suggested local stakeholders thought that the seagrass beds were likely to further decline and disappear soon without efficient management in place.

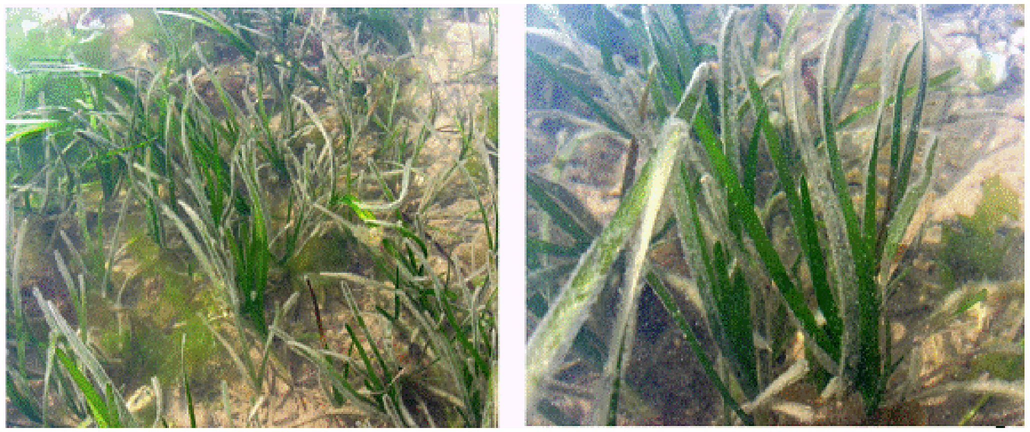

Figure 2 Trials of seagrass bed restoration using seed from Z. marina. Ya Ping Gao YSFRI, P.R. China

New management actions

The new management measures that were accepted include:

(1) Systematic surveys of the existing seagrass beds for a complete mapping and prioritising of the site to protect and/or restore. For decades there has no such survey, which constrains our knowledge on the seagrass beds and hinders further activities.

(2) Further promotion of public (and governmental) awareness of the seagrass beds value for biodiversity and human welfare. This is fundamental to any successful and sustainable management actions. An ideal state would be that majority of the public (and the government) regard seagrass beds as natural heritage, from the bottom of their hearts.

(3) Sound protection and use of the identified seagrass beds. This is largely due to the severe condition of existing seagrass distribution and immediate threats from coastal urbanisation and industrialisation. There is no choice but trying to protect what we can. However, protection should be well designed to incorporate the sound use and active involvement by local stakeholders.

(4) Research and practice towards restoration of the seagrass beds. Only in this way, can we quickly and successfully expand the distribution of seagrass beds which is very limited at present, and make their functions (values) more apparent to the public (and the government). This will also help the protection of exisiting seagrass beds and the development of those under protection.

Implementation of the management actions

Work with local government and other stakeholders to ensure proper co-ordination

A regular mechanism, a combination of reporting, meeting, phone calls and the specific website was established from the beginning. This mechanism ensured sufficient meeting and dialogue with the local government and other stakeholders from the start, and assisted management of the protected habitat. Currently the focal point in this mechanism is the contractor and the Center he serves, which is a public department serving the wide range of fishermen and aquaculture farms directly under the administration of the local marine management sector.

Liaise with the YSLME Project Management Office and other demonstration projects to ensure the effective implementation of management actions

Regular communication has been maintained with the YSLME PMO (Project Management Office) through e-mails, reporting and other approaches whichever was needed. The website is not only a window to the local stakeholders but a window showing the Project's progress to PMO. We also actively attended the meetings and introduced the status and future projections of the seagrass bed(s) to WWF and PMO visitors and exchanged experiences of MPA (Marine Protected Area) management with Korean partners at the first Yellow Sea Regional MPA Network Workshop.

Close contact and sharing of information, through phone calls, SMG, e-mails and face to face meetings, has been made with the other two demonstration projects (for the public awareness and stakeholder training, respectively) at the site.

Promotion of public awareness

The members of this project and the other two demonstration projects have been making every effort in promoting public (and governmental) awareness of the seagrass beds value to for biodiversity and human welfare. Among these, those related with this contract include: the website, the lectures to marine managers and NGO "Yellow Sea Utility" members on ecological functions and the protection/restoration of seagrass beds. We also provided ideas for the local introductive booklet "Ning Jin" to incorporate introductions on seagrass related fishery and folk culture.

In July, we co-organized in Weihai a domestic seminar entitled Ecological Restoration and Protection of Chinese Seagrass/Algal Beds with the Fishery Branch of Chinese Association of Agricultural Ecology and Environment Protection, and the Marine Research Institute of Weihai.

Suggestions to improve management in other potential seagrass MPAs

We made suggestions to the State Oceanic Administration (SOA) during the draft of National Marine Special Protection Area (MSPA) Management Regulation Measures, so that seagrass beds are identified as national MSPAS in the draft. Sound management and use of such MSPAS, promotion of public awareness and involvement in the MSPA management was also reflected in the draft.

Implement the new management plan with the new MPA

The seagrass bed north of Chudao Village Ningjin Community, has been approved as a provincial level MPA. This is the first seagrass MPA in north China, with a core area of 223.8 ha and total area of 544 ha, the MPA targets protecting the seagrass germplasm bank with a focus on the major growing and reproductive season June to September. This established the legal identification for the protection of the seagrass from any activities that may damage or pose significant harmful impacts on the habitat or vegetation of the seagrass bed.

Figure 3 The bulletin board of the seagrass MPA around Chudao.

The first year's management plan includes capacial building (installation of MPA signs and warnings of protection, establishment of a monitoring unit and the use of the boat) and primary monitoring and protection of the environment and seagrass bed. Other activities of the MPA include promotion of public awareness through various media and promotion of eco-tours. The MPA receives financial support from the Shandong Province and local companies and government also contributes. It's expected the seagrass bed area will expand to 200 ha and sea cucumbers, sea urchins and benthic shellfish will increase through the protection.

Discussion and recommendations

We decided that it was important to work with local stakeholders from the very beginning to develop a new improved management plan for the important habitat. This approach was efficient and useful, as previous experience had shown that no such plan will be successful or sustainable without stakeholders understanding and support, no matter how important the habitat is – Man's will and activities determine the fate of our neighbouring habitats.

The major problems affecting the habitats were identified as improper uses of the sea area and lack of protection and restoration actions. Accordingly, we developed and implemented measures by integrating activities into the new specific MPA, to resolve these issues. The site was chosen because of its significance of seagrass distribution, naturalness, close linking with folk culture and threats from adjacent development. We wish to use the successful experience in this MPA to help other areas facing the same issues to solve the problems.

We realise that the measures for protection and management of the seagrass bed in the current MPA is still local and limited, so we are trying to i) incorporate other important seagrass beds in this region into a network, so that they could benefit from each other and yield greater service to the ecosystem through synergy effects; and ii) integrate the MPA(s) targeting natural systems, with the folk seagrass culture, thus building a man-sea harmonised super system to let them benefit from each other.

Figure 4 Mr. Xinjun Zhang assisting members of the other two demonstration projects in visiting local 'seagrass' villages

Improving Stakeholder Training :
The Rongcheng Seagrass Beds

Prepared by

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December 2009

Introduction

Seagrass is a unique group of flowering plants that exist fully submersed in the sea. The taxa, regarded as seagrasses, include 60 species and belong to a very limited number of plant families; all classified within the sub-order *Alismatiflorae* (Dahlgren et al., 1985.). Seagrasses and the services they provide, are threatened by coastal development and growing human populations as well as climate change. Humans impact seagrasses in three main ways: eutrophication, sedimentation and contamination (Larkum, et al., 2006). Most assessments have concluded that increased nutrient loading of estuarine and nearshore marine waters are more of a detriment than a benefit to seagrass habitats. Two important processes have been linked to eutrophication-related declines in seagrasses; shading by phytoplankton and overgrowth by epiphytes, both result in a reduction in the light reaching the seagrass (Larkum, et al., 2006). The problem of sedimentation is mainly in sediment re-suspension which increases water turbidity and also the attenuation of light (Larkum, et al., 2006). As for the contamination, its sources include: herbicides, heavy metals and petrochemicals, which are all toxic to seagrass to different degrees.

In the Yellow Sea eco-region, seagrass beds are one of the most important components, distributed along the coastal area of Shandong Province, especially Yantai and Weihai City and dominated by 4 species of Zostera (Yang. 1979). Like many other places of the world, the seagrass beds in Shandong coastal area are undergoing accelerating degradation: according to the record of a survey in 1982, there were seagrass beds of 1334 Km^2 in the coastal area around Furong Island in Jiaozuo Bay, however, few seagrass patches were recorded in 2000's survey (The Compile Committee of China Bay Records, 1991). If this problem is left unattended, the loss of the entire seagrass habitat, along with the ecological and economical services they provide, could soon become reality.

There is a general lack of awareness about the conservation needs and rational utilisation of the sea grass bed resources in the local community. Salt marshes, mangroves, and coral reefs receive 3-fold to 100-fold more media attention than seagrass ecosystems, although the services provided by seagrasses, together with algal beds, deliver a value at least twice as high as the next most valuable habitat (Costanza et al. 1997). Therefore, this project was initiated to arouse public awareness of the sustainable utilisation and conservation of seagrass beds in our demonstration site through the provision of a series of stakeholder training activities with specific objectives. These were to;

1.Disseminate information on the ecological and economical significance of seagrass to different stakeholders;
2.Enhance co-operation between governments, NGOs and research institutes in seagrass bed conservation;
3.Derive successful experiences or lessons for replication activities in the future.

Demonstration site - Rongcheng city

Rongcheng is within Weihai City and located at the eastern tip of the Shandong peninsular. It is also a popular tourism site well known for its "seagrass houses" (Figure 1) - one of the most important and unique ecological folk houses in China and has a history of more than 200 years. The popularity of such houses reflects the abundance of seagrass at that time.

Figure 1 "Seagrass house" with sun-dried seagrass as roof in Rongcheng

To get general information of the distribution of seagrasses in Rongcheng City, three sites were visited, Zhu Island (also known as Chudao), Swan Lake and Yangyuchi Bay (Figure 2(a)). Two different conditions of seagrasses were identified, represented in Swan Lake and Zhu Island (Figure 2(c). Swan Lake, as a national protected area, had better preserved seagrass beds than other areas with *Zostera marina* being the dominant plant species (Figure 2(b). In contrast, Zhu Island only supported small patches of degraded seagrass.

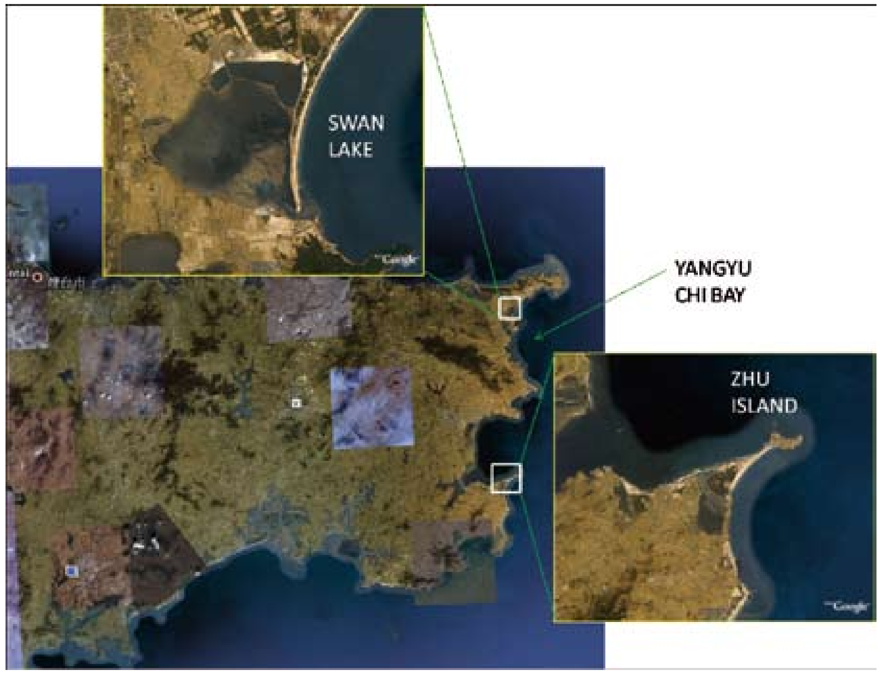

Figure 2(a) Geographic location of the 3 sites in the coastal area of Rongcheng city

Figure 2(b) Seagrass bed in Swan Lake, Zostera marina

Figure 2(c) On Zhu Island only patches of seagrass remains (left), an example of relative healthy beds (right).

No comprehensive studies have been conducted to investigate the cause of seagrass bed degradation in the coastal area of Shandong province. However, it is known that the health of seagrass is closely linked to the water quality, with eutrophication being the most common threat (Larkum, et al., 2006). Several investigations into sea water quality along Shandong province have revealed serious pollution, for instance, Shuangdao Bay (Zhou, et al., 2009), Weihai Bay and Jiaozhou Bay. It was notable that fishing and aquaculture industries are extremely well developed in Weihai, especially in Rongcheng City. Large-scale aquaculture commonly practiced there generates large amounts of organic waste, suspended solids, oxygen depletion and eutrophication. Local people also reflected on how large numbers of nets used in kelp and oyster farming now take up the area where seagrass used to grow.

Training activities

Training activities targeting different groups of stakeholders was conducted. The training for fishermen was conducted in Zhudao, Rongcheng City in the middle of May, 2009, involving 32 fishermen. The training team focused on two topics: the link between the seagrass and benefits to fishermen; existing regulations on the seagrass beds.

Training for researcher staff in the Institute of Fisheries, Rongcheng City was conducted on 19th, March 2009 with 15 participants. The issues analysed in the training workshop included; problems in the marine environment, especially anthropogenic threats to the livelihoods of the people that depend on it.

Training for the Fishery Bureau of Rongcheng City - relevant departmental officers from the local government office conducted training on 25th April 2009 and 6th Aug 2009 with a total of 46 participants. This training was specifically designed to build capacity in the management and utilisation of seagrass beds.

A public awareness campaign in the local community “Protect crucial habitats in crisis - protect seagrass beds” was carried out for 2 hours in the residential area, Zhongshengyuan, in Weihai City. 10 volunteers distributed more than 300 brochures to the pedestrians and held a public lecture on the importance and urgency of seagrass conservation in the Zhongshengyuan residential district Weihai, with more than 60 attendants.

The training designed for school students took the form of an interesting lesson. The lesson for primary school students was conducted in 3 primary schools- Zhudao Primary School, FuXin primary school in Rongcheng City and Rongcheng Central Primary School, which contained about 120 students per class.

For the lesson for middle school students- Rongcheng No. 19 middle school with 70 students, specially designed handouts were distributed to students for their further reading and sharing with other classmates. Stories relating to the handout were told to the students which encouraged them to tell these stories containing scientific information, to other people.

For the lecture for university students, a volunteer group called “the Yellow Sea Guard” was formed which gave training to the volunteers so that they could obtain enough knowledge and skills to teach basic principles and practices in wildlife conservation to their peers. These students were a major force in organising subsequent training activities, including those in schools and residential communities. “The Yellow Sea Guard” remains in place to organise further conservation campaigns spontaneously and participate in the future. New members will be recruited every year.

The “China seagrass bed recovery and conservation workshop” was hosted in Weihai on 15 Jul, 2009, co-organised by “the Chinese Society of Agro-Ecological Environmental Protection, Sub-Society for Fishery Environment Protection”, College of Ocean, Shandong University at Weihai and the Ocean and Fisheries Bureau, Rongcheng. The significance of this workshop was to provide a platform for information exchanges and inter-communication between different researchers working on seagrass and different stakeholders.

Other activities

Co-operation with the Fishery Technique Extending Station of Rongcheng City, in building a website "http://www.seagrass.org.cn/"http://www.seagrass.org.cn/ for sharing information on seagrasses, also providing up to date knowledge to the public (Figure 3).

Figure 3 A website created on seagrass

A visit for local fisheries bureau staff to the demonstration sites at Xiamen and Hepu, Guangxi improved their understanding of Integrated Coastal Zone Management (ICZM) involving marine environmental and resources protection in Xiamen, China.

Recommendations

Lesson 1: In the project, a group-execution team “Yellow Sea Guard” with several experts as advisors was very necessary.

Lesson 2: It was important to do an analysis in the planning of the training activities, to assess the knowledge levels of different groups.

Lesson 3: “Seagrass bed recovery and conservation workshop” was an important output in the project not only for information sharing, but also for an in-depth analysis of the status of seagrass research and directions for future research.

Lesson 4: The involvement of volunteers in public awareness campaigns could attract more attention and add to the success of such activities.

Improved Public Awareness of the Benefits of Biodiversity Conservation

Prepared by

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January 2010

Introduction

Seagrass/algal beds are a critical habitat, hosting a diversity of marine life and providing valuable services to human society. In the Western Yellow Sea particularly near Weihai City, there used to be many seagrass/algal beds along the coast. None of these seagrass/algal beds have received sufficient concern or effective conservation. As a result, due to increasing threats from coastal development, these submerged vegetation beds have declined (by ca. 90% for the seagrass and 60% for macroalgae) in comparison to their extent that existed twenty years ago (personal estimates). It has been shown by many relevant cases that without the public’s concern, involvement and support, management actions will not be readily accepted. These critical habitats, which are located close to human habitation and subject to threats from adjacent development, will never be conserved successfully without this. Therefore, the seagrass/algal beds off Weihai are proposed as target areas to demonstrate the management action “Promote public awareness of the benefits of biodiversity conservation” and address the YSLME SAP Regional Target “Maintenance of habitats according to standards and regulations of 2007”. It is expected, through these activities, to improve public awareness of the importance of seagrass/algal beds in the region and contribute to the improved management of these habitats.

Methods

Before conducting further activities, we first identified the audience/stakeholders for the activities by analysing social links to seagrass/algae areas and the proximity of the target audience to the team. Questionnaire surveys confirmed the focal audience. To raise awareness of the importance of seagrass/algal beds by the identified audience/stakeholders, three approaches were used: i) direct open public information posted on bulletin boards, dissemination of materials on the street and in the media (newspaper and TV) , which all targeted the audience within Weihai; ii) indirect information in the form of an introductory booklet at the Expo show and via tourism agents, which targeted a much wider audience primarily from outside Weihai; and iii) a lecture/seminar to educate and discuss with more specialised stakeholders. Some information was passed to interested participants in the questionnaire survey. The results of two questionnaire surveys, one at the beginning of the task and the other after the major activities were concluded, as well as feedback from other activities, were used to evaluate the effectiveness of these actions.

Results

Identification of the audience/stakeholders

Weihai is a City with a long history of close linkages to the marine economy, especially fisheries (and marine ecotourism). Both seagrass and algal beds provide valuable services to the City which makes it the primary and immediate stakeholder. From this population, three groups of local people were selected as the focal target audience for the task: i) people below thirty because they have little perception of the seagrass/algal beds due to their age and life style; ii) people living by the sea because they have more chance to affect/protect the seagrass/algal beds; and iii) aquaculture companies because they access some benefit from the seagrass/algal beds while at the same time may pose a threat to the beds. On the other hand, the marine products of Weihai are not only sold locally, but consumed by people outside of the City. Additionally people outside the City will benefit when they make sightseeing trips along the coast. Local people from Weihai were chosen for the survey depending on their accessibility to the researchers. Those with related professions were also targeted as well as the wider public outside Weihai.

Direct open public displays

Bulletin board shows

The audience for the shows included the local public who lacked understanding of the benefits of the seagrass/algal beds. Posters (Figure 1) were designed to be easily understood and read. They introduced the basic concept of seagrass/algal beds and showed the most important aspects of biodiversity supported by the beds and the benefits of conserving them. The posters were shown on bulletin boards at over thirty villages (coastal) and communities (rural and urban) to ensure a wide reception. People maintaining the bulletin boards (one for each), received training in basic technical aspects of seagrass/algal bed biodiversity so that they could answer questions by people reading the post. The feedback information they helped collect, showed that the post had been well designed and reached the general public.

Figure 1 An example of posters for the bulletin shows. This poster introduced the major seagrass species in the waters of Northern China. It showed that seagrass beds shelter many marine animals and support high levels of biodiversity. It also reported that seagrass has experienced significant declines and requires protection and restoration.

Dissemination of introduction materials

In order to increase opportunities for local people living by the sea to obtain information on the seagrass/algal beds, hundreds of introductory leaflets on seagrasses were disseminated and discussion were held with local people face to face in the street (Figure 2). This activity was also adopted in the Weihai and Rongcheng Government's action of science literacy (to popularise scientific knowledge to farmers and people in remote areas), so that the information could be repeatedly given out each year.

Figure 2 Public awareness activities targeting local people.

Media reports

The bulletin show and dissemination activities were reported by local TV news, thereby further widening the audience. This was evidenced by the fact that several interested writers reported on special issues on seagrass in three issues of the local newspaper, the Weihai Daily.

Indirect dissemination of information

Distribution of booklets to potential visitors

The most important information in the bulletin board post and introductory leaflet was revised and written into an easily readable and understandable booklet (Figure 3) which was produced by the local government. Hundreds of copies of the booklet were produced and freely distributed to tour agencies and visitors to the local area. It could have been considered as both an introduction to tourists and as promotional material to increase investment interest in the region. It helped expand the audience outside of the scope area and created potential opportunities to develop ecotourism associated with seagrass/algal beds.

Figure 3 Local introductory booklet "Ning Jin" with an introduction on seagrass related fishery and folk culture.

Expo show

As a result of suggestions to the Weihai Government, the seagrass thatched house was chosen as the representative showpiece of Weihai City at the 7th (China) International Garden & Flower Expo (Figure 4). The Expo was held at Changqing, Ji'nan City, Shandong Province from October 2009 to May 2010. Weihai's showhouse, with a roof of seagrass, was well received and lots of visitors took photos there.

Figure 4 Overview of the representative showpiece of Weihai City at the 7th (China) International Garden & Flower Expo.

Lectures/seminar

Seminar on the re-habilitation of Moon Lake

The team assisted two other demonstration contractors in the preparation and organisation of a seminar entitled "Ecological Restoration and Protection of Chinese Seagrass/Algal Beds" in Weihai. At the seminar, discussions of seagrass protection took place, using the case of Moon Lake, which used to have healthy seagrass but has now been degraded due to improper management and exploitation. The participants all agreed that Moon Lake was a representative case of habitat misuse and restoration and made further suggestions on seagrass protection and restoration.

Another seminar was held in August at Rongcheng, where ten representatives from different sectors; (the Mashan Group, responsible for management and recovery, representatives of local villagers adjacent to the Moon Lake, the Fishery Panel of the Association of Emeritus Professionals, the Center for Fisheries Technology Extension of Rongcheng, the Weihai Association of Science and Technology, and the Rongcheng Ocean and Fishery Bureau), met to discuss the changes at Swan Lake and suggest future projections on its re-habilitation. Recommendations on relevant studies and future actions were agreed and submitted to the local government for discussion through the Weihai Association of Science and Technology. The recommendations included three major points: i) to call for suggestions on studies to examine the best approach to restore the habitat; ii) to call for cautionary exploitation of the adjacent waters; and iii) to further improve awareness of the importance of seagrass and its appropriate management (although located in the nature reserve which is designated for its swan populations, seagrass is not a target for special protection at the site). As a partial response, the local fishery research institute started to study techniques for seagrass transplanting.

Evaluation of task outputs

Feedback showed that the information reached a broad audience. Comparing results (Figure 5) of the two surveys (about 100 people interviewed in each), an improved public awareness of the benefits of biodiversity conservation within seagrass/algal beds was observed. In the first survey, fewer people (ca. 40%, especially youngsters) could tell the difference between seagrass and macroalgae (kelp). People usually know macroalgae (such as the typical product, Haidai) but often mistaken seagrass also as an algae and rarely know its importance. In the second survey (focusing on people between the ages of twenty to thirty interviewed after the activities), more youngsters (ca. 70%) could tell the difference between seagrass and macroalgae (kelps) and the importance of seagrass and algae. This increase in public awareness demonstrated the effectiveness of the interpretive actions that were undertaken in that they helped more people gain basic knowledge and a strong perception of the importance of the seagrass/algal beds.

Nonetheless, there was still a considerable proportion (ca. 30%) of people who lacked or had only a limited awareness of seagrass or algal beds, even those with higher education levels (university students) and some aquaculture farmers. People were generally less aware of seagrass than macroalgae. This might have been a result of their limited contact with seagrass previously in their everyday lives, whereas macroalgae has been an important component of their food regime. The results also showed the need for further continuous promotion and education of this now rare habitat.

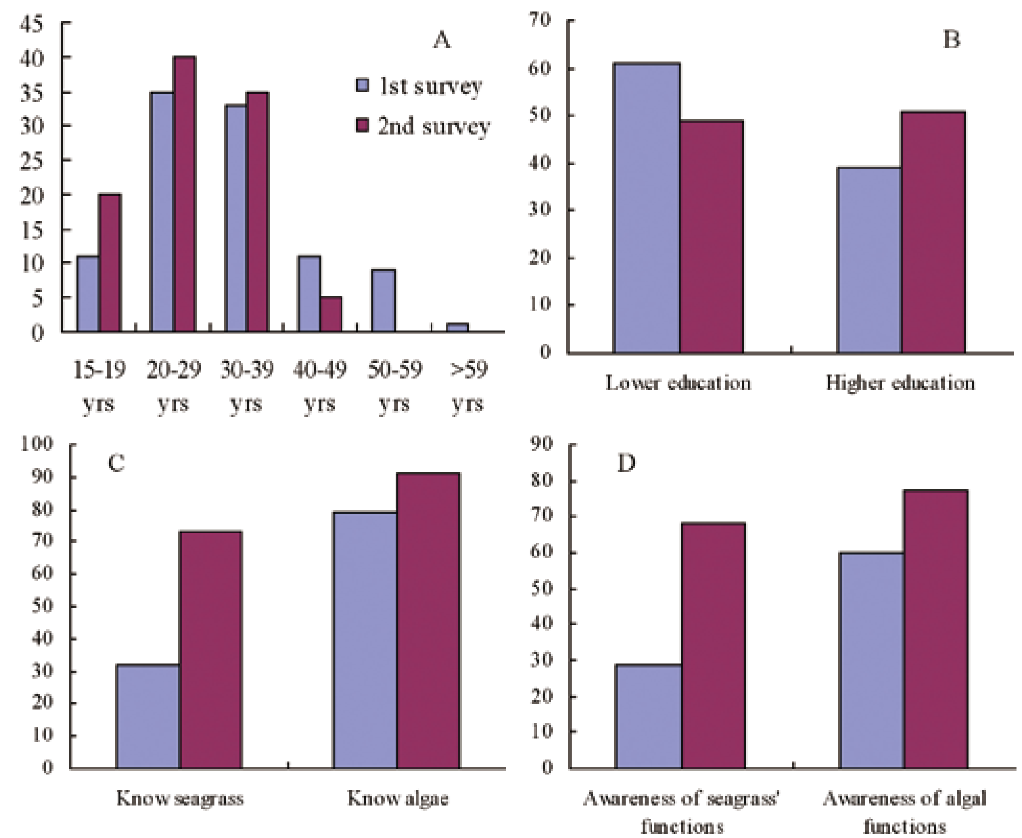

Figure 5 Questionnaire survey results: percentages of the surveyed people's age (A), education (B), knowledge of seagrass/algae (C) and awareness of their functions (D).

Summary of outputs achieved

1. Materials were designed and distributed via posters, leaflets or booklets, to engage the public and raise awareness of the benefits of seagrass conservation with an estimated 50,000 people having been reached.

2. Through these activities, public awareness was raised concerning the benefits of biodiversity conservation and seagrass/algal beds. Suggestions were also made to local government on the conservation of the seagrass/algal beds and studies have started on seagrass restoration.

Recommendations

The fact that there has been an increase in the awareness of the value of seagrass and algal beds suggests that the activity was successful. However to educate the public further, much more effort will be required. These activities are just the beginning. A concerted approach to future interpretation activities is recommended.

Figure 6 This poster introduces seagrass/algal beds and the functions they provide in biodiversity protection, water quality control and coastal erosion protection.

Improved Management of Critical Habitats around the Yellow Sea

Prepared by

Aqualab System
Hoon Park

February 2010

Introduction

The Ganghwa Southern Tidal Flat on the west coast of Korea is an internationally recognised habitat of critical importance for a variety of marine resources. It remains as the largest tidal flat in the west coast since the controversial embankment around the Saemangeum tidal flat in Jeonbuk Province was completed. It is best known as a stop-over site for many migratory and endangered water birds (e.g., black-faced spoon bill).

Tidal flats abound in organic material and are dominated by benthic organisms supported by benthic phytoplankton and the detrital food web. As such, benthic ecosystems provide a suitable habitat for shorebirds and migratory birds and feeding grounds for estuarine fish. Ganghwa tidal flat has a large inventory of benthic species with polychaetes and molluscs as dominant components (MOMAF 2003, 2006).

However, the habitat is facing a multitude of threats from pollution, siltation, ongoing conversion of the tidal flats for agriculture and urban and industrial development, with tidal power plants planned for the region. The water quality of the region is poor, and currently seawater is of the lowest level (quality level III) as assessed by National Fisheries Research and Development Institute (NFRDI's) water quality criteria. This is due mostly to excessive discharges of organic and inorganic nutrients via the Han River, which increases the biological and chemical oxygen demand. The major human impacts identified that will have the greatest effects on the biodiversity and the habitat quality are: nutrient pollution, tidal power plants and associated reclamation, and marine litter.

Currently several management plans are in place to protect the biodiversity and environmental quality in this region. However, no cross-review of their effectiveness and potential conflicts among those plans or with local socio-economic interests has been made. The goal of this project is to identify major environmental problems facing the area and review current management plans and laws related to these major environmental concerns that may have impacts on the biodiversity and ecosystems of the Ganghwa Southern Tidal Flat (GSTF). A final objective is to develop a comprehensive and integrated new management plan.

Materials and methods

Information on environmental data and issues was collected through various sources such as national reports, web sites, NFRDI's monitoring data centre, published articles and institute reports etc. Existing environmental laws and regulations were reviewed along with plans for coastal zoning related to the GSTF at the central and local level. Three stakeholder meetings were held to explain our findings and to hear from representatives about their plans for environmental management.

Results

Review of Existing Management Plans

With respect to the MPA around the habitat, several laws were enacted to protect the MPA. In addition, Ganghwa County established the Coastal Management Local 2nd Plan in consultation with KORDI in 2009. The local plan, established under Coastal Management Act Article 8, divided the coastal area into five different regions for different purposes (absolute conservation area, semi-conservation area, development area, development adjustment area, and development encouraged area). Under this plan, GSTF remained only as a semi-conservative region (Figure 1), partly because of the fierce objection of local residents to the area being designated as an MPA, which they thought could have undermined their properties' value in the south area adjacent to the tidal flat.

The plan was the most comprehensive management plan associated with the habitat. Locally the plan served as a guideline for private development plans (e.g. permit process). However, a major problem with the plan was that the current Coastal Management Act and the local plan were superseded by other marine environmental laws and other plans established under other environmental laws. Therefore they had no power of jurisdiction over national development plans (e.g., tidal power plants) which were subject to higher level statutory laws. The plan also lacked detailed management actions for Incheon's Tidal Power Plant and other development proposals.

Current Status of Environmental Conditions and Problems relating to the Habitat

Nutrient Pollution and Pollution Loadings in the Habitat

The status of nutrients shows that the water quality in the tidal flat was very poor, (Level III, judged by water quality criteria), with notable decreases in water quality since 2003 and large seasonal fluctuations. Total nitrogen was especially high during 2003-2006 periods, whereas total phosphorus seemed to increase steadily over the years (Figure 2). The trend of COD appeared to follow the pattern of TN, high during the same periods of 2003 to 2006. N/P ratio also closely followed the variation of TN, but was back to normal level for seawater (about 16 in molar ratio) in 2007 when the TN concentration dropped, but TP increased (data from NFRDI web site). Despite high nutrient concentrations, red tide events in the GSTF and the Han River Estuary are very rare due to the high turbidity (<< 30cm in Secchi depth) and strong tidal currents reaching 3-4 knots (NORI, 1997).

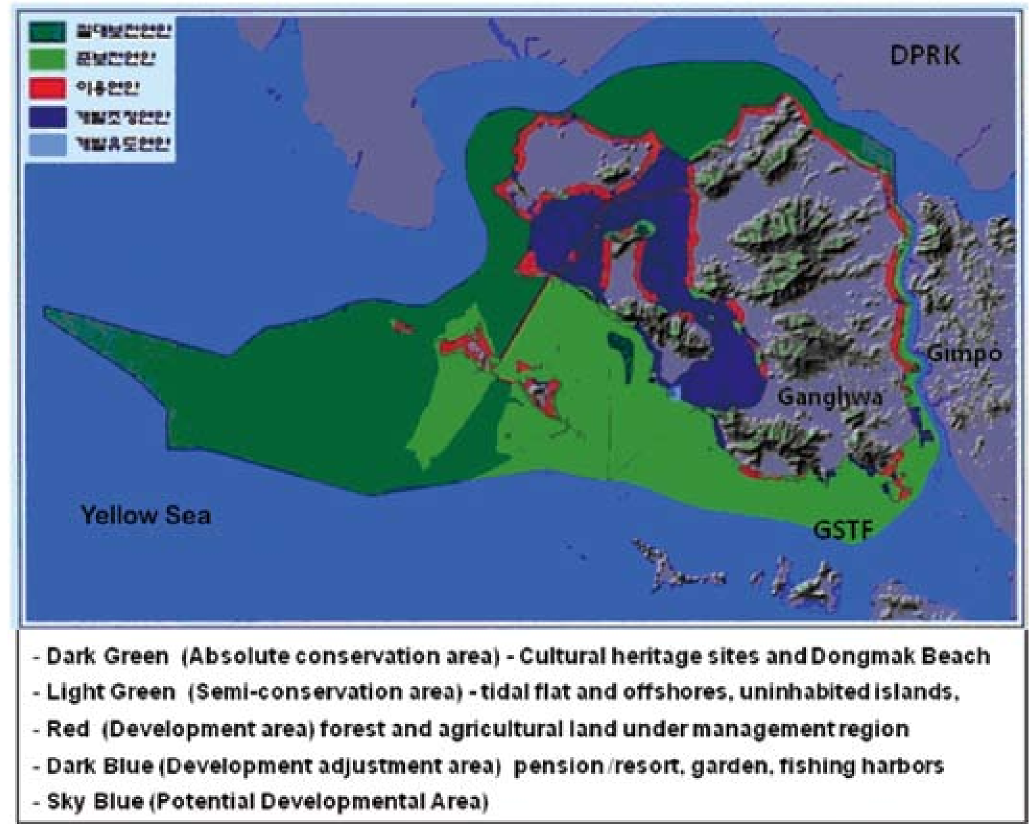

Figure 1 Coastal zoning in the GSTF according to the Ganghwa Coastal Management Local Plan (GCMLP, Ganghwa County, 2009).

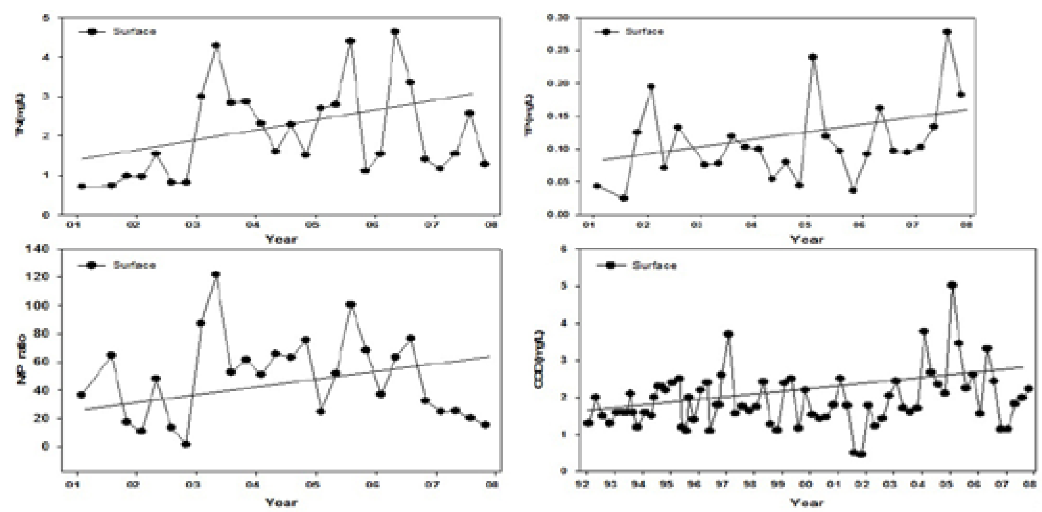

Figure 2 Temporal trends of total nitrogen (TN), phosphorus (TP), and COD in the GSTF station located in the east of Ganghwa tidal flat. (data from NFRDI web site)

Pollution load analysis showed that most of the discharge load is coming from the Han River, with little contribution from the local area. Households contribute the most as point-sources of nitrogen discharge and land as a non-point source.

A total maximum daily load (TMDL) was introduced in 2002 by MOE in three major river watersheds (Geum River, Sumjin River, and Nakdong River Basin), although some provinces already implemented TMDL. In the Han River watersheds, TMDL was introduced in Gwangju City and Youngin City in Gyeonggi Province in 2003. There was also a goal of reducing BOD to 5.5mg L-1 by 2007 in Suh-an bo of Gyung-ahn cheon (stream), the dominant water supply to the Paldang Reservoir in Gyeonggi Province, This is one of the two major drinking water supplies for the citizens of Seoul and its satellite cities. This was for the protection of major drinking water resources but no such implementation had been introduced in other tributaries downstream of the Paldang Dam, which lead to the Jamsil Drinking Water Reservoir in Seoul City, the other major water supply. In fact, the BOD level appeared better in Gyung-ahn cheon than those located downstream, which may have been of more concern for the water quality of the Han River.

In the past, sewage treatment plants were considered a major source of nutrient inputs into aquatic systems. Though wastewater treatment facilities still contribute nutrients, a great deal of progress has been made in reducing the levels of nitrogen and phosphorus introduced into major rivers through pre-treatment programs, facility upgrades and maintenance of the treatment processes. By the amendment of the Sewage Management Act (amended in Oct, 2001 which became effective in Jan 2008), Seoul City has upgrading four treatment plants from low to high degree treatment processes. This is to reduce the discharge level of BOD from 20 to 10ppm, TN from 60 to 20ppm, and TP from 20 to 2ppm (Kwak, 2004; Lee, 2006). Also, Incheon City plans to increase the daily treatment capacity of Songdo Sewage Treatment Plant from 30,000 to 90,000 tons per day by 2011 (www.hiconst.com).

Marine Litter Pollution

According to the data submitted by the government to the national assembly for the national audit in 2006, the amount of solid waste produced is the greatest around the Han River, topping 56,000 tons per year, greater than any other coastal area in the country and distantly followed by Jeon-Nam Province (Seonm-Jin and Young-San River). Nearly 90% of the total marine litter generated made its way to the coast, the highest among the provinces.

Regular monitoring of marine litter around the Han River was conducted at only two beaches, Eul-Wang Beach near Incheon International Airport in Incheon City and Dongmak Beach in the GSTF. The monitoring data in Dongmak Beach showed that plastics are the most commonly found litter by number of items (34%) followed by paper (21%), metals (15%), vinyl (8%), glasses (7%), and Styrofoam (6%). Monthly collection data showed that the amount of litter was highest during August and September after heavy rainfall. This monthly fluctuation indicates that the major sources of marine litter are throughout the river.

Tidal Power Plant Plans

Two tidal power plants have been proposed around the habitat, the Ganghwa tidal power plant (GTPP) planned on the west coast of the Ganghwa Island and the Incheon tidal power plant (ITPP) on the south side (Figure 3). The local proposal for building the GTPP may be dropped given the enormous cost for construction of each power plant (>2 billion USD). Meanwhile the ITPP has been included in the 4th National Power Supply Basic Plan (year 2008-2022), suggesting that the plan could proceed as proposed.

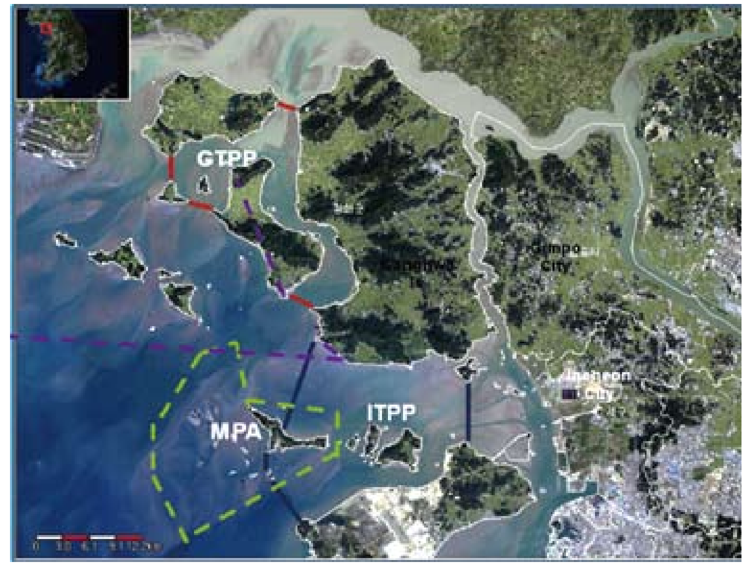

Figure 3 The planned location of the two tidal power plants around the Ganghwa tidal flat. GTPP is located in the west side and ITPP in the south of Ganghwa Island. MPA indicates Ongjin-Jangbong Marine Protected Area by MLTM

The power plant will have various environmental impacts which are hard to predict. The power plant would decrease the area of the tidal flat by 15% from 146.5 km^2 to 124 km^2 due to the reduced water exchange by the dams (MLTM, 2008). A major decrease of the tidal flat, is due to the increase of subtidal area because of the reduced water exchange by the dam. Two conflicts remain as obstacles to the construction of the power plant. The tidal flat around the Jang-bong Island is protected under the Wetlands Protection Law and designated as MPA. In addition, the tidal flat near the south-western part of the GSTF is protected under Cultural Property Protection Law to protect the black faced spoon bill habitats. Both protected areas sit right on or in the proposed construction area and will inevitably be affected both physically and ecologically. The tidal flat around Jangbong Island (68. 4 km^2) has been designated since year 2003 as a wetland protected area, re-designated in 2008.

Changes to the tides and currents during construction and then later during the operation of a barrage will cause changes in sediment characteristics, salinity and the quality of the water, which to a large extent governs the ecosystem. The placement of a barrage in an estuary has a considerable effect on the water inside the basin and on the ecosystem. Tidal barriers effectively decrease turbulent energy in the tidal system causing sediments and other particles to settle and accumulate as deposits of mud, sand and silt. Turbidity (the amount of matter in suspension in the water) decreases as a result of smaller volumes of water being exchanged between the basin and the sea. Estuaries often have high volume of sediments moving through them, which is especially true for the Han River, from the rivers to the sea. Sediment accumulation within the barrage affects the ecosystem and also the operation of the barrage. Many fish and birds rely on the estuaries for food, and access to that supply might be affected by a tidal barrage. Meanwhile, reduced turbidity allows light from the sun to penetrate the water deeper, improving conditions for phytoplankton growth. The changes would increase the biological productivity and thus potential food, causing a general change in the ecosystem. The average salinity inside the basin decreases as a result of less water exchange with the sea, which would also affect the ecosystem, but with the barrage in place, water would become clearer as silt would drop out due to reduced tidal flows.

Proposed Management Plans for the Protection of the GSTF

Water Pollution Management

In order to reduce nutrient pollution loads in the GSTF, different management practices should be applied for urban and rural areas. For urban areas, it is more efficient to construct domestic and industrial waste water treatment systems and additionally expand sanitary sewer systems, which are the most widely used method for reducing pollution from population and industries. On the other hand, it is more desirable to apply the non-point pollution management practices in the rural areas such as Ganghwa County and its vicinity. Therefore, the establishment of the Han River Basin Working Group (HRBWG) for the GSTF and the Han River Estuary is proposed to reduce the pollution input in the area. Water quality improvement programmes and local partnerships must be built to reduce the pollution input through the Han River and Ganghwa Island and its vicinity. Central and local governments, community groups, and local agencies have to commit to the implementation. In terms of the local level approach, we recommend to build a sewage treatment plant to control the domestic sewage input from the southern part of the Ganghwa Island to the GSTF.

Marine Litter Management

Figure 4 Litter collection with local communities

The current management plan is focused on retrieving marine litter once it is introduced into estuarine and coastal waters, not using preventative measures. This post-management policy needs to be shifted to a preventative policy of proactively reducing the amount of land-origin litter being flushed down into the river. Regional management plans must be incorporated with detailed action plans including specific reduction targets of marine litter. Marine litters are virtually a point source and therefore, public awareness needs to be strengthened through publishing brochures and pamphlets.

NGOs and communities are very important to accomplish marine litter control in the GSTF. Financial support of local NGOs and communities can increase the local activities related to the marine management programme. By financially supporting the International Coastal Cleanup, activities can be expanded to the drainage basin of the Han River (currently it is limited to the coastal area), and also make the marine litter monitoring programme more effective. Beach cleanup activities can be conducted. Discarded fishing gears on the sea bottom and this can be solved by real name-registration of gears and a buyback programme for old gears.

Tidal Power Plant Plans

The current marine environmental laws are written very loosely and vaguely, as such they are vulnerable to changes required by national development plans and other special laws. In comparison, Ramsar Convention Article 4 Clause 2 dictates that "Where a Contracting Party in its urgent national interest, deletes or restricts the boundaries of a wetland included in the List, it should as far as possible compensate for any loss of wetland resources, and in particular it should create additional nature reserves for waterfowl and for the protection, either in the same area or elsewhere, of an adequate portion of the original habitat." To better protect MPAs, the Cultural Heritage Protection Law may need to be amended so that adjustments of the protected area cannot not be made within 10 years since the designation date and are reviewed every 10 years to assess the appropriateness of the adjustment. The Wetland Protection Law could also be made more protection-oriented by including a clause in accordance with the Ramsar Convention to restore the same size of wetland lost or provide an alternative area equivalent to the area of wetland that is lost.

In terms of the local level management, planning for the current Ganghwa coastal zone must be re-established as little consideration was given to the socio-economic and ecological importance of the GSTF. The western part of the GSTF overlaps with the Ongjin-Jangbong MPA and most of the mud tidal flat surrounding the Island is designated as National Heritage No 419 in order to conserve the habitat for black faced spoonbills. Ecological services are also very important in the GSTF in terms of the socio-economic aspects of Ganghwa County. Therefore, GSTF should be upgraded to an "absolute conservation area" from its current designation of "semi-conservation area" under coastal zoning plans. This can provide impetus for further designation of the area as an MPA at a national level. To achieve this goal the bottom-up approach from local to central level is proposed because the designation of protected areas at national level depends on local agreement even if the MPAs are designated by central government (MLTM). Therefore, re-zoning of coastal use in Ganghwa Island needs to have the local agreement from land owners and individuals. This can be accomplished by an increase in public awareness, education and training programmes for local people to stress the importance of the ecological services and ecological conservation in the GSTF. Inclusion of the tidal flat area as a trekking course, currently being developed, may be a good way to increase the public awareness of the importance of tidal flats for their ecological services.

Implementation of Management Plans

For GSTF management plans to succeed, commitment of the top management and involvement of local community are essential. This indicates that GSTF management must include both top-down and bottom-up approaches, as local people are not sufficiently motivated to conserve the tidal flat. For the top management level, the Department of Marine Ecosystem of MLTM is the key department to successfully implement management plans as it has responsibilities for wetland conservation and MPA designation/management. At the local level, the Fishery and Greenzone Division of Ganghwa County is the responsible body for coastal zoning and management. Local and central government can formulate GSTF management plans for local people but the general acceptance of the plan by the local people is not always assured, never the less, it is essential for implementation. Currently the conservation prospect for the GSTF is negative as most local people are development-orientated. Possible solutions are to increase public awareness, education and training for the local people to make them understand the importance of the ecological roles and services of the tidal flat. By continuous and consistent efforts there will be a gradual change in public opinion on the conservation of the GSTF.

Conclusions

Tidal flats are a major habitat type in the Yellow Sea, especially in Korean coastal areas. However, the management of this habitat is not simple because coastal management is a complex interaction of laws, programs, and efforts to evaluate trade-offs and make decisions about how to use, conserve, and value the resources and opportunities of the coastal zone (Gordon et al., 1998). The fundamental questions coastal management seeks to address are: as a society, how do we want our coasts to function, what do we want them to look like, and what uses do we want them to accommodate? We value the ecosystem functions of coastal areas and want to preserve them for future generations. Our coastal areas are also important economic zones and need to accommodate certain coastal-dependent uses. Finding the right balance requires the engagement of all levels of government, research institutions, private citizens, industry participants, and non-governmental organizations. In this report we focused on the two facts, sustainable use and integrative management planning for tidal flat conservation.

During the last three decades (1970-2000), the Korean economy developed very fast with average GDP growth of 7.2% during this period (Hur, 2009). During this rapid development, about 30% of tidal flats disappeared to provide industrial and residential land use. The remaining areas were regarded as a major resource for protein producing shellfish and common octopus. Still there is a tendency to look at the tidal flat as a target for further development and as a fisheries resource, rather than a natural resource to be conserved for future generations and a major source of ecological services. Therefore, it is important to increase the public awareness of the ecological significance of tidal flats as a habitat. Practical and detailed programs for the public education and training at the national level must be developed to meet the various levels of public involvement. Re-evaluation of coastal habitats such as tidal flats and estuaries must be made through research projects to assess the ecological importance and to investigate their role in terms of socio-economic considerations. Most of the coastal habitat conversion and deterioration are adverse products of political short-sightedness rather than sustainability. A two way approach to solve these problems is proposed, bottom-up and top-down, Zagonari (2008). As a top-down approach central governments need to provide temporary financial relief for those adversely affected by the new management plans, research funding to develop public education and training programs, and identify values and ecological services which can be attributed to coastal habitats. It is also essential to increase the public awareness for coastal conservation as a bottom-up approach because there is no efficiency in conservation planning without public help and engagement. Therefore, public awareness of nature conservation is crucial in the successful implementation of management actions. Gradual and continuous education and training the public about nature conservation can help the public understand the importance of coastal ecosystems and the benefits of sustainability rather than short-term development.

Integration of management plans is also another crucial element to make the management implementation more successful and efficient (Juhasz, 2003). The current environmental management system in Korea is very unproductive due to the two separated management bodies. The Ministry of Environment (MOE) covers the terrestrial environment only and MLTM (former MOMAF) manages marine environments (Noh and Lee, 2006). Therefore, transitional areas such as estuaries are a grey area for environmental management as there is no integration body between central ministries. GSTF management plans are mainly established by MLTM, but the Han River and its basins, which contribute 95% of the COD loading for the GSTF, are managed by MOE. However, there is no integrative body or networking to discuss the management plans for the coastal area between the two ministries. Local governments are in the same condition as central governments. They are not concerned about the transboundary matters. Therefore, we proposed management plans with a more integrated focus in terms of the water quality and marine litter management between local governments and central ministries etc.

Tidal power plant construction is the most threatening issue for the GSTF conservation. The plan includes the construction of dykes surrounding the GSTF which will limit water exchange significantly within the tidal flat area. These development plans must be re-evaluated in terms of the sustainability and economic values if green energy production by the tidal power plant is to be comparable to the economic values from the GSTF ecological services. Cancellation of this plan will be the challenge for proposed management and implementation plans. The proposed bottom-up and top-down approaches can greatly contribute to increasing public awareness of the need for sustainability in coastal use and conservation. Integration of management can provide an effective means of ensuring successful implementation.

Figure 5 The endangered black faced spoon-bill

Stakeholder Training and Public Awareness: Demonstration Activities on the Ganghwa Island Tidal Flats, RoK

Prepared by

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April 2010

Introduction

The Ganghwa Southern Tidal Flat (GSTF) is located in the south of Ganghwa Island, in the mouth of the Han River Estuary and is one of the principle islands of Ganghwa County. It was designated as a demonstration site for the Yellow Sea Large Marine Ecosystem (YSLME) biodiversity project in 2008. The tidal flat is 16km in width (west to east) and 5-10km in length (north to south) and is located between Ganghwa Island and Incheon International Airport on Young Jong Island.

Figure1 The demonstration area

The GSTF is an important ecosystem for various marine and estuarine species and includes habitats such as waterways, bays, intertidal mud flats, sand beaches and coastal brackish/ freshwater wetlands. The whole area of the tidal flat was designated as a national monument to conserve the black faced spoonbill nesting area and also as a marine protected area (MPA) in the west part. Major fisheries include intertidal shellfish and fish/crustacean in both of channels of the island. Most of the residents of the Island are rice farmers rather than fishermen.

Recently, the tidal flat has faced environmental degradation due to increased water pollution, visitor numbers (tourists) and developmental plans which included tidal power plants. Moreover, new constructions of pensions and restaurants in the south of Ganghwa Island increased water and sediment pollution from domestic sewage and have had adverse effect on the water bird populations.

Ganghwa Island has a variety of natural resources such as mountains, coast, tidal flats and migratory birds. Among these resources, the southern tidal flat of Ganghwa Island is an internationally recognised critical coastal habitat for endangered migratory birds. Yet public awareness and education programs have not been developed in respect of the value for the critical habitat and other natural assets. This project has improved public awareness and education/training by helping the public recognise that conservation of biodiversity in this region is a win-win strategy, not only for the nature but also for the public. To that end, existing brochures and materials that related to tidal flats and wetlands in other regions and countries were reviewed. Pamphlets and brochures focusing on the Ganghwa tidal flat with specific emphasis on its economic value (e.g., income generation) for the public and local residents were drafted. The study aimed to provide materials/events that raise awareness of the biodiversity supported by these habitats, the benefits that they provide and the consequences of their loss or degradation. This demonstration activity to "Improve public awareness and education/ training of the benefits of biodiversity conservation around the Yellow Sea" addresses the SAP Management Action 10-4: Promote public awareness of the benefits of biodiversity conservation.

Methods

To accomplish these demonstration activities a project steering team including Anyang University, Ganghwa Tidal Flat Center (GTFC), Ganghwa People's Network and Ganghwa County was assembled. We reviewed existing public awareness programs mainly operated by GTFC and Ganghwa County and involved specialists in tidal flat ecosystems and water birds. The local government office, website and organisations to collect data and information about Ganghwa County and its natural environment, were investigated.

Major activities, including training, exhibitions and the production and distribution of public awareness materials, were carried out at the GTFC with support from Ganghwa County. On-site eco-tour programs were conducted at and around the tidal flat on the Island. For details of each activity and its results, see the following section.

Results

Identification of the target audience

The target audiences were identified and public awareness activities/education programs developed, along with a review of the potential problems caused by a lack of public awareness in the area. The target audience of the GSTF were identified as fishermen, farmers, pension owners, eco-guides, public servants and tourists etc. These were then classified into primary and secondary groups, based on the degree of tidal flat use and contribution to GSTF conservation. The primary groups needing immediate awareness raising and education and included farmers, fishermen, pension owners, public servants and eco-guides. The secondary groups were visitors and young people in local community.

There had been no systematic education/training and public awareness programs for conservation at the GSTF, previous activities had been insufficient to raise public awareness because of the limited budget and human resources available. The possible adverse effects on tidal flat conservation without further public awareness and education were thought to be;

- Insufficient understanding of tidal flat ecosystems and their benefits for stakeholders
- Inappropriate use of the GSTF by visitors who have no guidelines/regulations to instruct them on how to conduct their visit
- Declines in the GSTF's functions such as filtration of pollutants, habitats, and fisheries
- Negative feedback from uninformed local residents about the downfall of the local culture and economy because of the GSTF, resulting in further destruction of the area.

Activities for increasing public awareness

Water bird exhibitions at the Ganghwa Tidal Flat Center

Posters and pictures on the migration routes, ecology, and the conservation value of GSTF's main migratory bird species such as the black-faced spoonbill, the red-crowned crane, and other shorebirds, were created and exhibited at the GTFC. The exhibitions were held during March through May, 2009 for red-crowned crane, June through August, 2009 for the black faced spoonbill, and September through November, 2009 for the other shorebirds. About 15,000 people attended the exhibition during these periods. In addition to these, spoonbill exhibitions were also held in Songdo Spoonbill Island in Incheon City and Ganghwa High School, the shorebirds exhibition was held at Incheon Yeil High School and Ganghwa Women's Hotline Bazaar. The total number of visitors was said to be around 10,000 people. 108 questionnaires were analysed to estimate the effectiveness of the exhibition and the results are as follows. Only 5% of visitors know about shorebird ecology before the exhibition which increased to 47% after their visit. 73% of participants recognised the importance of GSTF as an important area for migratory birds and fisheries. 93% objected to plans for tidal power plant to support GSTF conservation.

Production of black faced spoonbill pocket notebook

Pocket notebooks about spoonbills were produced to raise public awareness about the birds. About 2,000 notebooks were produced and distributed to the visitors of Ganghwa Island through local pensions, restaurants, and environmental organisations.

Production of promotional booklets

Three types of booklets (pamphlets) covering the major migratory birds were produced to raise public awareness about the importance of shorebirds and were distributed to visitors and local people. These were the red-crowned crane (#202 national natural monument, NNM), the black-faced spoonbill (#205 NNM), general shorebirds, Their migration routes, ecology and conservation needs were illustrated. These birds are listed as endangered species. The content of the booklet was such that it could be understood by the public, an English translation was provided for foreigners. The major contents of the booklets were behaviour, prey, observation points for cranes, the role of rice paddies, migratory routes, breeding grounds, hazards, and tagging research for the spoonbill. They also included general information on shorebirds such as the roles of the GSTF its morphology and ecology, and species identification guides for birds. A total of 1,800 booklets were produced and distributed to GTFC visitors and local teachers. Effectiveness was measured through questionnaires handed out to 43 visitors to the GTFC as well as 18 teachers. Understanding of migratory bird ecology increased from 20% before receiving the information, to 85% after reading the booklets.

Promotion through Banners and Stickers

Banners on migratory birds were displayed in various locations as part of a long-term outdoor promotion. 15 types of spoonbill stickers were designed with comic pictures and a total of 1,000 sets were produced showing the bird's life cycle from breeding to flight (Figure 2). The stickers were distributed to GTFC visitors, local people like restaurant and pension owners, and NGOs.

Figure 2 Spoonbill stickers, pocket notebook, and banners.

Activities for stakeholder training and education

Stakeholders of the GSTF vary in terms of their education level, occupation and interest in natural conservation. Therefore, they were divided into three homogenous groups in which each group had similar education levels and backgrounds.

Education and Training

Education and training activities for GSTF stakeholders were attended by 104 people over 2 days. Classroom lectures were held at the GTFC and also out on the tidal flat. We invited public servants to introduce the strategies and plans for eco-tourism on Ganghwa Island for local residents and other stakeholders. Also various lecturers from other fields were invited to give practical education to local stakeholders including information on the ecological services of GSTF, the ecology of shorebirds/benthos/halophytes, production of an ecotourism map, ecotourism programming, general ecology, environmental education, and the identification of shore birds etc. From the survey, participants were interested in all the topics; ecotourism 18%, importance of tidal flats 23%, migratory birds 20%, benthos 18% and halophytes 21%. 86% of participants thought that conservation policies should be focused more on the specific activities and promotions such as tidal flat public awareness programs, rather than on general environmental conservation programs. Through these activities they realised the importance of Ganghwa Island itself (57%), the importance of environment (22%), an understanding of local government (14%) and the importance of GSTF (7%).

Eco-tourism Programs

Two eco-tour programs were held in August and October, 2009, respectively (Figure 3). The first eco-tour was focused on the local economy and targeted local stakeholders like pension owners, farmers and fishermen. The major themes explored included the ecology of the black faced spoonbill, the relationships between spoonbills and eco-tourism, eco-tours with storytelling, and values of eco-tourism in Ganghwa Island etc. For the second tour, the program was focused on establishing a set of examples of how eco-tourism could work together with the local residents. The eco-tour sites were extended to forests and historic sites. 18 questionnaires were analysed to measure the results of the tour. Participants showed interest in promoting and following-up actions from the tour, but were not interested in direct involvement as eco-guides for visitors. Some of the local residents, such as fishermen, skipped the afternoon session showing their lack of interest. However, those who stayed to receive the afternoon session, such as the pension owners, actually showed more interest in eco-guiding. Further education and training may be needed to involve the local farmers and fishermen in this area.

Figure 3 and lectures Bird watching

Plans for Increasing Local Values

Local people do not appear to recognise the equal value of natural resources and historic sites on the Island for the local economy so the following actions were suggested.

- Continuous development and implementation of education and training programs
- Development of guidelines for visitors to the tidal flat
- The establishment of a GSTF Conservation Committee involving the local community, NGOs and research sectors
- Further development of natural and cultural resources and visiting programs
  - -Visitor programs for fishing/farm villages and fishing and farming experiences
  - -Extension of bird watching programs and sites
  - -Temple/historic site visiting programs
  - -Development of historic sites
- Further development of eco-tour programs combined with natural and cultural sites
- The development of an Island walking trail around the tidal flats and forests
- Increasing values of local products through organic farming.

Figure 4 Environmental education is vitally important to manage the Yellow Sea in the foture.

Conclusion

Public awareness and education/training programs were developed and conducted to increase awareness of the importance of GSTF and its values for the GSTF stakeholders. Major activities and programs included a water bird exhibition, production/distribution of pamphlets, education/training of major stakeholders, and eco-tours.

The public awareness programs were focused on exhibitions and promotions which provided information on tidal flat ecosystems and their functions as wildlife habitats. A wide range of promotional material was produced and distributed. After the exhibitions and promotion there was a significant increase in understanding in the tidal flat ecosystems and a tendency towards the sympathetic conservation of the tidal flat system. 95% of the participants (mainly tourists) stood positively against the tidal power plant plan in the GSTF and were concerned about impacts on the shorebird population. Promotional books were popular among children and some of the teachers indicated that they could use them as teaching materials. The booklets were expected to have a positive effective in increasing the value of the GSTF. However, their distribution was limited to local people due to budget restraints.

Education/training and eco-tour programs were also developed and implemented to increase the public's awareness of the GSTF. Lectures and eco-tours were conducted in the classroom and out on the tidal flats. Local stakeholders such as fishermen/farmers, pension owners and eco-guides were major participants on these programs. Lectures were focused on the understanding of the tidal flat ecosystem and its services because of the lack of knowledge on these aspects. Major topics for discussion were about tidal flat ecosystems, migratory birds, benthos, halophytes and eco-tourism on the GSTF. Before these programs visitors obtained information about the tidal flat through mass media like TV and newspapers but only had a rudimentary understanding/knowledge of tidal flats.

The participants were interested in the aspects of the training, especially in wildlife and eco-tourism. However, the frequency of the lectures was limited due to the time constraints from their own businesses. The best time for training fishermen and farmers is during winter time when they are usually free and during the weekdays for pension owners. 50% of local stakeholders like fishermen, farmers and pension owners were in favour of the planned tidal power plant plan and still expected a boost in property prices as a result of the power plant development.

GSTF is the last remaining river mouth tidal flat in South Korea and is constantly exposed to threats of development, pollution and misuse due to its proximity to the Seoul metropolitan area. To mitigate against these threats it is recommended to;

- Establish guidelines/codes of conduct for visitors to the tidal flat
- Develop systematic education/training programs for local stakeholders/visitors
- Extend GTFC roles by fund raising and an increase of government support
- Establish a GSTF Conservation Committee to steer the major conservation activities

Figure 5 Environmental education activities in China

Integrated Multi-Trophic Aquaculture

Prepared by

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Introduction

With the rapid development of intensive mariculture, the impact of the industry on the ecosystem has become so serious that the degraded environment has led to a high mortality in mariculture organisms. The mariculture industry worldwide is searching for more sustainable methodologies. Integrated multi-trophic aquaculture (IMTA) is a new technique that integrates the culture of feed species, such as finfish, seaweeds, and suspension and deposit- feeders, to minimize the negative effects of the mariculture industry on natural ecosystems. IMTA has been proposed to reduce waste and the ecological footprint of mariculture operations whilst at the same time enabling economic diversification and improving the social acceptability of culturing systems. IMTA has the potential to contribute significantly to the sustainability of mariculture.

In the past, most studies focused on land-based systems and only a few to-date investigated the possibilities of IMTA farming in open water. In the past fifteen years, the integration of seaweeds with marine fish culturing has been examined and studied in Canada, Japan, Chile, New Zealand, and USA (Buschmann et al., 2008; Troell et al., 2003; Chopin et al., 1999, 2001, 2008; Abreu et al., 2009). IMTA has been commercially successful at industrial scales in China for many years. Depending on the prevailing conditions at the culture site there are many different options for IMTA combinations. Given the vast number of cultured species around the world there are combinations that can be used in all situations from tidal flats to tropical estuaries and sandy beaches.

The main purpose of this demonstration project was to show the effectiveness of polyculture vs. monoculture taking into account production, economic and environmental considerations.

System components

The system comprised of several different levels. In the first, excretory and waste products generated by abalone were taken up as nutrients by kelp and converted into plant biomass to provide food for the abalone. The culture of marine animals often results in the production of ammonia as the primary nitrogenous excretory product which can cause eutrophication. However seaweed can transform ammonia-nitrogen into plant protein-nitrogen by photosynthesis which can be used as a source of nutrition for herbivores, e.g. abalone. Here, seaweeds were used to remove and transform dissolved inorganic nutrients from effluents of both finfish and bivalves and in return, provided dissolved oxygen (DO). Bivalves were used as filters to remove suspended organic material.

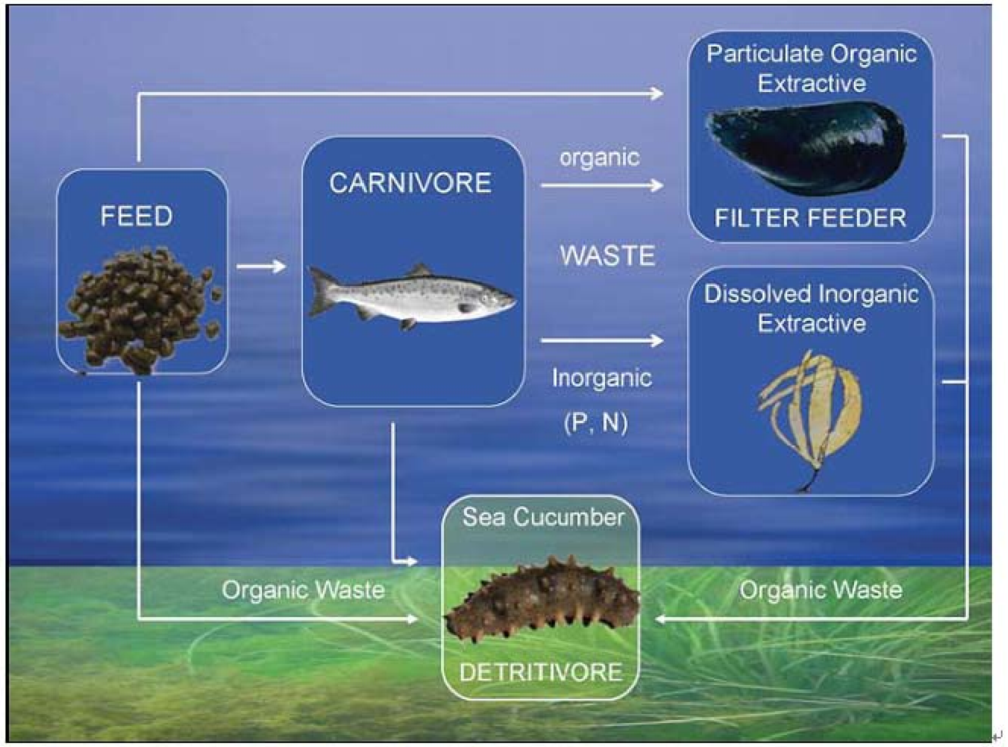

Figure 1 The IMTA of concept

In the next part of this IMTA system, seaweed and clams were recruited from the natural environment. Seaweed was used as food for abalone and sea urchins, while sea grass in the system provided shelter for swimming animals and benthic organisms and for nutrient cycling. The faeces of clam and abalone and natural organic sediment, were utilised as food by the sea cucumber. Ammonia-nitrogen excreted by feeding animals was absorbed by phytoplankton and seaweed. Phytoplankton was used as food for the clam and seaweed and phytoplankton provided DO for the animals.

A review and summary of historical data on monoculture

Located on the west coast of the Yellow Sea China, Sanggou Bay is an important area for shellfish and seaweed mariculture. When seaweed culture started in the 1950s, the cultured area and annual production were small. In 1985, annual production was 4.4Mts but thereafter escalated rapidly. From 1985 to 1996, dramatic increases also occurred in shellfish production, with figures rising from 400 tones per annum to approximately 56,000 tones. Since 1997, the yields of scallop declined as a result of high summer mortalities so the culture of shellfish shifted from scallop to oyster. The cultivated area and annual yields in Sanggou Bay increased gradually and has now spread outside the Bay. In 2000, the annual yields of shellfish and kelp were 65,000 Mts and 84,000 Mts respectively.

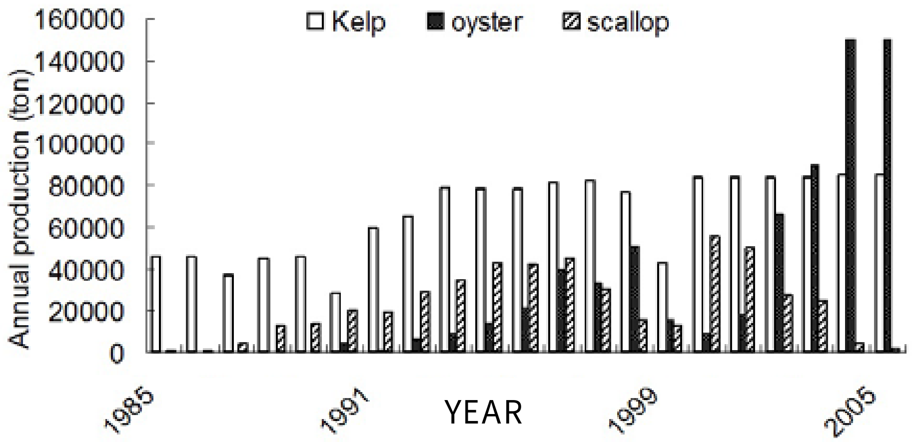

Figure 2 Annual yields of mariculture, shellfish and seaweed in Sanggou Bay from 1985 to 2005. Note: data from local Bureau of Fisheries

Today, over 70% of the Sanggou Bay area is used by longline mariculture except for the sea-routes. The mariculture areas in the Bay are arranged as follows: shellfish are mainly cultivated along the coast of the Bay; shellfish and kelp polyculture are in the middle and kelp is cultivated on the outside of the Bay.

A review of current efforts in IMTA, estimating the environment and economic impacts to farmers using modelling

Current monoculture practices especially that of carnivorous fish culture can potentially negatively impact the environment. Integrated multi-trophic aquaculture (using seaweeds, herbivores, omnivores and detritivores) has a significant economic advantage compared with monoculture as the whole three dimensional space is used and the waste products of one trophic level are utilised by the other, so stocking densities can be increased. IMTA is just at the experimental stage in the open sea in China, its uptake depends on the willingness of each farmer.

A multi-species model for shellfish and kelp polyculture in Sanggou Bay was developed which integrated a 'Bay- wide' ecological simulation with individual-based modelling of scallops and oysters combining the individual processes for the target species by means of a multi-cohort population dynamics model. The model included physical exchanges with the ocean boundary, biogeochemical processes within the Bay, individual growth and population dynamics of target species and human exploitation (seeding and harvesting). The model was influenced by light, temperature, man and exchanges of dissolved inorganic nitrogen, phytoplankton and suspended particulate matter at the ocean boundary. The model was used to estimate the exploitation and carrying capacity for scallops and oysters in the system, the harvest potential for different seeding and harvesting scenarios, and the impacts on the ecosystem of different polyculture management strategies. Recently, a new mathematic model for finfish mariculture in the north of Sanggou Bay was developed. In this model, the response of environmental factors to fish culture was simulated and the carrying capacity of finfish in a virtual farm was estimated. Using these theoretical models, the IMTA of finfish (*Sebastodes fuscescens*) was investigated with the longline culture of bivalves (scallop *Chlamys farreri*, oyster *Crassostrea virginica*) and kelp (*Laminaria japonica*). At the time of writing, the outputs of the model were not known.

Selection of demonstration sites, methods and results

A) Ecological Benefit Enhancement Demonstration Area. The Chudao Island Company, located in south coast of Sanggou Bay, was the co-operation partner for the enhancement project on the bottom culture of sea cucumbers (*Apostichopus japonicus*), abalone (*Haliotis discus*) and clams (*Ruditapes philippinurum*). This was based on the ecological carrying capacity

B) Environmental-friendly Mariculture Demonstration Area. The Xunshan Fishery Company, located in north coast of Sanggou Bay, was the co-operation partner mainly for implementing Integrated Multi Trophic Aquaculture (IMTA) of:

(1) Longline culture of fish (*Sebastodes fuscescens*), bivalves (scallop *Chlamys farreri*, oyster *Crassostrea virginica*) and kelp (*Laminaria japonica*);

(2) Longline culture of abalone (*Haliotis discus*) and kelp (*Laminaria japonica*).

Long-line culture of abalone (*Haliotis discus*) and kelp (*Laminaria japonica*) in Sanggou Bay.

Longline mariculture of abalone is predicted to expand rapidly in Northern China in order to meet increasing consumer demands. As abalone are cultured in stacked plastic trays, feed has to be supplied, usually as fresh and dry macroalgae. The resulting excretory products and food detritus can have negative effects on the natural ecosystem and may eventually impact on the health of cultured abalone if water quality declines sufficiently. New approaches to include the introduction of integrated mariculture of abalone and kelp are required to minimise the negative effects of the growing mariculture industry on the environment. A potential benefit of IMTA is that of the cycling of nutrients is facilitated. Excretory and waste products generated by the abalone are taken up as nutrients by the kelp and converted into plant biomass to provide food for abalone.

Methods: A demonstration area of longline culture of abalone and kelp was setup at The Xunshan Fishery Company, located in north coast of Sanggou Bay (Figure 4). The experimental culture was carried out from April, 2009. This is because the abalone were transported to Southern China to pass the cold winter and then transported back in April when seawater temperatures had increased to about 10 ºC.

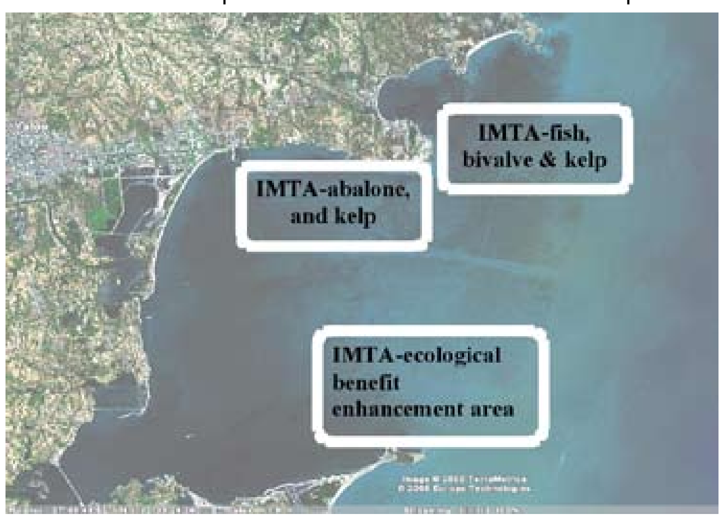

Figure 3 Demonstration areas in Sanggou Bay

For each cultivation units, there were four longline rafts. The length of one longline was 80m, the distance between two longlines was about 5m. Therefore, the total area was about 1600m^2. For each longline, 30 net cages were hung and kept at 5m in depth. About 280 abalone (shell height: 3.5-4cm) were cultivated at each net cage.

The kelp, *Laminaria japonica*, were hung at a horizontal level between the abalone lantern nets. There were about 70 kelp plants cultured on each rope. The interval between two kelp culture ropes was about 2-3m. In total about 33600 individual abalone and 12000 individual Laminaria were cultivated in each cultivation units. Kelp was cultivated from November, 2008, and harvested in June, 2009.

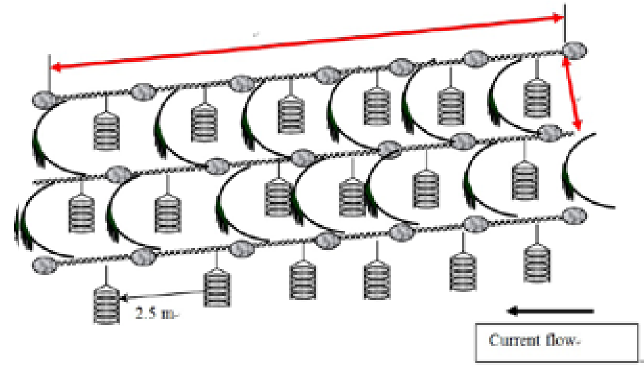

Figure 4 Cultivation units of the IMTA of kelp and abalone

When the Laminaria reached 1m in length they were removed from the culture rope and put into the net cage for feeding abalone. The net cage was fed and cleaned once a week. In this way, the abalone could reach marketable size (8-10cm) in 2 years.

Environmental parameters were monitored at the cultivation site (8 sampling sites in the mariculture area, 2 sampling sites beside the mariculture and at a control site outside of Sanggou Bay, without any mariculture). Water temperature, pH, DO and salinity were measured with YSI6600. Water samples were collected from 2m depth and filtered through 0.45um filter paper. The ammonium, nitrite, nitrate, phosphorus, POM, COD and chla tests were performed following the GB standard.

Result: Environmental conditions at The Xunshan abalone and kelp IMTA demonstration area. During the experiment, water temperature ranged from 6.2 oC to 23.21oC, and the salinity was about 31±0.6. Overall, no signs of eutrophication or significant increases in phytoplankton biomass in the water column were found in the demonstration area. The water quality of the abalone and kelp mariculture area was in good condition. From April to October, DIN and phosphorus concentration were low, according to the National First Class Water Quality Standards for China, except in August when DIN fell into the second class. Comparing with the control site, the nutrient concentrations were not significantly higher which may mean that the effect of abalone polyculture with kelp on the environment was limited. However a temporary increase in ammonium concentrations in August- NH_4-N increased from 0.96umol/l in June to 5.94umol/l meant that this became the dominant DIN form. NH4-N accounted for more than 60% of the total inorganic nitrogen in the abalone mariculture area. By August, Laminaria had been harvested and totally removed. With temperatures increasing, the excretion rate of abalone also increased which could account for the significant increase of ammonia at the mariculture site.

The optimum co-culture proportions of abalone and seaweed. Water quality is an important factor in terms of the impacts of abalone farming on the environment and the removal of ammonia excreted by abalone is more likely to influence abalone production than the available supply of kelp. From the survey results at the abalone farming areas, ammonia concentration showed significant increases in summer. Therefore, at the co-culture mode (abalone and kelp), ammonia was considered as the limited factor. Ammonia excretion rates of abalone should not exceed uptake rates by kelp in order to ensure good water quality for abalone growth. According to the ammonia excretion rate of abalone and the biomass of abalone at a mariculture unit, the total ammonia released into the water column from April to November was estimated to be 2.16 kg N. Based on the growth rate of kelp and its content of N (1.34% of dry weight), the theoretic biomass of kelp that is needed to absorb the nitrogen excreted by the abalone from one mariculture unit was calculated to be 10080 individuals. In the demonstration area of abalone and kelp longline mariculture, 12000 individuals of kelp were cultivated per unit which is enough to absorb the ammonia excreted by this density of abalone. The yield of abalone every 2 years of such IMTA units is about 900kg. Based on the market price in 2009, the production value of each IMTA unit is about 70000 yuan/ 1600m^2 (equal to 10000 US$) in two years. In future, research into the hydrodynamics and mariculture waste transport in the Bay should be carried out. If other seaweeds are cultured in summer to utilize the nutrients and feed abalone, the mariculture density of abalone may be increased.

IMTA enhancement of abalone, sea cucumber, clam and sea weed.

The IMTA experiments of sea-ranching abalone, sea cucumber and clams were carried out in the area of the Chudao Island Company (site B), located in the southern part of Sanggou Bay. The enhancement of abalone, sea cucumber, sea urchin, clam and seaweeds took place at 5-15m depth. The main sediment type in Chudao Island was sandy-silt, although most of Sanggou Bay's surface sediments were of the clay-silt type. The total IMTA demonstration area was nearly 665ha. The main species of enhancement were; sea cucumber *Apostichopus japonius*, abalone, *Haliotis discus hannai*, sea urchin *Strongylocentrotus nudus*, arkshell *Scapharca broughtonii* and clam *Ruditapes philippinurum*. In the IMTA area, natural beds of sea grass and seaweed were abundant, the cover area by sea grass being about 400ha. In the spring (April/May) of every year, nearly 300000 juveniles of sea cucumber and 150000 juveniles of abalone are released into the area with the other species being recruited naturally. In 2009, the production values of the demonstration area (665 ha) were 1.5 tonnes for abalone, 20 tonnes for sea cucumber, 180 tonnes for manila clam, 80 tonnes for arkshell and 2.5 tonnes for sea urchin with a value of more than 10450 yuan RMB per ha.

Table 1 Annual production, market price and income of some sea-ranching species and natural species in Chudao Island

Species	Annual Production (kg)	Unit price (Yuan/kg)	Sub sum (yuan)
Sea Cucumber *Apostichopus japonius*	20000	160	3200000
Abalone *Haliotis discus hannai*	1500	600	900000
*Sea urchin *Strongylocentrotus nudus*	2500	56	140000
*Manila Clam *Ruditapes philippinurum*	200000	7	1400000
*Conch *Rapana venosa*	20000	10	200000
*Agar *Gelidium amansii*	80000	6	480000
Pacific oyster *Crassostrea gigas*	300000	0.5	150000
*Washington Clam *Saxidomus purpurratus*	80000	6	480000
Total Sum			6950000

DIN was higher in April and September, with values above 14umol/l, at the second level of the National Seawater Standard Level of China. The highest concentration of P and Si at Chudao Island was about 0.48umol/l in September-October and 23umol/l in October-November, respectively. Overall, the water quality of the IMTA area was good, suggesting that the impact of mariculture on the environment was not high.

The mutually beneficial mechanism in the IMTA of fish and algae.

In China, marine fish cage farming has proved to be a productive sector of the industrial economy and has already become the main fish culture method in the coastal zone. Following this rapid development, marine fish cage culture has systematically been implicated as a potential source of serious environmental impacts on its surrounding aquatic environment. The greatest impact arises from the output of large amounts of organic waste in the form of uneaten food, faeces and other excretory products, which can cause localised hyper-nutrification and ultimately, eutrophication. In order to reduce such effects, integrated multi-trophic aquaculture (IMTA), where "extractive" and "feed" species are grown simultaneously, has been proposed as a means of using the waste resource.

The field work to demonstrate this feature, was carried out at the farm site of Ailian Bay in the Yellow Sea, China. The surface area was 5.56 km^2 and the maximum water depth was 11.0 m. A total 26 cages were cultured in this area. Sea bass *Lateolabrax japonicus* and black rock fish *Sebastodes fuscescens* were the main species cultured in cages which occupied 71.82% and 28.18% respectively. There were 26 polyethylene fish cages (dimensions 5 m × 5 m × 5 m). 500 individuals were cultured with an annual production of about 125 kg per cage. Fish were fed with iced trash fish (*Engraulis japonicus*, *Ammodytes personatus*, etc.) and the culture period was usually from April to January of the next year.

Results. The special growth rate (SGR) of L. japonicus and S. fuscescens in May was negative growth which could be explained by the adaption process of the larval fish after stocking in the cage in April. During the culture period, the growth trend was different for L. japonicus and S. fuscescens. From June to December, the SGR of L. japonicus ranged from 0.0571 to 0.5214 and reached a peak in August, while the SGR of S. fuscescens ranged from 0.1709 to 1.0229 reaching a peak in September.

The ingestion rate was calculated by the food consumption rate and the standing stock. Results showed that the ingestion rate for L. japonicus ranged from 1.36% to 4.38% and S.

fuscescens ranged from 0.06% to 3.50%. The maximum ingestion rate appeared in August and July respectively for L. japonicus and S. fuscescens suggesting higher ingestion activity in the summer.

Oxygen consumption of the main cultured fish varied in different seasons. It can be seen that about 49t DO was consumed by fish from April to December. Taking the ratio of oxygen consumption and weight into account, the L. japonicus reached 4.15t in July and S. fuscescens reached 13.68t in August.

The total amount of nitrogen released into Ailian Bay as a result of cage culture was about 3.13t nitrogen, 1.66t and 1.47t for S. fuscescens and L. japonicus respectively The nitrogen excreted by S. fuscescens from July to September account for 75% of the whole year. And also, the nitrogen excreted by L. japonicus from July to August account for 71% of the whole year.

Faeces production of the main cultured fish in different seasons was noted. Results showed that about 12.37t (dry weight) particulate matter was dispersed to water column. L. japonicus accounted for 98.11% of the total faeces production and the monthly average faeces excretion was 1.34t, the maximum faeces excretion appeared in August and September, which was 2.427 and 3.145t respectively.

It can be estimated that the optimum co-culture proportion of fish stocking (kg) and macroalage (kg) in this area was 1 kg fish: 353.25 kg Laminaria and 1 kg fish : 457.6 kg for Gracilaria.

IMTA of Abalone *Haliotis discus hannai*, kelp L. japonica and sea cucumber *Stichopus japonica*.

The sea cucumber is a detritivore species feeding on decaying organic matter in coastal sediments. This makes it an interesting candidate for use in integrated multi-trophic aquaculture (IMTA), where its feeding on sedimented particulate matter enables it to occupy an unused ecological niche compared to other extractive organisms such as filter-feeding bivalves (extracting suspended particulate matter) and seaweeds (extracting dissolved inorganic nutrients). In China, sea cucumbers have a high market price and are commonly cultured in tidal ponds or indoor tanks. Abalone and kelp are co-cultured on a large scale from suspended longlines in the coastal waters of north China. In this study, sea cucumbers were added directly to abalone cages without any modification of the culture equipment, for a simple and low cost production-line. To evaluate the feasibility of this co-culture model, the growth of sea cucumbers was studied during a 7 month field experiment in Lidao, near Sanggou Bay, Shandong Province, north China.

Methods. The cages used were standard abalone cages (60x50x50 cm) containing 3 layers suspended from kelp longlines, to a depth of 5 m. Abalones (52.3±0.9 mm) were stocked at 250 per cage and fed with kelp according to normal production procedures. Sea cucumbers (65.5+2.0 g) were added to the cages at 4 densities: 1, 2, 4 and 6 individuals per layer (treatments were named “1SC”, “2SC, “4SC” and “6SC”). One control cage contained 1 sea cucumber per layer, but no abalones (”1SC-0A”). There were 3 replicate cages for each treatment, except for 6SC and 1SC-0A, which had only one replicate. The experiment lasted from October 2008 to May 2009. The wet body weight of all sea cucumbers was recorded monthly. Water was sampled monthly for analysis of particulate organic matter (POM) and total nitrogen (TN). In March, April and May, sediment traps were deployed at the culture depth in order to calculate sedimentation rates.

Results. During the 7 month experiment, average sea cucumber body weight increased by 96 %, from 65.5 g in October to 128.8 g in May. The average specific growth rate (SGR) for all treatments during the whole experiment, was calculated as average percent growth per day, and equalled 0.33 % per day. Growth was highest during the first month (October-November) with an average SGR of 1.00 % per day. As the temperature dropped from 18 °C in October, to 3 °C in January the growth rate decreased. During the winter (November-April) growth was slow, with an average SGR of 0.14 % per day. In May, the temperature had increased to 11 °C, and during the last month (April-May) average SGR increased to 0.48 % per day.

IMTA of sea cucumber, abalone and kelp in Sanggou Bay

Experiment outline: Sea cucumber (stichopus japonious) are co-cultured with (Hdiotis discus hamnai) in net cages at stocking densities ranging from 3-18 sea cucumber cage-1.The abalone density is 250 cage-1. 1 control group contains sea cucumbers abalone. The abalone is fed with fresh kelp (Laminaria japonca).
Experiment start: October 2008.

Figure 6 The IMTA Experiment

Discussion and analysis.

During the experiment period from October to May, the fresh mean body weight of sea cucumbers increased from 70g per individual with a culture density of 6 individuals to a cage, to almost 140g per individual. Bigger animals weighed >200g each. Sea cucumber, *Apostichopus japonica* will stop growing when the water temperature is higher than 20^{o}C. According to records of local water temperature changes in summer, until early July, the water temperature was lower than 20^{o}C at the experimental site. This means that there are another 2 months for sea cucumber to grow which should allow for the production of 1kg sea cucumber for each net cage. By then, almost all of the sea cucumbers can reach market size. In 2009, the market price of fresh sea cucumber was 160 yuan/kg. The production value of sea cucumber was about 160 yuan/cage. As described above, there were 30 net cages hung in one longline for abalone culture. Therefore, the extra production value of sea cucumbers co-cultured with abalone can reach 19000 yuan/1600m^2. Including the value of abalone, the unit production value was almost 90000 yuan/1600m^2, much higher than the IMTA of seaweed and abalone. Deducting the cost of juveniles of abalone and sea cucumber, the net income of such IMTA is about 37000 yuan/ 1600m^2.

This kind of IMTA can produce more environmental benefits because the sea cucumber can utilise the POM (particulate organic matter) more efficiently by feeding on the faeces of abalone and the bio-deposits inside the net cage. The sedimentation rate in the IMTA demonstration site was high with a maximum of 1185 g DW m^{-2} per day in March and a minimum of 863 g DW m^{-2} per day in May. This is well above the range reported for the remaining areas of Sanggou Bay of 50-500 g m^{-2} per day. Organic matter ranged from 7,67 % in March to 8.29 % in April, lower than reported by Cai *et al*. from Sanggou Bay (8-14 %).

The available food sources for the sea cucumbers, included abalone faeces, kelp detritus and "background" sediments from the water. The high sedimentation rate and the high growth rate of the sea cucumber control group (1SC-0A), indicates that background sediments may be an important food source. Large amounts of sediments were observed in the cages when they were removed from the water.

The high overall growth rate of sea cucumbers measured in this experiment shows that adding sea cucumbers directly to abalone cages may be a feasible production technique. Compared to production in land based facilities, tidal ponds, or extensive bottom culture, this method is simple and requires a minimum of extra labour or additional investments. Considering the high market price of sea cucumbers, it should be an economically attractive idea for abalone farmers. In addition to adding income to farmers and increasing the production output, the sea cucumbers may reduce the aquaculture impact on the local environment by assimilating nutrients and organic matter wasted by other farmed species.

Analyses of the environmental and economic benefits of IMTA

As one of the major human activities, aquaculture provides not only material products but also many other service functions. Based on the 17 major evaluating parameters and methods by Costanza *et al*. (1997), the core services of mariculture ecosystems in Sanggou Bay were selected and quantified (figure 6) by the market value approach, carbon tax approach and the shadow project approach, respectively. Using the systemic evaluation approach, the value of the mariculture ecosystem services in Sanggou Bay using four different modes was estimated. They included a Kelp monoculture mode, scallop monoculture mode, abalone & Kelp IMTA mode, Kelp & Abalone & Sea cucumber IMTA mode which were estimated and evaluated using a 'systemic evaluation approach'. The following figure shows the classification of aquaculture ecosystem services and functions.

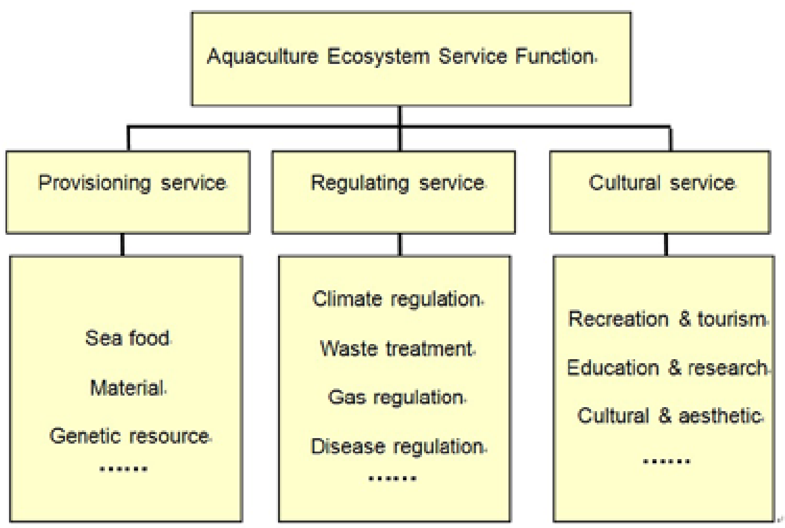

Figure 6 Classification of aquaculture ecosystem service & function

Results

Table 2 Value of food provision services in difference aquaculture modes

Aquaculture mode	Aquaculture species	Yield kg/ha/a	Market price y/kg	Income (Y/ha/a)	Cost (Y/ha/a)	Value (Y/ha/a)
monoculture	kelp	27000	6.0	162000	67500	**94500**
monoculture	scallop	18000	4.6	82800	22500	**60300**
IMTA	kelp	30000	6.0	0	72900	0
	Abalone	17308	200	1730769	1032808	697962
	Add up			1730769	1105707	**625062**
IMTA	kelp	30000	6.0	0	7.2900	0
	Abalone	16615	200	1661538	926815	734723
	Sea cucumber	3600	120	216000	21600	204000
	Add up			1877538	948415	**929123**

Table 3 Value of waste treatment services in difference aquaculture modes

Aquaculture mode	Removed TN kg/ha/a	Released TN kg/ha/a	Removed TP kg/ha/a	Released TP kg/ha/a	Value (Y/ha/a)		
					Benefit	lost	total
Monoculture kelp	440.1	0	102.33	0	813.65	0	813.65
Monoculture scallop	1079.108	408.1829	/	1.2689	1618.66	614.18	1004.48
IMTA kelp+abalone	2769.288	0.769712	113.7	/	4324.48	1.155	4323.33
IMTA kelp+abalone+ sea cucumber	2768.566	0.754151	118.7438	0.00015	4360.965	1.1776	4359.79

Table 4 Total value in different aquaculture modes

Aquaculture mode	Total benefit (Y/ha/a)	Total lost (Y/ha/a)	Economic value (Y/ha/a)	Environmental value (Y/ha/a)	Total value (Y/ha/a)
Monoculture kelp	185006	67500	94500	23006	117506
Monoculture scallop	86327	23145	60300	2882	63182
IMTA kelp+abalone	1765531	1105769	625062	34700	659762
IMTA kelp+abalone+sea cucumber	1912619	948459	929123	35036	964160

It can be seen that the value of the mariculture ecosystem services provided by IMTA modes were much higher than monoculture and IMTA modes.

The key technical requirements of IMTA are listed in the full paper on disc within the full version of this report.

Figure 7 Harvesting Kelp, a commercial seafood product and valuable component of the IMTA system

Limited Water-exchange Shrimp Culture

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July 2009

Introduction

Shrimp culture is one of the most important aquaculture activities along the Yellow Sea coast of Korea and northern China. In 2004, 1,179 and about 150,000 metric tons of farmed shrimp were produced from the Korean and Chinese coasts, respectively. Most shrimp farms in these areas are semi-intensive in earthen ponds using the conventional flow-through method. This method of shrimp farming discharges huge amounts of waste water, causing coastal eutrophication and the introduction of viral pathogens via water-exchange, which results in mass mortalities of farmed shrimp. These issues have forced the shrimp farming industry to seek out more sustainable management practices in shrimp farming. The objectives of this study are to demonstrate shrimp culture practices to enhance production and reduce negative environmental effects in the Yellow Sea. Two different systems were investigated.

Commercial-scale greenhouse-enclosed grow-out system

To develop a super-intensive shrimp culture technology under limited or no water exchange, a commercial-scale greenhouse enclosed shrimp production system (two tanks of 300 m^2 each) was constructed and stocked with Pacific white shrimp, L. vannamei juveniles (408 ind/m^2 in density). The shrimp were cultured for 152 days under no water exchange conditions.

Figure 1 Greenhouse-enclosed super intensive system and HDPE-lined outdoor ponds used in this study

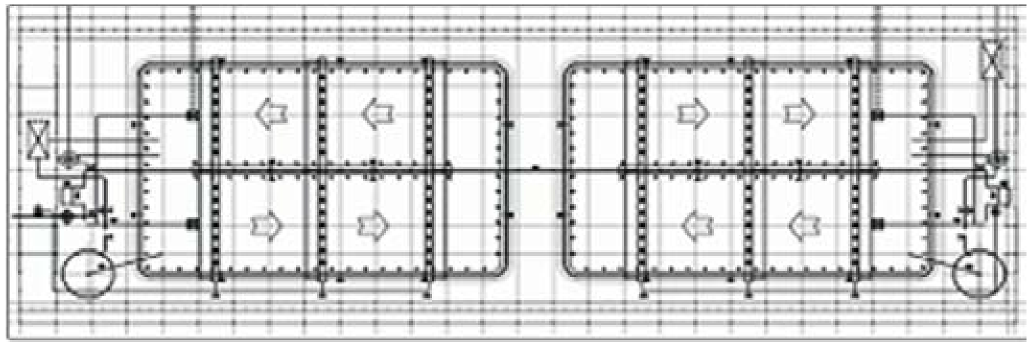

Figure 2 Layout of greenhouse and raceway tanks (top view)

Production of shrimp was 5.47 kg/m^2 (about 20 times higher than traditional pond methods, the survival rate was 88.3% and food conversion ratio (FCR) was 1.22 (40-50% lower than the traditional method) (Table 1). Production and the FCR demonstrated in this study are about 20 times higher and 40-50% lower than traditional pond method. The results demonstrated that the super-intensive indoor shrimp culture using no water exchange can enhance production, improve feeding efficiency, minimise viral introduction and greatly reduce coastal pollution by water discharge.

Table 1 Summary of stocking and production of Pacific white shrimp, L. vannamei culture under no water exchange conditions for 152 days

	Initial B.W.(g)	Stocking density(/m^2)	Days	Final B.W.(g)	Yield (kg/m^2)	Total(kg)	Survival rate (%)	FCR
Tank1	0.038	408	152	15.17	5.47	1640	88.30	1.22
Tank2	0.038	404	152	13.6	4.03	1210	73.43	1.32

Outdoor HDPE-lined ponds

In order to demonstrate a super-intensive shrimp culture technology in outdoor ponds using the no water exchange method, two HDPE-lined outdoor ponds (550 m^2 each) were prepared They were stocked with nursery-cultured L. vannamei juveniles (BW 0.5 g, 185 ind/m^2) and post larvae (BW 1.7 mg, 185 PL/m^2) in each pond respectively.

In the 138-day culture trial, 1.75 kg/m^2 of shrimp (BW 19.1 g) was produced from the nursery-cultured stocking pond and 1.02 kg/m^2 of shrimp (BW 13.2 g) was produced from the direct stocking pond (Table 2). The results showed that this method can increase production to 6 times that of traditional pond culture. Stocking with nursery-cultured juveniles is better than direct stocking in terms of the final size of shrimp, total production, survival rate and FCR. This method also give additional advantages including reducing coastal pollution due to very limited water discharges and minimising viral transmission through reduced water exchange.

Table 2 Summary of stocking and production of Pacific white shrimp, L. vannamei cultured in HDPE-lined outdoor ponds for 138 days

	No. stocked PL	Stocking density (/m^2)	Initial B.W.(g)	Days	Final B.W.(g)	Total (kg)	Yield (kg/m^2)	Survival rate (%)	FCR
Pond 1	102,000	185.5	0.5	138	19.1	965	1.75	49.53	2.19
Pond 2	102,000	185.5	0.0017	138	13.2	565	1.02	41.96	3.91

Effect of biofloc on the growth and immune activity of shrimp

In order to understand the effects of biofloc on growth and immunological activity of shrimps, individuals were cultured in different concentrations of biofloc water for 63 days in tanks of 190 L in volume.

The growth rate of shrimps cultured in water mixed with biofloc was 5.6-27.5% higher than clean seawater. FCR in all treated groups with biofloc was 2.9-19.4% lower than the control group. This result suggests that bioflocs have an effect on shrimp growth and shrimps may indeed consume the biofloc as additional diet. In addition, shrimp cultured in biofloc water showed higher ratios of granular and semi granular cells, and PO (prophenoloxidase) activity than in the control.

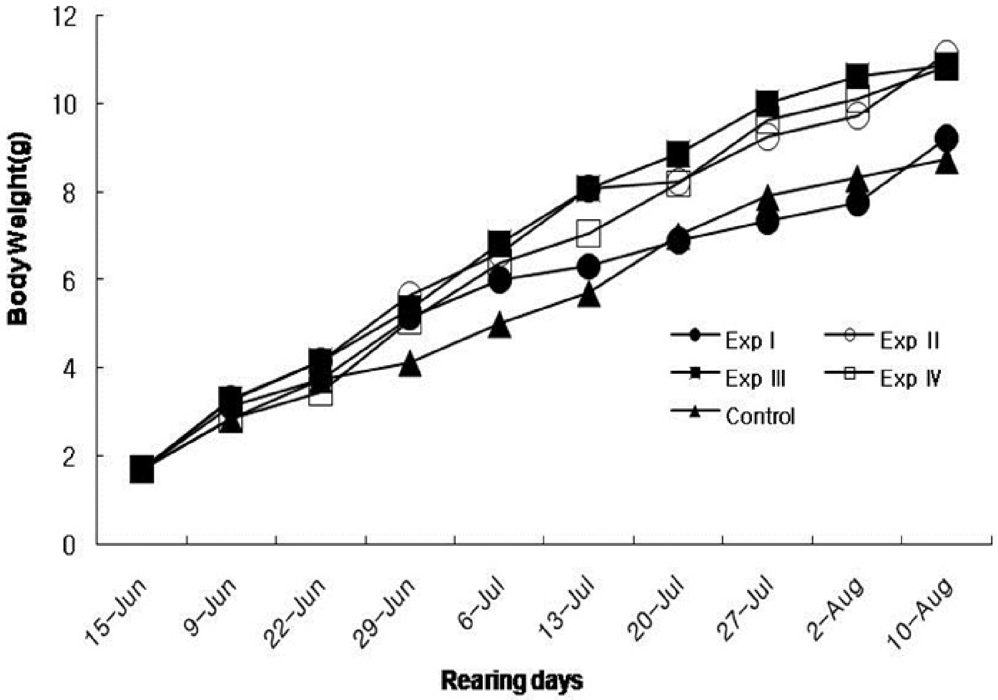

Figure 3 Changes of body weight in Pacific white shrimp, L. vannamei of five experimental groups with different biofloc concentrations during the 63-day culture. The five different concentrations of biofloc groups were as follows: Exp I, 100% biofloc water; Exp II, 75% biofloc water mixed with 25% clean seawater; Exp III, 50% biofloc mixed with 50% clean seawater; Exp IV, 25% biofloc mixed with 75% clean seawater; control, 100% clean seawater.

Commercialisation of greenhouse-enclosed super-intensive shrimp culture

This project demonstrates that commercialisation of the new technology - greenhouse-enclosed super-intensive shrimp culture under no water exchange, is very feasible. A farm unit with 600 m^2 under culture area can make a net profit of about 40,000-70,000 USD per year (45,000,000-76,000,000 KW per year) depending on the price of shrimp. When the system is improved and management is updated, the profit from a unit can be increased to 143,000-230,000 USD per year. The construction cost takes about 200,000 USD, but many of local governments in Korea will partially support the construction expenses for aquaculture businesses using new technologies, in particular environmentally-friendly business trials. At present, however, it has some limitations for commercialisation in Korea because of a lack of infrastructure. Firstly, there are no special hatcheries which can provide post larvae or nursery-cultured juveniles throughout the year. Secondly, most farmers are not experienced in the management of this new technology. The lastly, markets consuming live shrimp year-round are not existent in Korea.

Conclusion and recommendations

In this study, super-intensive shrimp production trials were conducted in a commercial-scale greenhouse enclosed system as well as in HDPE-lined outdoor ponds, under limited or no water exchange conditions. It demonstrates that this method can dramatically reduce water consumption by 98%, compared with the traditional flow-though pond method. Shrimp production per area was increased up to six (in outdoor ponds) to twenty (in greenhouse systems) times higher than the traditional methods. Based on a pilot experimental study to characterise biofloc water in greenhouse production systems, it was found that shrimp cultured in this way had a better FCR, higher immunity activity and growth rates as compared to clean seawater. Economic analysis of the greenhouse shrimp production system showed very positive results for commercialisation. In fact, a few farmers in Korea have already constructed commercial-scale greenhouse enclosed shrimp production systems and have begun to culture Pacific white shrimp. Several other farmers are ready to construct similar facilities.

This technology has some important advantages which can improve shrimp production and food safety as well as reduce environmental pollution and disease introduction. However several issues need to be resolved prior to implementation in the private sector and commercialisation. (1) A practical manual for farmers should be prepared. This technology has recently developed and there is little information or standard criteria published for the successful operation of this system. (2) Commercial hatcheries should be prepared to provide post larvae or juvenile shrimps to production farms year round. In Korea, all shrimp hatcheries produce post larvae once a year in a limited season. (3) Development of related technologies should be followed, such as the production of high efficiency diets for super-intensive shrimp culture, innovated methods for reducing energy costs for heating water, economically efficient production system designs and so on. In addition, economic support for construction costs will be very helpful for farmers. This method of production is environmentally-friendly and can dramatically reduce coastal pollution caused by discharges from shrimp ponds. Therefore, central and local governments should encourage this type of development which clearly falls within the classification of ‘Green Technology’.

Cost-benefit Analyses of Improved Sustainable Mariculture Techniques

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July 2009

Introduction

Integrated multi-trophic aquaculture (IMTA) or polyculture is an approach used to mitigate the ecological effects of mariculture and as such is one of the important management actions suggested in the Strategic Action Programme for the Yellow Sea Large Marine Ecosystem Project. The Yellow Sea Fisheries Research Institute (YSFRI) implemented the IMTA demonstration activity with two large commercial companies operating IMTA systems in Sanggou Bay, P.R. China.

In order to examine the economic aspects of implementing IMTA systems, Cost-Benefit Analysis (CBA) and the Emergy analysis were employed. In the CBA and Emergy analysis, the following culture modes were compared: the monoculture of kelp, the monoculture of scallop and the polyculture of kelp and scallop.

The Demonstration site

Sanggou Bay is situated in the Yellow Sea near Rongcheng City, Shangdong Province, P.R. China. It is a coastal embayment covering 143.2km^2 of water and 20km^2 of intertidal habitats. The average water depth of the Bay is 7-8m, (maximum is 15m). There are no large rivers running into Sanggou Bay but some small ones such as the Sanggan River, the Yetao River, the Gu River, and the Xiaoluo River. Most of the rain falls in July and August. Having started in the 1960’s, mariculture is now the main anthropogenic activity in the Bay. The main mariculture species include kelp, scallop, oyster, abalone, and finfish. There are different culture modes, longline culture (Figure1) and cage culture (Figure 2).

Figure 1 Longline culture in Sanggou Bay

Figure 2 Cage culture in Sanggou Bay

Compared to monoculture, IMTA has many advantages such as; the maximum use of marine space, efficient recycling of nutrients and reduced financial risks. IMTA in Sanggou Bay includes the longline culture of kelp and scallop, the longline culture of kelp and oyster, and the longline culture of kelp and abalone. Among the culture modes, the longline of kelp and scallop (*Chlamys farreri*) is one of the main IMTA modes in Sanggou Bay and was thus chosen as the example to demonstrate the effectiveness of IMTA in terms of the economic perspective and its ecological sustainability.

Method

Cost-benefit analysis of integrated multi-trophic aquaculture

The economic analysis of IMTA was made through a comparison between a single-species aquaculture (monoculture) of kelp and scallop individually and IMTA (polyculture of kelp and scallop together). It was anticipated that by comparing the results of the three culture modes in terms of costs and output, the potential benefits of polyculture would become apparent. Based on experience, it was assumed that polyculture was less risky economically because the operator is depending on more than one species and the system is less dependant on weather related variations in yield.

To estimate the economic value of monoculture and polyculture, market prices of the cultured species and production costs were used. The production costs of monoculture and polyculture were estimated from the data collected by interview surveys. The fixed costs included depreciation costs, lease or rent of mariculture farms, and insurance. The variable costs included wages, feeding, seeding (e.g., stocking and larvae), salaries, energy cost (e.g. electricity, fuel, gasoline, coal, and oil), maintenance cost, pesticides and chemicals, medicine, and waste management cost. The quantity of nutrients removed from the environment by the animals was also obtained from the interview survey. The environmental benefit was calculated by multiplying the amount of removed nutrient by the cost of sewage treatment.

In this project, an integrated model combining the net present value (NPV) and the benefit to cost ratio (BCR) was used as the decision rule which was implemented as follows;

(1) NPV and BCR were calculated. If NPV was greater than 0 and BCR was greater than 1, then the program was regarded as a candidate program; the discount rate was 8%.

(2) All candidate programs were identified according to the above procedure;

(3) NPVi and BCRi were the NPV and BCR of the 'ith' candidate program, the Relative Co-efficient (RC) was calculated as:

$RC_i = NPV_i \times BCR_i$

Where $^{i=1,2,...,n}$ n was the number of a candidate programme (In this project, n refers to the different types of IMTA).

(4) the program with the greatest value of RC was selected.

In this project, a new index (RC) was proposed. When the benefit and efficiency are not accordant, identifying the optimal program is difficult. The RC addresses this issue by providing an integrated index to evaluate different alternative programs. The economic benefit and the environmental benefit are multiplied and then costs of waste treatment are subtracted. This is calculated for each year of the life of the project using the constant discount rate. Through the CBA, the program with the highest NPV and BCR was chosen. When the results of NPV and BCR were not accordant, the program with the highest RC was chosen.

(The NPV mainly considers the total net benefit during the program period. BCR uses the efficiency of the output (benefit) to input (cost) so the maximum value may not always coincide at the same time in the project.)

Price and cost of the cultured species in Sanggou Bay

From the survey, economic data on the price and cost of cultured species in Sanggou Bay was collected. The production of the cultured species was estimated and averages used to estimate the benefits and costs of production. The price of kelp and scallop were 4 yuan/kg and 2.8 yuan/kg in 2008, respectively. The cost and production under different culture modes in Sanggou Bay were as follows.

(1) For the monoculture of kelp, the total cost was 7298.6 yuan/mu. Salary and wages accounted for 55% of the total cost; depreciation, 16%; seeding, 19%; stock, 6%; energy, 2%; maintenance, 1%; and others, 1%. For the monoculture of kelp, the production of kelp was 2500 kg/mu.

(2) For the monoculture of scallop, the total cost was 6916.5 yuan/mu, in which salary and wages accounted for 47.1%; depreciation, 39.54%; seeding, 5.06%; stock, 4.82%; energy, 2.44%; maintenance, 0.6%; others, 0.44%. For the monoculture of scallop, the production was 3150 kg/mu.

(3) For the polyculture of kelp and scallop, the total cost was 9324 yuan/mu. The cost of polyculture was higher than that of monoculture because more labour, seed, and energy are used in polyculture. 38.44% of the cost was spent on salaries and wage, 36.06% on depreciation, 18.77% on seeding, 3.93% on stock, 1.99% on energy, 0.49% on maintenance, and 0.32% on others. For the polyculture of kelp and scallop, the yield of kelp and scallop were 2000 kg/mu and 3100 kg/mu, respectively.

Estimation of environmental benefit

Shellfish mariculture is considered to have a positive environmental impact as the production of shellfish is near the base of the trophic chain (e.g. Naylor et al,2000) and there are potential enhancements both of primary production and biodiversity (Gibbs, 2004; McKindsey *et al*., 2006). Shellfish can also remove particulate organic nitrogen from the marine environment (Ferreira, 2007). To assess the role of cultured shellfish in nutrient removal, the quantity of nitrogen and phosphorus in the body of shellfish was calculated. The cultured shellfish will be harvested and the nitrogen and phosphorus in their body will be taken out of the ocean. This will reduce the quantity of nutrients in the marine environment, and it is useful for controlling eutrophication. (The N content of the scallop soft tissue was 12.37%) (Zhou yi, *et al*., 2002).

Kelp mariculture plays a more important role in controlling eutrophication. Kelp can directly absorb the nitrogen and phosphorus from the environment during photosynthesis. In polyculture, kelp and shellfish could be beneficial for each other, and kelp can absorb ammonia excretion produced by shellfish, recycling organic matter and nutrients. For the assessment of cultured kelp in nutrient removal, the quantity of nitrogen and phosphorus in the body of kelp was calculated. These nutrients were removed from the marine environment when the kelp was harvested. The quantity of nitrogen and phosphorus accounted for 4.818% and 0.322%, of the body weight of kelp (Huang Daojian, et al., 2005). The environmental benefit here refers to the nutrient removal by the cultured species. This will help in controlling eutrophication. The "cost of sewage treatment" was used as a proxy to measure environmental benefit. The costs of restoring water quality can also be used to measure the environmental benefit of polyculture but this is more problematic and less accurate.

The environmental benefit is the product of the quantity of nutrient removed by cultured species multiplied by the cost of sewage treatment. The cost of sewage treatment is estimated as 1.5 yuan/kg for N and 2.5 yuan/kg for P (Zhao Tongqian, *et al*., 2003).

Emergy approach

The Emergy evaluation measures the energy used directly and indirectly in production, in units of solar emjoules (sej) (Odum, 1988). This evaluation provides a quantitative way to find what policies and patterns are sustainable for humanity and nature.

In the emergy analysis, each form of energy in a system is translated into its solar energy equivalent by use of a conversion factor (transformity) that reflects the energy's qualitative value. Through multiplying the inputs and outputs by their respective transformities, the Emergy amount of each resource, service and corresponding product can be calculated. Based on the same unit, these amounts can be analysed easily through a series of Emergy related ratios and indices, which are used for the evaluation of the system. These indices indicate various performance characteristics of the system in terms of efficiency and sustainability (Campbell, 1998).

Associated with the above ecosystem, some basic indices of ecological interest are as follows:

EYR=Y/F

EYR (Emergy yield ratio) is taken as the Emergy output (Y) divided by the Emergy input (F) as a feedback from the outside economy. The higher the value of this index, the greater the return obtained per unit of Emergy invested.

ELR=(F+N)/R

ELR (environmental loading ratio) is the ratio of the total Emergy of the non-renewable inputs (F+N) to the Emergy of the total renewable inputs (R). ELR indicates a load on the environment. The lower the ratio, the lower the stress to the environment.

ESI=EYR/ELR

ESI (index of sustainability) is the ratio of the Emergy yield ratio EYR to the environmental load ratio ELR, indicating if a process provides a suitable contribution to the user with a low environmental pressure. The ESI takes both ecological and economic compatibility into account. As pointed out by Ulgiati and Brown (1998), a higher ESI is not just provided by a lower requirement of feedback, but by a larger renewable input in comparison with the feedback itself. The larger the ESI is, the higher the sustainability of a system.

Results

Cost-benefit analysis of monoculture and polyculture in Sanggou Bay

(1) Monoculture of kelp

The benefits of the monoculture of kelp included the economic benefit and environmental benefit. The economic benefit was defined as the yield of kelp production (2500 kg/mu) multiplied by its price (4 yuan/kg). The environmental benefit was obtained by multiplying the quantity of nutrient removed with kelp production by the cost of sewage treatment. The quantity of reduced nutrient was 128.5kg/mu, (nitrogen- 120.45kg/mu and phosphorus - 8.05kg/mu). The cost of monoculture of kelp was 7298.61 yuan/mu. Based on the above improved CBA method, NPV, BCR and RC could be calculated as follows.

B1:economic benefit + environmental benefit
= 4*2500 + (120.45*1.5+8.05*2.5)
=10200.8 yuan
C1:7298.61 yuan
NPV:24773.32 yuan
BCR:1.4
RC:34682.65

(2) Monoculture of scallop

The benefits of monoculture of scallop included the economic benefit and environment benefit. The economic benefit could be calculated based on the scallop yield (3150 kg/mu) and its price (2.8 yuan/kg). The environmental benefit was obtained by multiplying the quantity of nutrient removed with scallop production by the cost of sewage treatment. The quantity of reduced nutrient was 32.42kg/mu, (nitrogen -30.37kg/mu and phosphorus- 2.05kg/mu). Based on the survey, the cost of monoculture of scallop was 6916.5 yuan/mu. NPV, BCR and RC could be estimated as follows.

B2: economic benefit + environmental benefit
=2.8*3150 + (30.37*1.5+2.05*2.5)
=8870.7 yuan
C2:6916.5 yuan
NPV: 16681.2yuan
BCR:1.28
RC:21351.94

(3) Polyculture of kelp and scallop

The benefits of polyculture of kelp and scallop included the economic and environmental benefit. The economic benefit was the yield of kelp and scallop production multiplied by their prices. The environmental benefit was obtained by multiplying the total quantity of nutrient reduced with kelp and scallop production by the cost of sewage treatment. The quantity of reduced nutrient was 134.7Kg/mu, (nitrogen - 126.24Kg/mu and phosphorus- 8.46Kg/mu). The cost of polyculture of kelp and scallop was 9324 yuan/mu. Based on the above improved CBA method, NPV, BCR and RC could be calculated as follows:

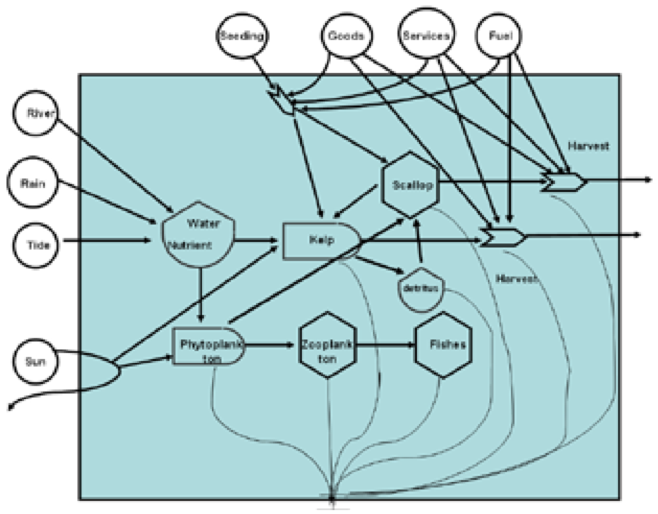

Figure 5 Emergy diagram of the polyculture ecosystem of kelp and scallop

B3: economic benefit + environmental benefit
=4*2000+2.8*3100 + (126.24*1.5+8.46*2.5)
=16890.51 yuan
C3：9324 yuan
NPV：64588.32 yuan
BCR：1.81
RC：116904.86

(4) Comparison of monoculture and polyculture

From the above, NPV is greater than 0 and BCR is greater than 1 in all culture modes; i.e. benefits outweigh costs. This result shows that the polyculture of kelp and scallop has the highest NPV, BCR and RC followed by the monoculture of kelp and then monoculture of scallop. Therefore, polyculture of kelp and scallop is the culture mode that should be recommended and promoted in the Yellow Sea.

The BCRs of the polyculture of kelp and scallop, the monoculture of kelp, and the monoculture of scallop were 1.81, 1.4 and 1.28, respectively. The efficiency of the output (benefit) to input (cost) in these different culture modes is similar. A possible reason for such a result is that a charge for sea area utilisation is low, about 30 yuan/mu for mariculture in China, and therefore, there are few incentives to maximise the use of marine space. The advantage of polyculture making full use of marine space can not be reflected in this situation.

Emergy analysis of demonstration activities in Sanggou Bay

In this project, the Emergy method was used to compare monoculture and polyculture. The actual energy flow, the solar Emergy and Emdollar① value of renewable resources; and the economic feedback and yield in the monoculture of kelp, the monoculture of scallop, the polyculture of kelp and scallop were considered. Then, the ESIs (sustainability index) of different culture modes were calculated to identify the most sustainable culture mode. Finally, the result of the Emergy analysis with that of CBA was compared.

①This is obtained by dividing the Emergy by the Emergy/dollar ratio for the selected year. The Emergy/dollar ratio is obtained by dividing the gross national product by the total contributing Emergy use by the combined economy of man and nature in that country that year.

(1) Monoculture of kelp. The solar Emergy of renewable sources(R), economic feedback (F) and yield (Y) were 1.06×1014, 7.62×1015, and 1.04×1016. Based on the formula (given in the full report), the ESI of monoculture ecosystem of kelp was calculated as 0.019.

(2) Monoculture of scallop. The solar Emergy of renewable source (R), economic feedback (F) and yield (Y) were 1.06×1014, 72.24×1014, and 9.21×1015. The ESI of monoculture ecosystem of scallop was 0.0187.

(3) Polyculture of kelp and scallop. The solar Emergy of renewable source, economic feedback and yield were 1.06×1014, 0.97×1016, and 1.74×1016(Table 10). The ESI of polyculture of kelp and scallop was 0.0196.

(4) Comparison of monoculture and polyculture

From the above result, the ESIs of monocultured kelp, monocultured scallop and polycultured kelp and scallop were calculated as 0.019, 0.0187 and 0.019 6, respectively. In these three culture modes, the polyculture system of kelp and scallop had the largest ESI; therefore, this culture mode was thought to be the most sustainable from economic and ecological aspects. The ESI of monoculture of scallop was the lowest and least sustainable of the three culture modes. This result corresponds to the result of CBA.

Conclusion and discussion

Mariculture is a developing industry in China and makes a significant contribution to the national economy. The sector provides an important animal protein supplement for the majority of people in the coastal area of China. However, mariculture in some areas causes the degradation of species (Zhu *et al*., 2000), the loss of biodiversity (Zhang *et al*., 2005) and a decline in ecosystem function (Zhu *et al*., 2000).

Sangggou Bay is a typical mariculture area in the north of China. Large scale mariculture activities have a great impact on the ecosystem and its services. It is necessary to evaluate different culture modes and identify the most sustainable. In this project, the CBA and Emergy method were used to compare different culture modes operating in Sanggou Bay. In the CBA method, a new index (RC) was used to evaluate the benefit and efficiency of the culture modes in a balance way. As an integrated index, the RC can provide important and comprehensive information for decision-making. In the Emergy approach, an Emergy analysis framework of mariculture systems, the energy process of different culture modes and the procedure to

	NPV	BCR	RC	ESI
Monoculture ecosystem of kelp	24773.32	1.4	34682.65	0.019
Monoculture ecosystem of scallop	16681.2	1.28	21351.94	0.0187
Polyculture of kelp and scallop	64588.32	1.81	116904.86	0.0196

(1) The polyculture of kelp and scallops had the highest values in terms of NPV, BCR and RC, compared to the two monoculture modes. The nutrient removal of the polyculture of kelp and scallop, the monoculture of kelp, and the monoculture of scallop were 134.7kg/mu, 128.5kg/mu and 32.42kg/mu, respectively. Polyculture was shown to be better for the environment than

the other modes in terms of nutrient removal. It was concluded that polyculture of kelp and scallop was the most sustainable culture mode in the three modes from both economic and environmental aspects, and therefore, this culture mode should be recommended and promoted in the Yellow Sea.

The BCRs of the different culture modes are similar. One of the reasons for this result is that the charge for sea area utilisation for mariculture is low (about 30 yuan/mu); there are few incentives to maximise the use of marine space.

(2) The ESIs of the monoculture ecosystem of kelp, the monoculture ecosystem of scallop, and the polyculture ecosystem of kelp and scallop were 0.019, 0.0187 and 0.0196, respectively. This result shows that the polyculture ecosystem is the most sustainable.

Based on the analysis, it was concluded that the polyculture should be recommended and promoted in the Yellow Sea. With regard to the economic benefit, the polyculture mode is larger than the monoculture modes. The Emergy analysis also supports polyculture as the most sustainable method. In this project, examples are presented on the use of CBA and Emergy methodologies to examine the effectiveness of IMTA of kelp and scallops. This approach could be applicable to other forms of IMTA in and beyond the region.

Fish Stock Assessment, Yellow Sea, Republic of Korea

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Introduction

In order to understand the distribution and migration of fish and their prey it is necessary to have an appreciation of the ocean currents prevalent in the region. This link is demonstrated in the paper and alludes to the relevance of climate change impacts.

In May, a branch of the Kuroshio and the Taiwan Warm Current in the East China Sea (ECS) flows to the Yellow Sea through the *ECS* and influences the hydrography, circulation and dynamics of the Yellow Sea (Naimie *et al*., 2001; Jacobs *et al*., 2000). Additionally, the Changjiang River discharges into the Yellow Sea. Weak southerly winds blow over the Yellow Sea after prevailing strong northerly winds during winter months. Then, weaker and transient winds combined with surface heating by solar radiation, result in very strong thermal stratification, isolating the bottom water (Naimie *et al*., 2001).

In September, the Taiwan Warm Current does not penetrate as far northward and the Tsushima Current continues to flow eastward in the Korean Strait. The cyclonic gyre associated with the Yellow Sea Cold Water expands over the Yellow Sea (Naimie *et al*., 2001). The water mass with higher temperature and lower salinity in the upper layer in the study might have been originated from the river discharge of the west coast of Korea, and the water mass with the lowest temperature and higher salinity may be due to the Yellow Sea Bottom Cold Water. The vertical distribution of water masses results from the thermocline generated by solar radiation in summer.

Methods

In order to understand the state of selected fisheries stocks in the Yellow Sea, specific parameters were measured such as; hydrographic conditions, catch composition, biomass, length-weight relationship, maturity, age composition and stomach contents of the target species,as well as zooplankton and ichthyoplankton. These were investigated under the agreed methodology between Republic of Korea and China in May and September 2008. During the 1st stock assessment workshop, differences in the sampling methodologies and subsequent analysis of samples, particularly for the aging of fish using otilith, and analysis of stomach contents were resolved.

Surveys were conducted at 12 stations (Figure 1) in the Yellow Sea by the RV, Tamgu-8, in May and September in 2008. Environmental data of surface water temperature (SST) was measured by CTD, wind speed, wind direction, air temperature and weather conditions. Fish samples were collected with a bottom trawl net. The sample sites mostly covered spawning grounds beyond Korean territorial waters during daylight, 0630 to 1900 hours (Korean standard time). A single trawl was hauled at each station. Trawling duration was one hour at the speed of about 3 knots to the sailing direction.

Biomass was estimated by dividing the catch (Kg) by the swept area (swept area = trawl distance calculated using geographical co-ordinates multiplied by the trawl net sleeve ends (Korea: 19 m, China: 25 m). In accordance with agreement at the 2nd Stock Assessment Workshop, catchability by species as used in China, was applied for calculating "estimated biomass" and the values are as followings: Anchovy = 0.3; Small yellow croaker = 0.5; Pomfret = 0.4; Chub mackerel = 0.2; Yellow goosefish = 1.0.

Fish samples collected with the bottom trawl net were classified by taxa on board the RV, Tamgu-8. Body lengths and weights were measured. Five target species were selected: Anchovy (figure 3), small yellow croaker (Figure 2), yellow goosefish, pomfret (not collected during the Korean survey) and chub mackerel. For the purposes of data exchange of age and stomach contents, the small yellow croaker and anchovy were selected. Fish species excluding the five target species were counted as bycatch species.

Target fish for the harmonisation of ageing methods using otilith and stomach content analysis were small yellow croaker and anchovy, because pomfret was not caught in the Korean survey. All commercial species were retained for measurements of body weights and lengths. 30 specimens for age composition and 50 for stomach contents analysis, of small yellow croaker and anchovy, were randomly selected and analysed using the harmonised methods. The international scale for stomach contents were applied for stomach fullness (0 – 4), where 0 was empty and 4 was 100% full. Stomach fullness and digestion condition (0-5), where 0 was no digestion and 5 was empty stomach, were determined. The length-weight relationships (Figure 3), sex ratio and gonad developmental stage (Figure 4) were analysed for the target species.

The size (diameter) and wet weight of jellyfish were measured on board, and the numbers of individuals were also counted (Table1). Ichthyoplantkton of fish eggs and larvae were collected using a larval fish net. Zooplankton were only sampled in September.

Species composition tables are given in the full report.

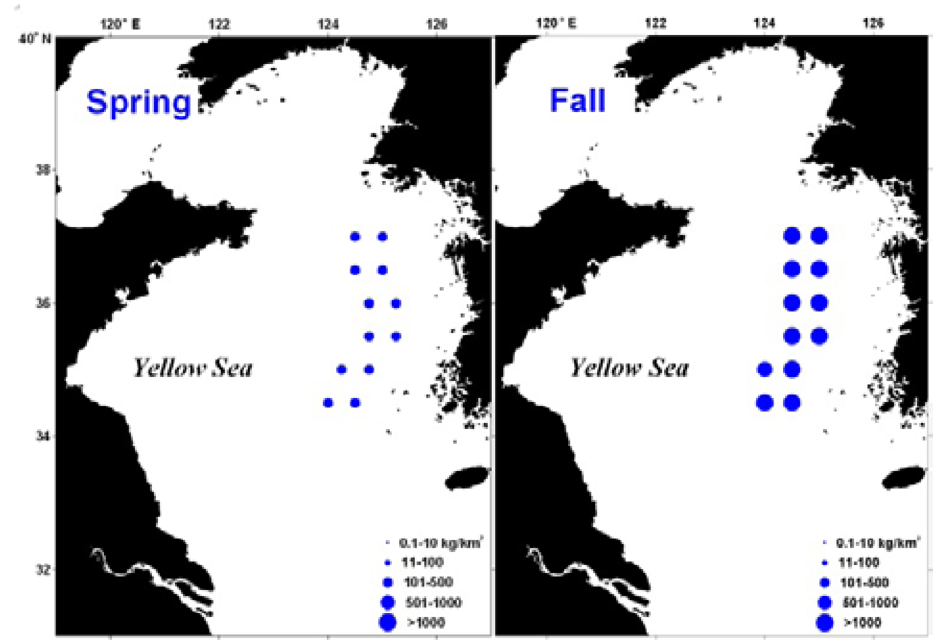

Figure 1 Estimated mean biomass (kg/km^2) of fish and shellfish in the Yellow Sea, South Korea in spring and autumn 2008.

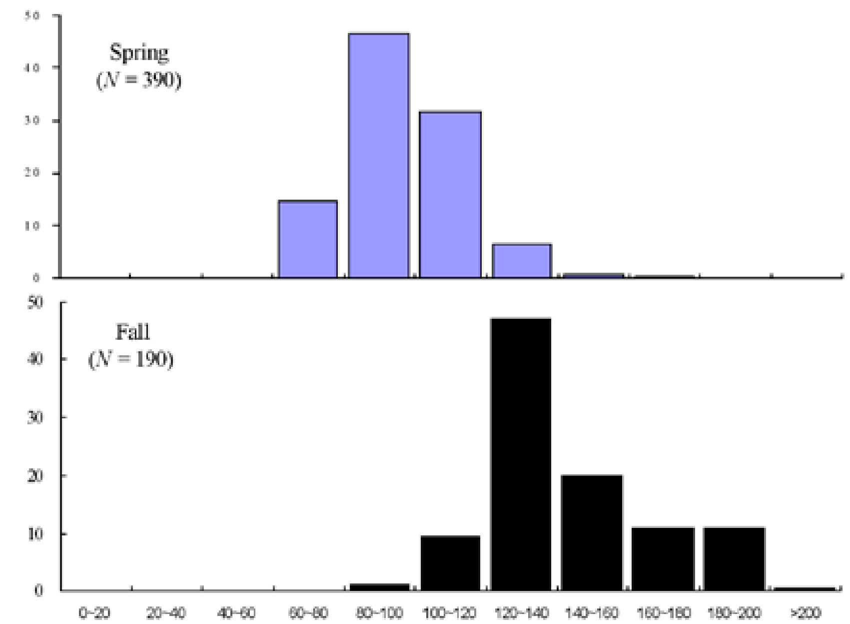

Figure 2 Size frequency of small yellow croaker *(Larimichthys polyactis)* in spring and autumn 2008.

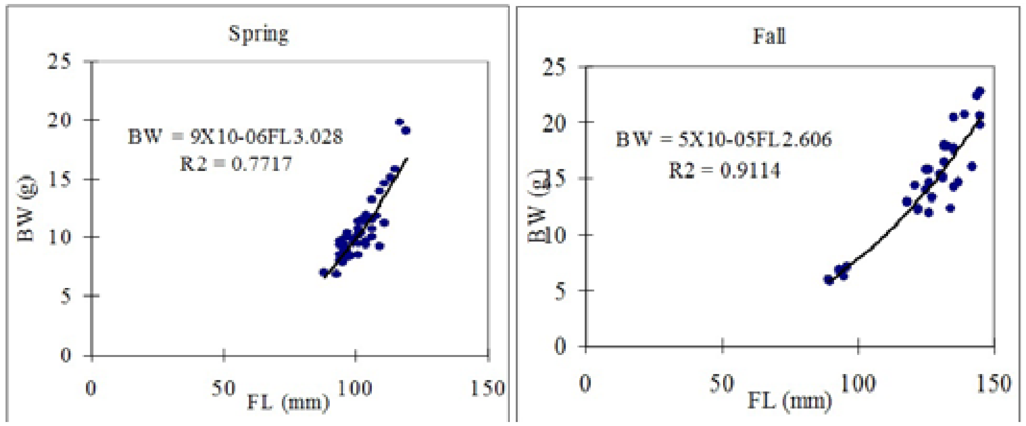

Figure 3 Length-weight relationship of anchovy (*Engraulis japonica*) in the Yellow Sea-South Korea in 2008.

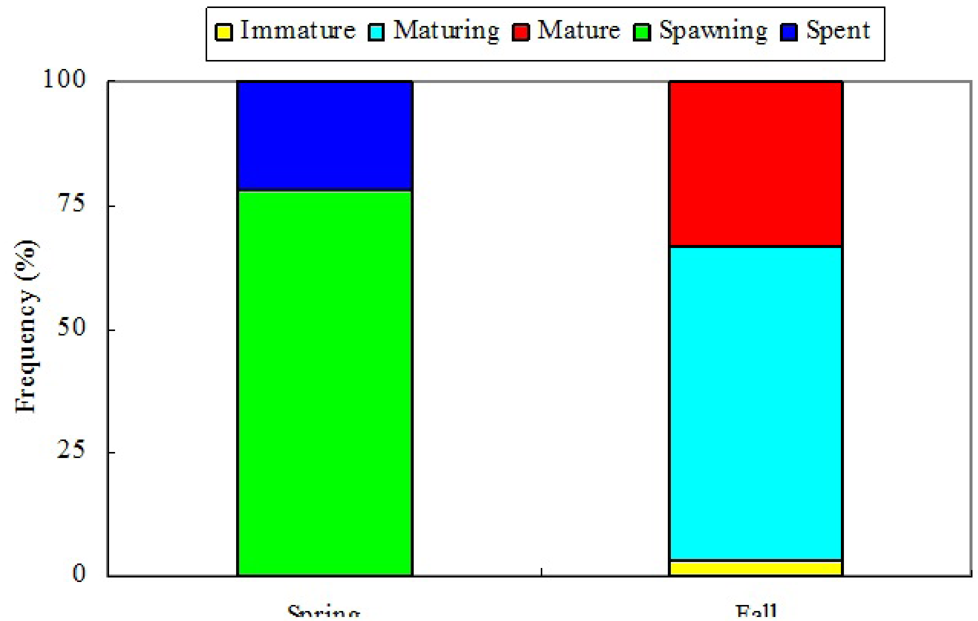

Figure 4 Maturity of anchovy (*Engraulis japonica*) in the Yellow Sea-South Korea in 2008.

Table 1 List of jellyfish found in the Yellow Sea-South korea in September 2008.

Station	Species name	Total length (cm)	Weight (kg)
2	*Nemopilema nomurai*	138.0	120.0
5	*Nemopilema nomurai*	104.0	40.0
	Cyanea nozakii	-	2.0
6	*Nemopilema nomurai*	136.0	
	Nemopilema nomurai	92.0	186.0
	Nemopilema nomurai	132.0	
10	*Aequorea coerulescens*	19.0	2.7
11	Unidentified sp.	-	5.0
12	Unidentified sp.	-	4.5

Results and discussion

The current results of September survey cannot be directly compared with previous survey results because of lack of data. However, a comparison of species composition may be possible. In this survey, Tanaka's snailfish was the most dominant species, but in the 1999 survey, bighead hairtail was the most dominant species. The species ranked top five were Tanaka's snailfish (26.9%), yellow goosefish (17.7%), pacific cod (11.1%), hakodate sand shrimp (7.1%), anchovy (4.8%) in 2008, but they were bighead hairtail (16.2%), beka squid (12.2), blue crab (8.5%), pomfret (6.5%), cuttlefish (6.2) in 1999 (WSFRI, 1999, 2001). Comparison between current and past records noted that the species composition changed from more expensive species to lower value species. In this survey, yellow goosefish was a major dominant species in the both seasons. In May, the dominant species (over 3% in the total landings) were: yellow goosefish, sea raven, jacopever, tanaka's snailfish, mottled skate, goldeye rockfish, Pacific cod, yellow croaker and beka squid while in September, Tanaka's snailfish, yellow goosefish, Pacific cod, anchovy and hakodate sand shrimp dominated.

The mesh size of the cod end in the 1981 survey was 50 mm, but in others it was 22 mm. The survey areas in the other surveys were about twice the width than those in this study. Despite the difference in mesh size and dimensions of the survey area between present and past surveys, this survey indicated that the population of small pelagic species increased and that of demersal species had decreased. NFRDI, 2005; Kim, 1990; Yeon et al., 1991; Yeon, 2001, supporting this study.

Although the direct comparison of survey results between 1981 and 2008 is not possible because of the differences in analysis methods between those two years, density differences between areas by years are distinguished: The high distributional. density areas were located in the south-western area in 1981, but were scattered in the central and northern areas in this study. It may indicate that the warm temperate species migrated further to north, resulting from climate changes in which water temperature increased almost 1°C during the last 30 years in Korean waters (Suh *et al*., 2003).

Conclusion

The Yellow Sea is surrounded by the Republic of Korea (R. Korea), the Democratic People's Republic of Korea and People's Republic of China, and shared by the countries. The fishery yields and fish sizes decreased because of climate change, overexploitation and pollution and most of fishery resources in the sea are transboundary species.

The current survey agreed with previous studies (NFRDI, 1988, 1990; Yeon, 2001) that species composition in the eastern area of the Yellow Sea has changed from higher trophic level, more expensive, larger demersal species like largehead hairtail and small yellow croakers, to lower trophic level, cheaper, smaller, pelagic species like anchovy. The size of the species in the current survey became smaller, and their age was 0 or 1 year old, younger than the first maturity ages. This phenomenon may be driven by over-fishing (Kim, 1990; Yeon, 2001, NFRDI, 2005) and climate changes. Thus, with fisheries management, we need to investigate potential impacts of ocean climate changes on changes in fish populations.

Accordingly, fish populations in the Yellow Sea need to be managed appropriately for sustainable products, especially based on ecosystem-based fisheries management. Proposed measures could include size limits (at 50% maturity), closed seasons during spawning periods and closed areas for spawning grounds, total allowable catch (TAC) and total allowable effort (TAE), and MPAs for protecting habitats. Re-establishing a fishery i.e a rebuilding programme, stock enhancement and habitat restoration could also be suggested.

ROK, DPRK and China share fisheries resources in the Yellow Sea. Therefore, they have to manage the sea very carefully and co-operatively under proper management methods.

Fish Stock Assessment, Yellow Sea, China

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Bo Zhang, Jiancheng Zhu, Qiang Wu

November 2008

Introduction

Many of the fish in the Yellow Sea like the small yellow croaker *Pseudosciaena polyactis*, pomfret *Pampus argentus,* and hair tail *Trichiurus haumela*, undergo seasonal migrations from their overwintering water (around the boundary of the Yellow Sea or the East China Sea), to the spawning waters off the coasts of China and the Korean Peninsula. These resources are shared by the countries around the Yellow Sea- China, South Korea and North Korea. With the implementation of the EEZ, China and North Korea are both paying great attention to the decrease of fishery resources in the Yellow Sea, thought to be resulting from global warming, increased fishing effort and the change of habitats as a result of human activities. The Yellow Sea Fisheries Research Institute and the Chinese Academy of Fishery Sciences have been conducting much scientific research into the fishery resources in the Yellow Sea, including catch composition, distribution and changes in community structure (Liu, 1990; Zhao, 1990; Tang and Su, 2000; Jin, 1996a, 2000a). From the end of 1950's to the middle of 1980's, there were great changes in the community structure, species composition and annual species diversity of fish in the Yellow Sea. These changes were mainly caused by overfishing and the interaction of species (Jin, 1996a) and were said to be severely restricting the sustainable development of fishery resources in the Yellow Sea (Xu et al., 2003). Much of the data previously gathered has been used to good effect for joint research with Korea, mainly to assess the dynamics of the shared stocks. This activity is supported by UNDP/GEF's Yellow Sea project.

The UNDP/GEF project entitled "Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem" is using the concept of ecosystem-based management to manage the marine resources of the Yellow Sea sustainably by fostering international co-operation between China and Korea. One of its important tasks is the Joint Regional Stock Assessment of Target Species. For this task, two surveys were conducted in Chinese waters in spring and autumn 2008, using methodologies harmonised with R. Korea, to gather biological information about the target species. The target species determined after the spring survey were the Japanese anchovy (*Engraulis japonicus*), small yellow croaker (*Pseudosciaena polyactis*), pomfret (*Pampus argenteus*), yellow goosefish (*Lophius litulon*), and chub mackerel (*Pneumatophorus japonicus*). The main aims of the spring survey were as follows:

- To promote better understanding of the state of target fisheries stocks;
- To develop regionally agreed methods for observation, monitoring and sampling of the marine

environment in the Yellow Sea

● Enhance co-operative mechanisms for regional monitoring and observation
● Increase mutual understanding and trust among the participating institutions
● Contribute to future joint-regional stock assessments
● Estimate the swept area abundance index of total catch and target fishes, including Japanese anchovy and small yellow croaker, etc.

The purpose of the autumn survey was to:

● Obtain catch composition data from bottom trawls
● Map the geographical distribution of target fish stocks
● Obtain biological characteristics (length and weight, reproductive stage etc.) of target species
● Collect and analyse stomach samples from the two target species (Japanese anchovy and small yellow croaker)
● Collect and analyse olilith samples for ageing from two target species (Japanese anchovy and small yellow croaker)

Methods

12 sampling stations in the coastal waters of the Yellow Sea were surveyed in May, 2008, which included the spawning ground of small yellow croaker in the south of the Yellow Sea and the anchovy's spawning ground off the southern Shandong Peninsula. Fishery resources in these areas were typical of fish resources in China's waters of the Yellow Sea.

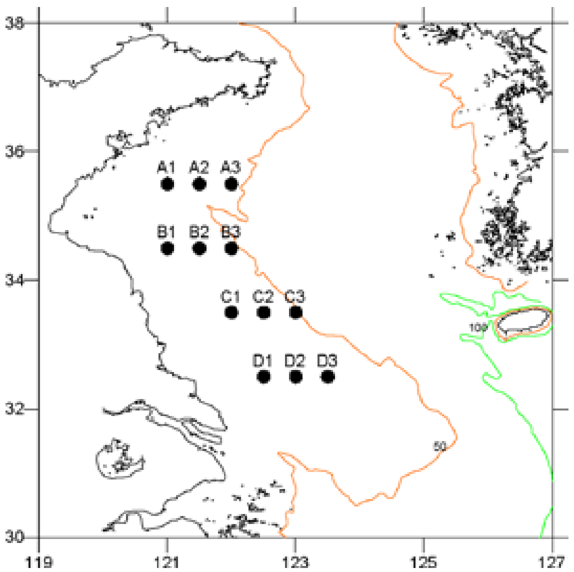


Figure 1 Sampling stations in the spring survey

Sweep area fish density was estimated for each target species with the equation:

d=c/(q ×a)

Total biomass within the fished area was estimated for each target species with the equation:

B=A×d

Samples of < 50 individuals and >more than 50 individuals were randomly collected. All samples were preserved at -20℃ on the R/V Bei Dou and biological measurements and stomach content analysis carried out. Harmonised ageing analysis was conducted using fish otoliths.

Results

Catch composition. 44 fish, 24 crustaceans, and 7 cephalopods were caught in the spring survey. The total catch weighed 150.17 kg. Fish were dominant in terms of catch weight and crustaceans were dominant in terms of numbers of individuals. In the autumn survey, 37 fishes, 14 crustaceans, and 4 cephalopods were caught. The total catch weighed 739.60 kg, composed of 159707 individuals. Fish were dominant by weight and crustaceans were dominant by numbers of individuals,

Distribution: Japanese anchovy; were found at 8 stations. The highest catch was found in the northern part and the southern part of the survey area in spring, but anchovy mainly concentrated on the northern part of the survey area in autumn. Though the average catch density of anchovy in the autumn was higher than that in spring, its proportion of the total catch decreased in the autumn. Pomfret; were caught at almost every station in the survey area, and catch frequency was 83 %. Though the average density of pomfret in the autumn survey was higher than in the spring survey, the proportion of the total catch actually declined in the autumn survey. For small yellow croaker; in the spring survey, the average catch density was as low as 4.38±0.79 kg/km^2, with the catch frequency of about 75 %. Small yellow croaker were scattered over the survey area. The catch density was higher in the northern part of the survey area . In the autumn survey, the average catch density was 20.8±11.29 kg/km^2, with the highest catch found in St. 11. They were spread over the survey area, with highest catches obtained in the south. In the spring survey, yellow goosefish were mainly distributed in coastal waters, with an average catch density of 2.81±1.05 kg/km^2. In the autumn survey, yellow goosefish were mainly distributed in the outer waters of the survey area, with a lower catch frequency and an average catch density of 50.71 ±15.42 kg/km^2 at St.9.

The Length-weight relationship, gonad maturity and stomach contents fullness were measured for all target species.

For example

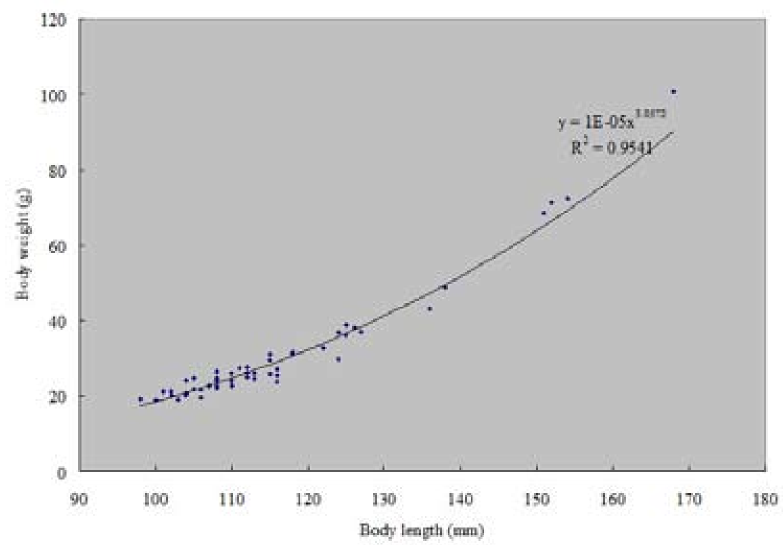
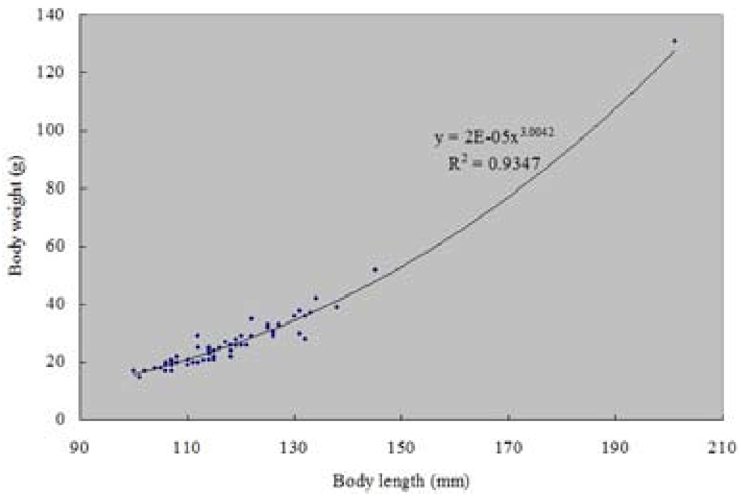
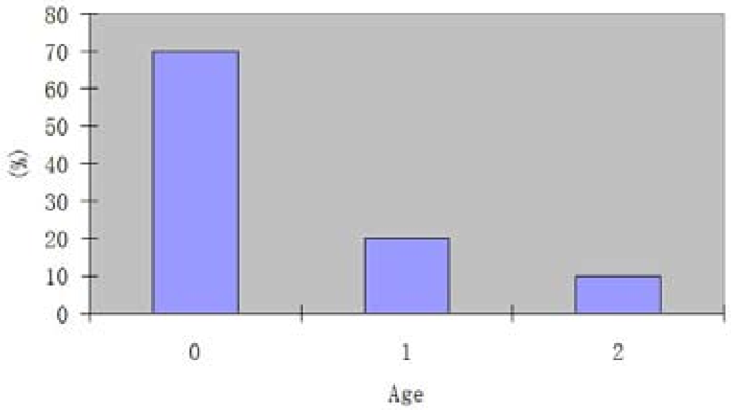


Figure 2 a) Length-weight relationship of small yellow croaker in the spring survey



b) Length-weight relationship of small yellow croaker in the autumn survey



c) The age composition of the sample was measured for anchovy and small yellow croaker which produced varying results, for example; Age structure (years) of anchovy in autumn survey

Stomach contents were analysed and compared for anchovy and small yellow croaker. This varied according to the season. The distribution of jellyfish also showed a marked seasonal variation. The species composition of the ichthyoplankton was also recorded with seasonal variations noted in eggs and lavae of anchovy and small yellow croaker.

Discussion

The southern Yellow Sea is the main overwintering ground for most of the migratory fish species distributed in the Yellow Sea, the Bohai Sea and the East China Sea (Liu, 1990). The complex environmental conditions and diverse fish species of the Yellow Sea make it the major fishing ground for the regional marine fishery and enable it to contribute significantly to the marine catch of China. Studies into the migration and distribution of commercially important fish, conducted in 1980s (Zhao, 1990), showed that most of the species in the area, e.g. small yellow croaker, mackerel and anchovy, carry out long distance seasonal migrations with the change of water temperature.

Change of species composition. The dominant species in the Yellow Sea have not altered in recent years, but the composition of the dominant fishery varies according to the sea region and survey time. For example, anchovy are mainly distributed in the central and southern part of the Yellow Sea in May, but later being mostly found in the northern and central part in October.

Change of catch rate. Although the number of species in the catch was larger in the spring survey than in the autumn survey, the total weight and number of individuals in the catch and the average catch density (excluding target species, chub mackerel) in spring were less than that in autumn. It was caused by the change of fish composition, as the majority of the spring catch were spawning stocks but in the autumn recruitment and/or overwintering stocks formed the catch. Fish were dominant in catch weight and crustaceans were dominant in the number of individuals in both surveys. The proportion of fish by weight and number of individuals increased in the autumn survey, in contrast the proportion of crustaceans by numbers of individuals greatly decreased. It reflected the changes of community structure and functional groups among survey areas.

Biological characteristics. In this study, the range of fork lengths of anchovy (50-150 mm) was wider than that in 1980s, which maybe due to the adaptation of ecological niches for maintaining race dominance in marine ecosystems.

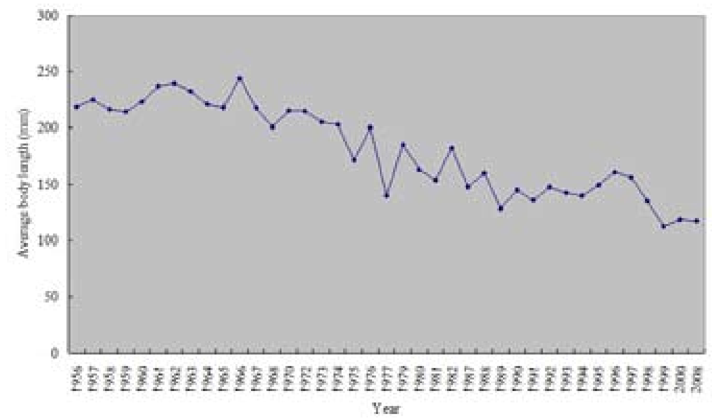


Figure 3
The average body length of small yellow croaker from 1956 to 2008.

The size spectra were determined by the changes of catchability and the distribution on the fishing ground. The dominant size spectra of most species in the survey was narrower than that in 1985 or 2000 and the proportion of individuals in the dominant size spectra decreased in the total catch of individuals. This might have been caused by the changes in the fish population structure as a result of overfishings. Also similar results were reported by Deng and Zhao (1991) and Xu et al. (2003). Results suggest that the current fishery resource is at the condition of overexploitation. In the present survey, most of the caught individuals were less than 1 year old, particularly in the autumn, which typified the simple age structure of small yellow croaker currently found in the Yellow Sea.

Conclusion

Based on the data of the bottom trawl surveys in May and October in the Yellow Sea and supported by historical data, the changes of the fishery resource, fish community, characteristics of some target species, ichthyoplankton and jellyfish were analysed.

1. The structure of the fish community has changed, a simplification of the population structure was found.

2. Simpler age structure, lower body length and earlier maturation of some target species compared to the 1980s was observed. Small-sized commercial species and small pelagic species, both with low age compositions, dominate the fisheries and manipulate the energy flow within the food web structure in the Yellow Sea.

3. The catch density of fishery resource and the biomass in autumn were larger than that in spring, so were the bycatch density and biomass.

4. Most of the ichthyoplankton were caught in spring, and were mainly anchovy eggs. Catches were composed of reproductive stock in spring, and recruitment stock and overwintering stock in autumn.

5. Analysis of stomach contents of anchovy and small yellow croaker indicated that the dominant food items changed with fork length and body length.

6. The biomass and distribution of jellyfish in autumn were larger than that in spring in the survey.

The Effectiveness of Closed Seasons/Areas in the Yellow Sea

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November 2009

Abstract

With the development of the economy and fishing technology, there are great pressures on fishery resources from overfishing and the deterioration of the environment. In order to help restore and protect natural fishery resources particularly the recruitment of commercial stocks, closed season/closed areas have been widely used as a fisheries management tool in Chinese coastal waters since 1995. Studies from the South and East China Seas have suggested that the biological, economical and social impacts have been largely positive. The present study concentrates on the Yellow Sea. The bottom surveys were carried out before/after the closed season in Taozi Bay, Langyatai and Lanshan in 2008 and 2009 for the purpose of assessing the effects of closed season/closed areas. The results showed that fishery resources appeared to recover to some extent according to the analysis of catch composition. Catches consisted largely of juveniles in September in Lanshan, following the reopening of fishing grounds which met the original aim of the closed season to protect the newly recruited population. In addition, the great decline in fishery resources and the ecological benefits of closed season was widely acknowledged by fishermen. A survey of fishermen indicated 100% support for the closure of fishing areas during the summer season as there was a good understanding of the reasons for the closure and 100% indicated that they were in favour of prolonging the closed season time.

Introduction

The seasonal closure of fishing grounds was introduced by the government and conducted by the fishery administration management department. It ruled that the ban on fishing during specific times and areas during the year was a positive and necessary measure to protect the threatened species and restore fishery resources. It also plays an important role in the sustainable development of fishery resources, particularly in protecting the early life stages (Zhu, 2009). The earliest report of a closed season was that conducted in the North Sea fishery from 1914 to 1918 (Ricker, 1954). The effects of regulations prohibiting fishing were systematically studied using bioeconomic models to determine optimal harvest rations in inshore and offshore fisheries by Charles and Reed (1985), and Greenberg *et al* (1994), and Hermann *et al*. (1998) reported the effects of pot limits for king and tanner crabs. More recently, studies to evaluate the effects of closed seasons mainly concentrated on biological and economic models, and observational methods, e.g. Warren *et al* (1982), who studied the effects of banning cephalopod fishing by biological and economic submodels. He found that when fishing effort decreased

(16%), the benefits increased. Similar effects were also reported by Watson and Restrepo (1995), Somers and Wang (1997), Roel *et al* (1998) and Katoh *et al* (2001). These reports all proved the positive function of introducing regulations for seasonal fishing ground closures for the restoration of fishery resources.

The deteriorating environment and overfishing have led to great declines in fishery resources in China. In order to restore fish stocks, the closed fishing season, combined with the other measures, have been implemented in the whole country from 1995 in China, and adjusted many times according to current scientific knowledge and real conditions in China. The closed season was determined by the biological characteristics of the stock (e.g. spawning and breeding habit) and the stock assessment in the different sea areas (e.g. the annual fishery density was 1 in the 1950s, decreased to 0.7-0.6 in the 1960s, 0.4-0.3 in the 1970s, and not beyond 0.2 after 1980s in China (Lin, 2004)). At present, the closed season is in force from 1st June to 1st September to the north of 35°N in the Bohai Sea and in the Yellow Sea and East China Sea from 2009, from 1st June to 16th September between 35°N and 26.5°N. Studies of the closure of sea areas to fishing in China have mainly concentrated on two aspects: firstly, how to improve the fishing ban rules, including closure times, management of the ban, specific measures and closure aims (Gao, 1999; Ma, 2000; Ding, 2001; Lian, 2003; Li, 2006; Liu and Yan, 2007); and secondly, the effectiveness of fishing closures in restoring stocks, including biological and economical effects, mainly in the East China Sea (Cheng et al, 1999, 2004,2006; Liu and Zhou, 2000;Xu et al, 2003; Yan et al, 2004, 2006, 2007) and the South Sea (Liu and Chen, 2000,2001; Shi et al, 2008). Though the closure of fishing areas has been carried out for a long time in the Yellow Sea, resulting in great benefits for fishermen, no studies have addressed the effects of closures on the restoration of stocks in the Yellow Sea. In order to assess the benefits to stocks from this type of fisheries management and demonstrate the benefits to fishermen, bottom surveys were carried out in Taozi Bay (Yantai), Langyatai (Jiaonan), Lanshan (Rizhao). They were also designed to determine the effects of closures on catch composition and stock recovery. In addition, fishermen in four cities distributed along the coast of the Yellow Sea from Northern part to Southern part, including Dalian, Rizhao, Yantai, and Rongcheng, were visited to assess the impact of the effectiveness of closed fishing seasons (Figure 1). The research was carried out in China's coastal waters and supported by UNDP/GEF's Yellow Sea Project.

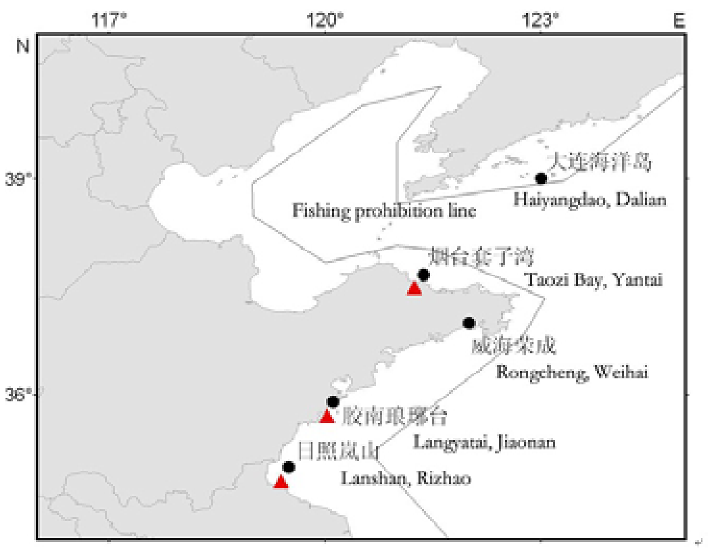


Figure 1 Cities of visiting fishermen (black solid circle), sampling sites (red triangle) and the boundary of closed season (the grey solid line)

Survey methods

Four trawl surveys were carried out on 16th September, 10th October, 7th November, 2nd December in 2008 and 23rd March in 2009 in Langyatai, Jiaonan, Qingdao. Two trawl surveys were conducted in 15th April, 23rd May, 13th September in 2009 in Lanshan, Rizhao. The species composition of each survey from the whole days catch was noted.

Four trawl surveys were carried out in 16th November, 2008, 15th May, 16th June, 20th October in 2009 in Taozi Bay, Yantai. The mesh size of the bottom trawls was as follows: cod-end 4mm, net mouth 3*16m, bottom warp 45*1.7m, empty warp 11*1.7m, halftone 45kg*2; second net mesh size 120mm, and towing warp 110*1.7m, and the duration of trawl was about 1hour.

Survey of fishermen after closed season/areas

To assess the effectiveness of closed seasons/areas, we collected relevant data from the coastal Oceans and Fisheries Bureaus of Dalian, Yantai, Qingdao, and the Regional Fisheries Bureau of the Yellow/Bohai Seas. 96 randomly selected fishermen from 9 fishing villages were visited in order to understand the socio economic impacts relating to the fishing ban policy, and 1,600 printed leaflets were distributed throughout the villages. There were 96 experienced fisher folk visited from four cities: Haiyangdao, Dalian, Liaoning province, Lanshan, Rizhao Yantai, Rongcheng, Shandong province.

Additional management measures to support closures

Strengthening the environmental awareness of fishermen

The education of fishermen was carried out in the closed season. Most of fishermen changed their concept of fisheries production, and were encouraged to pay more attention to ocean fishing and aquaculture to mitigate the decline in fishery resources in coastal waters. The effects of the closed season on the recovery of fish stocks was publicised through media posters, TV, and newspapers. The government encouraged fishermen to engage in aquaculture and aquatic processing in the closed season, and tried to increase the income of fishermen. Social support systems were also strengthened in fishing villages during the closed fishing season, and recreational activities were organised for the fishermen to ensure a healthy and positive mindset.

Education of fishermen in fishing regulations and technological improvements.

A course of lectures for fishermen was held during the closed season which included law, regulations, fishing technology, fishing techniques and safety at sea.

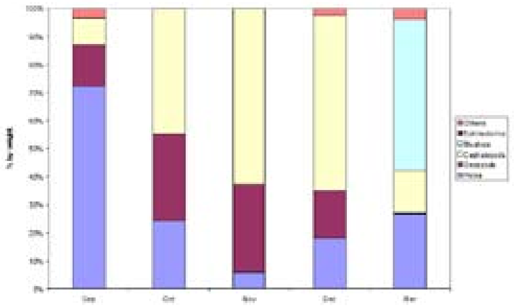
Preparation for fishing after the closed season

Fishermen were encouraged to take advantage of the closed season to repair their fishing boats and gear and increase their sailing skills.

Results

Catch compositions in Langyatai.

To determine the effect of closed seasons/areas on the community structure of fishery resources, the change in catch compositions from a single trawler was noted monthly from September to December 2008. The catch composition is given in Figure 2, cephalopods and fish occupied a relatively high proportion in all surveys, but bivalves were abundant in March, 2009. In terms of biomass, the catch in September, following the reopening of the fishing ground, was almost 3 times higher than that in the other surveys, but then declined and remained low until March in the next year (Figure 3). However the number of species caught in March, 2009 was higher than in previous months.



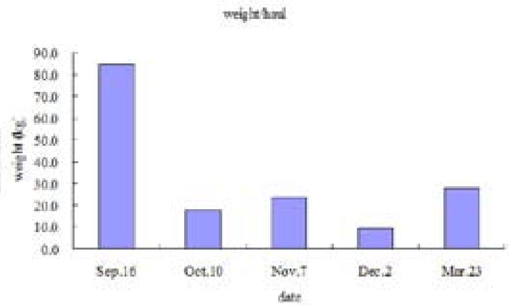


Figure 2 Catch composition by taxonomic groupings in Langyatai, Jiaonan

Figure 3 Weight of per haul from Sept. to Dec. 2008 and Mar. 2009 in Langyatai, Jiaonan

Catch composition in Lanshan

From the surveys carried out in April and September, 2009, the species composition and dominant species of Rizhao is presented in Figure 4. The catch weight in September in Lanshan was higher than that in April (Figure 5), but the number of species in September was lower than that in April. It was noted that the majority of the fish caught in the September survey were juveniles. The contribution of decapods to the catch increased significantly after the re-opening of the area to fishing, mostly due to shrimp *Trachypenaeus curvirostris*, which formed 27% of the catch by weight and 60% of the catch by numbers as most were juveniles. The mantis shrimp population appeared to have recovered dramatically during the fishing closures increasing from 3% in April to 22% of the catch by weight and 11% by numbers in September. In contrast, the bivalves *Ostrea denselamellosa* and *Atrina pectinata* were no longer present following the re-opening of the fishing area. It appeared that not only does the taxonomic composition change between April and September, but also the species composition alters dramatically with many species disappearing and new species emerging in the catch after the re-opening of these fishing grounds

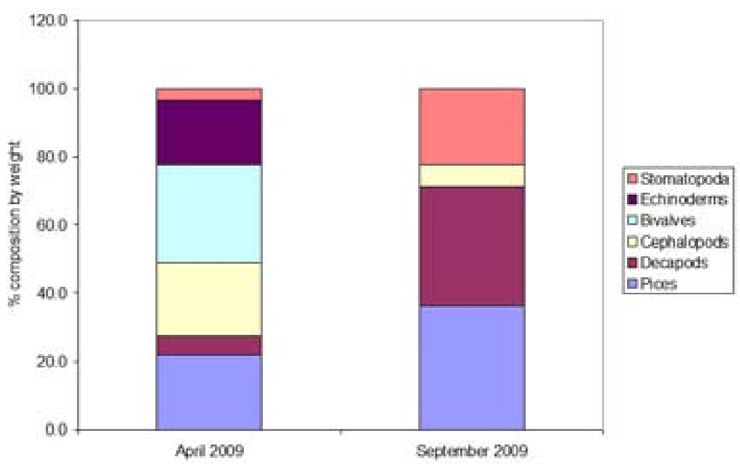
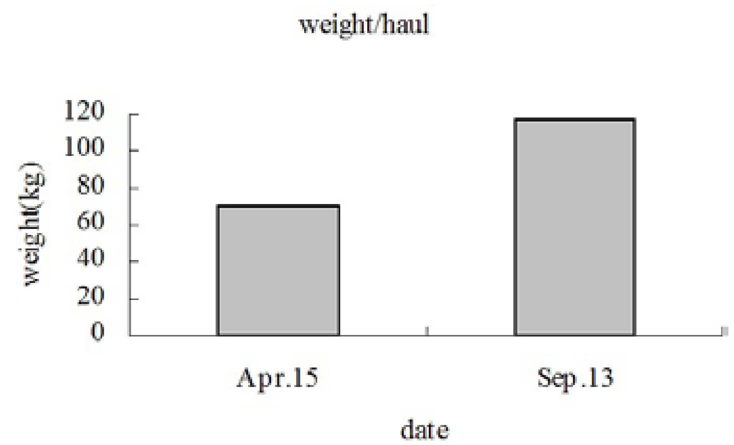


Figure 4
Taxonomic composition by weight of trawl surveys in Lanshan in April and September 2009

Figure 5
Weight of per haul Apr. and Sep.2009 in Lanshan, Rizhao



Catch composition in Taozi Bay

The surveys were carried out from November, 2008 to October, 2009. Fish catches in November, 2008 were dominated by were *Oratosquilla oratoria*, *Enedrias fangi*, *Oxyurichthys papuensis*. In May, 2009 the dominant species by weight were *Hexagrammos otakii*, *Hexagrammos otakii* , *Sillago japonica* , *Argyrosomus argentatus* , *Liparis tanakae*. Fish catches in June, 2009 were mainly of *Oratosquilla oratoria*, *Octopus ocellatus*, *Pseudociaena polyactis*. *Portunus trituberculatus*, *Octopus variabilis* and shrimp were the dominant species in October.

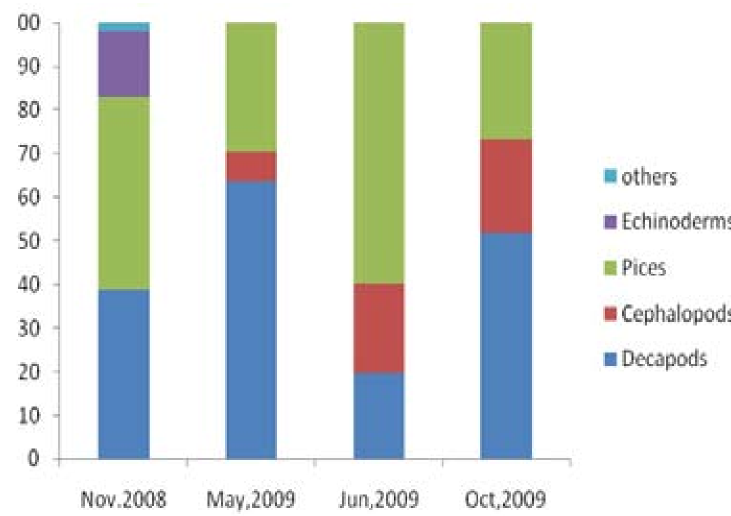


Figure 6
Catch compositions in a haul in Taozi Bay, Yantai

Survey of fisherman's attitudes to the closed season

(1) All fishermen supported the closed season measures and were all aware of the effectiveness of the closed season/area on the restoration of fish stocks. They knew that the closed season/area was to protect fish reproduction and growth, particularly of juveniles, thereby reducing the great decline of some species.

(2) Poachers were not found in coastal waters in closed season/area, and local government management played important roles in preventing poaching in the closed season.

(3) The closed season time would affect the harvesting of some species, such as *Ammodytes personatus* in Longkou, Shandong province. However, most fishermen thought the closed season should be prolonged, for example, from 1st May to 1st October and they would all accept it. Some fishermen even suggested prohibiting fishing for two or three years. If the closed season is to realise its full potential, they all thought that the law and legal institutions should be strengthened.

(4) The catch was not very good after the closed season finished, just one third of the previous year in Zhangzidao, Dalian, Liaoning province, it was similar situation in Shidao, Yantai, Shandong province; but the catch was better in Rizhao this year compared with last year. These were caused by their position and dynamics of fishery.

(5) Alternative employment was not easy for fisherman, primarily as they were only familiar with fishing techniques, being one of several generations of fishermen, secondly, to start out in aquaculture for example they needed to invest a lot of money, which would bring increased risk. The development of new industries was also controlled according to the regional administrations. Therefore it was difficult to reduce fishing pressure by decreasing the number of fishing vessels and persuading the fisherman to change livelihoods.

(6) In addition, some migratory species stayed in Chinese coastal waters during the closed season, but migrated to fishing grounds in other countries when the closed season was over. The fishermen all thought some measures should be taken to share these migrating stocks. This perception that other fishermen were benefiting from the closed reason might be one reason why fisherman illegally continued to fish during the closed season.

The closed season/areas had positive effects on the restoration of fish stocks, but small-sized fish still dominated the catch eg *Enchelyopus elongates*, *Engraulis japonicas*, and *Gobiidae* species. Additionally most of catch in the September survey, after the closed season in Lanshan had finished, were juveniles, suggesting that fish larvae and juveniles were successfully protected in the closed season which could play an important and positive role for the ecological benefits of closed seasons. However, there was another problem in that substantial numbers of juveniles were caught which could affect recruitment the following year.

The effectiveness of the closed fishing season

The closed fishing season has brought great ecological, economical and social benefits. The present study confirmed the results of a previous report, which suggested closed fishing seasons could have an immediate impact to help reproductive success and support recruitment. In contrast, quota regulations would take a long time before being effectively implemented and enforced (Shi et al., 2009).

The timing of fishing closures is critical. Fish spawning time is closely related to water temperature, which means that fish spawn earlier in warmer water environments (Chang *et al*., 1972; Chen *et al*., 1996, 2006). According to an analysis of the spawning times of the major target and minor target fish species in waters off Taiwan and the East China Sea, the period of closure did not coincide. with the maximum spawning activities for many commerical fish, which was from March to August, but especially from April to June, hence Shih *et al*. (2009) suggested the closure period should be adjusted to begin 2 months earlier.

Some problems were experienced as a result of the closed season policy: 1) a high intensity of fishing effort occurred after the re-opening of the fishing grounds, and the period immediately preceding the closure. Additionally, although fishing effort was restricted by limiting access, fishermen could increase their catches by increasing the power of boats, setting more traps and fishing longer (Waugh, 1984). In the East China Sea area, stocks greatly benefited from the fishing closed season, particularly the commercially important species (Cheng, 2004, 2008). However, the high intensity of fishing effort once the fishing grounds were re-opened, led to a decline in the abundance of fishery resources (Yu & Yu, 2008) to such an extent that the summer closure of fishing grounds only served to increase their body length and was not found to rebuild stocks (Cheng, 2004, 2008). From the present study as well as the previous studies, it can be concluded that the population structure of commercial fishery resource was improved. For example, the catch of the small yellow croaker in the East China Sea was mainly composed of 0 and 1 aged fish from 1992 to 1994 before the implementation of fishing closure. The 0-aged fish (body length not beyond 130mm) accounted for 43.14%, the remainder (body length beyond 140mm) accounted for 56.86%. By 2008, the proportion of 0-aged fish had increased to 74.64% of the total catch, with the rest accounting for 25.36%, which showed the closed season played an important role in the restoration of small yellow croaker recruitment population, just a short time protection for the recruitment cohorts of small yellow croaker. There was also found to be an increase in small-sized individuals and the trophic level of the fishery resource significantly declined e.g. small yellow croaker, *Scomberomorus niphonius* and *Muraenesox cinereus* decreased from 4.3, 4.6, 4.6 in 1985 to 3.61,3.41, 3.61 in 2008 (Cheng, 2008).4)

Changes in fishing gears

The closed fishing season was aimed at trawl and stow nets, so fishermen mainly carried out shrimp fishing during the closed season. The exclusion of shrimp fishing and the use of gill nets and purse seines from the fishing moratorium (ban) were helpful in the short term by increasing of income of fishermen, but they also extended the fishing grounds which damaged the fishery resource and surrounding habitats.

Management measures

The priority is to strengthen research in fisheries science especially with regard to stock assessments and, enhance the scientific approach to fishery management.

1 Surveys and evaluations of fishery resources: carry out the regular surveys in coastal waters; provide the evaluation reports on the status of important commercial species with estimations of allowable catch using recognised biological parameters.

2 Basic studies on fish stocks: carry out the studies on the function and succession of fishery ecosystem, particularly the spawning, and breeding ecology of important commercial species, pay more attention to the population dynamics of important commercial species, and strengthen the studies on fish diversity.

3 Applied and strategic studies on fisheries management: emphasize the importance of studies on communicating important information on fishery management, paying attention to the structure of fisheries (both onshore and offshore), and localised research on sustainable fisheries development.

The seasonal closure could be further extended to include various types of fishing gear such as trawling, purse seining and gill netting for the specific reproductive periods of target fish. The closed season should be prolonged to ensure the better protection and restoration of fish stocks, particularly spawning populations and juveniles. The scope of closed area should set according to the biological characteristics of fish in order to meet the aims of stock recovery.

These measures of closed seasons/areas should be conducted in co-operation with the other countries, so that enhanced benefits for fishermen such as the protection of spawning areas of migratory stocks exploited by fishermen in other areas or countries, can be regulated and harmonised.

Assessing the Effectiveness of Stock Enhancement in the Yellow Sea

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Abstract: In order to better evaluate the effects of stock enhancement on the restoration of the native olive flounder stock, juvenile release experiments were carried out in September, 2008 in Taozi Bay, P.R. China. The released olive flounder were made up of three groups: 50-70mm, 70-80mm and 80-100mm. The results showed that most of the released flounder belonged to the bigger size group with a tagged body length of 80-100mm. In total, 43 tagged olive flounder were recaptured, the recapture rate was 0.4%. With time, the weight of the recaptured tagged fish gradually increased. In addition, the mortality of the bigger size group (80-100mm) was 4.6%, and the missing tag rate was 3.2%, lower than that in the other groups. The tagged olive flounder was mainly distributed in Taozi Bay, and had the same migratory habit as wild olive flounder. According to the survey results, the survival rate of tagged flounder was 10.4% which had positive effects on the restoration of the native olive flounder resource. Stock enhancement is a long-term project and has the potential to help protect the natural resource and increase the income of fisher folks.

Key words: Olive flounder, Taozi Bay, Stock enhancement

Introduction

With the development of industry and growth of the human population, increasing food demand is becoming a challenge for modern society. Overfishing and the destruction of coastal habitats has resulted in a great decline of fishery resources and a deterioration of the coastal environment (Jin, 1996). Efforts are being made to protect coastal habitats, to restore the populations of aquatic organisms and to create new fishing opportunities. Traditional fisheries management requires re-orientation to meet new challenges (Liao, 1999; Chua, 2001). In recent years, stock enhancement has been recognised for its potential to increase and sustain coastal fisheries (Oshima, 1984; Bartley, 1999; Liao, 1999, 2002). Stock enhancement has been attempted at some level in over 25 countries worldwide (Bartley, 1999) with more than 100 species of aquatic organisms (fish, crustaceans, molluscs and other invertebrates) (Liao, 1999; Fushimi, 2001). Investment in stock enhancement is increasing (Figure 1). The species used for stock enhancement are mainly commercial species and endangered species, and the number of species used in stock enhancement has gradually increased in recent years. There were 104 species in 2007, including 95 commercial species and 9 endangered species.

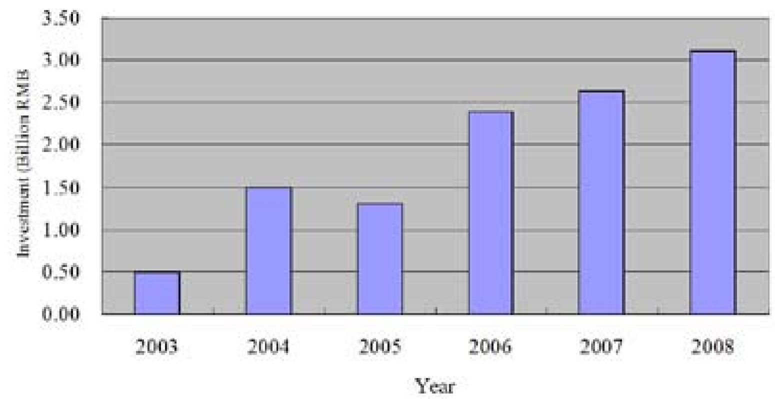

Figure 1 Investment in stock enhancement from 2003 to 2008

A well-planned enhancement project will attempt to recapture mature released juveniles or promote inter-breeding between released and wild populations, so that an enhanced self-sustaining population develops (Cross, 1999). This project has been initiated to better evaluate the effectiveness of stock enhancement, assess the benefits of this type of fisheries management to the fish stocks, and illustrate the benefits to fish folk and policy makers. The stock enhancement of olive flounder was carried out in Taozi Bay in Yantai, China.

Olive flounder *Paralichthys olivaceus* belongs to Pleuroneetiformes, Pleuroneetoidei, Bothidae, Paraliehthyinae. *Paralichthys* are cold water temperate, demersal species. They inhabit coastal waters with a sandy bottom and tidal current at an average depth of 20-50m. The juveniles usually live in the estuarine zone with less organic matter, more water movement and average depths of 10m. Olive flounder is an important commercial species in traditional fishery resources, and widely distributed in China, Japan, Korea and the Pacific Ocean waters (Chen, 1991). In recent years, catches of flounder have greatly decreased due to increased fishing effort and a deteriorating water environment (Tang, 1996). Though the artificial breeding of olive flounder was studied in 1950s, large-scale breeding of olive flounder was realised in 1970s, and the first releasing experiment of olive flounder was carried out in 1981. The tagged olive flounder releasing programme (a total of 60,000 individuals were released) began from 1983 in which fish were marked, tagged and implanted with an anchor tag, at the sliver line mark. The recapture rate reached 10% in 1984 for large size olive flounder (Liu, 2009). These good recovery rates, high economic value and ease of hatchery production suggested that this species was a excellent candidate for stock enhancement, as evidenced by the high economical and social benefits of the trial in Shandong province (Liu, 2009). The research was carried out in Chinese coastal waters and supported by UNDP/GEF's Yellow Sea project.

Methods

Tag selection and manufacture

Elliptical plastic tags outside the body (diameter 18mm, weight 8.9mg) were used in the demonstration project (2008), in three colours, red, yellow and blue and marked with tag serial numbers (Figure 2).

Figure 2 Tags of juvenile olive flounder

Selection of juveniles

Released juveniles were supplied by Yantai Tianyuan Aquatic Products Co. Ltd. Fertilised eggs were obtained from wild parent fish, only healthy juveniles were used in the stock enhancement project. The juveniles (total length [TL], 50-100mm) were sampled and examined 5 days before their release by the Fishery Inspection Center of Shandong province.

Tagging olive flounder

The juvenile flounders were contained in plastic ponds and the tag was introduced using sliver wire passed through the dorsal part of the body. The temporary culture of tagged juveniles improved the results of the release project. During this period, penicillin was used to treat any wounds of tagged juveniles and the activity, survival and missing tags was also noted. The juveniles were divided into different groups in terms of their standard length, and then total length and weight were measured. The tag serial number for each fry was registered.

The release site

Taozi Bay was the natural spawning and feeding ground for olive flounder, where there was a relatively stable production of olive flounder over a period of time. In recent years, the production of olive flounder in these sea areas greatly declined due to overfishing and changes in the water environment. But kelp and scallop also were cultured in this sea area, which prevented the released fish being affected from bottom trawls (or the other fishing gears). Taozi Bay and its adjacent waters were considered to be optimal release sites.

The release process

The release of the olive flounder was carried out at different times and site on the 12th and 13th September 2008. 500 juveniles were released on 9th as the first experiment, food was not available one day before the flounder were released. The juveniles were transported in plastic bags with oxygen-rich sea water which maintained 30 individuals, supplying enough movement space for juveniles. During transportation, the temperature was reduced with ice to decrease the activities and oxygen consumption of the flounder, which contributed to the increase survival rate of the released juveniles. The total number of released olive flounder juveniles was 11389, including 5000 juveniles in 12th and 5889 in 13th. Among them, 3800 juveniles belonged to 50-70mm standard length group, 3900 juveniles belonged to 70-80mm group and 3689 juveniles belonged to 80-100mm group.

Figure 3 Releasing juvenile olive flounder to the sea

Public awareness

In order to strengthen the social awareness of the project, 4000 picture posters were manufactured which described the need and historical significance of maintaining the sustainable development of fishery resources by juvenile releasing. The picture posters showed the juvenile releasing was important to restore the fishery resource, improve the environmental quality and maintain biological diversity. The shape and colour of the tag, the department of releasing tagged juvenile, the department of gaining recaptured tagged juvenile, full style (contractor, telephone number), and rewards were also included in the content of posters.

Picture posters were also delivered to each town and village in some key sea areas, which help to communicate the project and make sure that the recaptured tagged juveniles were collected and recorded. The media were also contacted and information given directly to fishermen.

Recapture rate estimation

In order to evaluate the effects of stock enhancement of olive flounder on the natural fishery resource and clarify the distribution, migration and growth of olive flounder, two recapture survey exercises were carried out in November, 2008 and June, 2009.

Survey methods

The samples were collected by single bottom trawls at each site, the towing time was 1h and the mean trawl speed 3.74 knots, two researchers recorded and analysed the results. The bottom trawl size was as follows: cod-end 4mm, net mouth 3*16m, bottom warp 45*1.7m, empty warp 11*1.7m, halftone 45kg*2, net mesh size 1.2cm, and towing warp 110*1.7m.

Results

The survival rate of tagged olive flounder in temporary cultured waters

The total number of tagged juveniles was 12469 individuals, survivors = 11389 individuals, and the survival rate was 91.3%. 491 tags were missed; the missing tag rate was 3.9%. The survival rate and tag-missing rate of tagged juveniles was different for different standard lengths. The survival rate and missing tag rate of juveniles with a standard length of 50mm to 70mm was 87.5% and 5.4%, respectively; 91.8% and 4.1% when the standard length of juveniles was 70mm to 80mm; and 95.8% and 3.2% in large-sized individuals (standard length 80-100mm). The release results demonstrated that it was a wise precaution to keep the tagged juveniles temporarily in the breeding workshop. Variation in the data may have been caused by;

1. Fishing gear: Olive flounder inhabit sandy and muddy bottom sediments, so the gear needs to be set so that it touches the bottom. In order to resolve this problem, the fishing gear was changed in that the rope length was increased.
2. Sampling stations and sampling time: Olive flounder might have begun their overwintering migration during the survey in November 2008, therefore the optimal survey time was missed. The sampling stations were also near to the releasing site, which may have accounted for the results.

Recapture

Forty-three tagged olive flounder were recaptured by commercial fishermen by the end of June 2009, the standard length varied from 64mm to 356mm, body weight varied from 3.4 g to 408 g, and the size of recaptured tagged fish increased with time. Tagged fish were collected in every month after the releases (excluding January, 2009). The highest number of recaptured tagged fish (11 individuals) was found in November 2008, only one tagged fish was collected in February 2009. Most of tags were in tact; a few tags were slightly damaged.

The recaptured olive flounder were mainly distributed in Taozi Bay and its adjacent waters, 37 individuals were found in Taozi Bay, 9 individuals were found in the northern part of Taozi Bay, 60% of the recaptured olive flounder were found within 6 nautical miles of the release sites, and only 1 individual was found 17 nautical miles from the release site in February, 2009.

Assessment of olive flounder in Taozi Bay

In June, 2009, the number of tagged fish was assessed in Taozi Bay and its adjacent waters by the swept area method. The formula of swept area method was as follows:

B=AD/pa

B was the olive flounder resource in Taozi Bay and adjacent waters, i.e. the number of olive flounder individuals;

D was the number of recaptured, here, 3 individuals;

A was the total area of survey sea area, i.e. Taozi Bay and its adjacent waters, 346 km^2;

a was the swept area of trawl, = 0.016 km (net width)* 3.74 knots *1.852 (conversion factor to kph)*10 (ten sampling sites) = 1.11 km^2;

p was the capture rate, here was 0.8.

Using this formula, the tagged olive flounder resource was estimated to be 1440 individuals in June 2009 and the survival rate was 12.6 %. When the fish were transferred from the workshop to natural waters, they required a long time to adapt to the new environment and learn to avoid harm from fishing gears and predators which may have accounted for the survival rate which was relatively high after 8 months from the release.

Biological characteristics of tagged olive flounder

Growth rate. The released olive flounders grew slowly within the first month whilst they took time to adjust to the bottom sediments and water currents at the release site. In addition, the flounder were mainly fed on artificial diets during the course of breeding and temporary culture, but on release, juveniles were required to initially forage on a natural diet. This probably caused the slow growth of the fish in the first month. After this time, olive flounder juveniles grew fast, the standard length increased about 1mm per day. The standard length and body weight didn't increase obviously from January to February 2009, i.e. from 110d to 145d juveniles released. Previous studies reported that during the overwintering time of the olive flounder, they did not feed when the temperature was below beyond 5°C. The temperature that olive flounder grow slowly or stop growing in their natural environment needs further research by releasing tagged juveniles.

Discussion

The results of the study of released and tagged olive flounder juveniles indicated their potential as a species for stock enhancement. The high mortality caused by the great changes of environment, may be reduced by the selection of local varieties, tagging technology and temporary culture. It is feasible to improve this process through the development of tags, tagging technology, even the selection of the suitable sea areas and timing of releases.

Choice of sea area

Olive flounder inhabit sea areas with mud-sandy or sand-muddy bottom sediments, high water quality and abundant diet. Sea water quality in Taozi Bay was consistent with marine water quality II, and the sandy bottom sediments and abundant diet were favorable for olive flounder growth. In addition, Taozi Bay retained a high density of aquaculture (scallop and kelp). The float rafting of aquaculture products supplied a favorable habitat for the released olive flounder and at the same time, prevented the use of many kinds of fishing gears, which might have reduced the survival of juveniles involved in the stock enhancement study. Similar conditions also proved successful in the olive flounder release study in Hebei Province (Zhao, 2008). Aquaculture in Shandong Province is well developed; scallop, kelp and other species are cultured almost throughout the coastal area. This provides good habitat for released olive flounder juveniles, as commercial fishing is limited and growth rates suggest that sufficient food resources are present, therefore the release of juvenile flounder could be reasonably developed in Shandong Province.

Growth rate

By recaptured surveys of tagged olive flounder and the analysis of their biological characteristics, we concluded that olive flounder grew slowly within the first month after being released, growth speed increased with time, the daily rate of standard growth was close to 1mm. Nine months later, the largest standard length and the highest body weight reached to 352mm and 405g, respectively. Tank based culture trials also resulted in similar growth rates, achieving 350mm total length fish in the same culture time of 250 days and starting with juvenile flounders of 7.5mm mean total length (Chang *et al*., 1995). The difference between the total (that includes tail) and standard lengths means that the smaller fish were initially stocked and later harvested. These results suggest that the olive flounder released into Taozi Bay quickly adapted to their natural environment and achieved good growth rates, indicating that it was an excellent species to release and the number of juveniles released could be enlarged.

The effectiveness of stock enhancement is limited by many factors, the survival rate of released olive flounder was key for the successful enhancement of the olive flounder stock. The mortality of released olive flounder could be more than 90% ten days after release (Furuta et al., 1998), and studies showed that the high mortality of olive flounder in a short term was attributed to the low abundance of diet (Furuta *et al*., 1998; Tanaka *et al*., 2006). Tanaka *et al* (2006) found that the young olive flounder (total length 43-45mm) mainly fed on small-size fish and Mysidacea species. Feeding intensity and survival rate was greatly affected by the density of small-size fish and Mysidacea species in sea waters. Meanwhile, the higher abundance of Mysidacea species in releasing areas, the higher ratio RNA/DNA of releasing flounder and the better nutritional condition, the lower the predation rate by wild olive flounder, However when the water temperature was beyond 22°C, the density of Mysidacea species greatly decreased (Gwak *et al*., 2003).

In addition, the mortality rate of released olive flounder due to predation was high, Sodu *et al*. (2008) reported the mortality rate of released flounder reached to 68% and 83% one week after release in 2001 and 2002, respectively. *Charybdis japonica*, *Inimicus japonicas*, wild olive flounder, *Cociella crocodile*, and *Platycephalus indicus* were the main predators of released olive flounder. Of this mortality, 34% and 41% in 2001 and 2002 was attributed to the swimming crab C. japonica (Sudo *et al*., 2008). In laboratory-based choice experiments between hatchery raised and wild individuals, wild olive flounder were rarely eaten. This suggested that wild flounder are better able to adapt to the natural environment from their morphology and behaviour, and could successfully avoid predators. Some behavioural changes were found between wild flounder and released flounder, such as feeding behaviour (Sudo *et al*., 2008).

Rigorous selection of released species

The release of certain species cannot help the recovery or improve marine resources but may lead to even further declines (Zhao, 2008). Therefore it is crucial to have a careful selection of species for stock enhancement through the release of hatchery-raised juveniles. Species that have qualities such as: short distance of migration, appropriate ecological habits to enable them to adapt to the aquatic environment at their release site, consumption of prey items that are low on the food chain, fast-growing, and have good disease resistance, should be considered. Selection of these species will assist in a high survival ratio, and improve the economic and social benefits.

The size of released juveniles is crucial in releasing technology, directly influencing the survival rate of released juveniles and cost. Survival rates of large-sized juveniles were relatively high as were costs. Avoidance of the "critical period" in the early life history of the olive flounder, in their release (especially of smaller sized individuals) would be helpful in increasing survival rates. The "critical period" of different species varies and requires investigation. In addition, the survival rates of releases were greatly influenced by the bottom sediments, the hydro-chemical environment and the biological environment (Zhao, 2008). The recapture and survival rates are important indices to evaluate the ecological and economic benefits of releasing juveniles. The optimal release time and location of release sites of different species also needs to be investigated. The quantity of released species should be determined according to the results of the ecological capacity and community structure at the release site. In the meantime, in order to increase the survival and recapture rate of released species, it is necessary to evaluate the growth rate and the fishery resources dynamics of released species.

Assessing the Effectiveness of Improved Fisheries Management Techniques

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Executive Summary

The ultimate goal of Korea's fisheries structural adjustment policy (i.e. buyback programs) is ecosystem-based, environmentally-sustainable fisheries management. Use of the Korean marine ecosystem by reducing stress from fisheries development and promoting more sustainable forms of exploitation from this densely populated, heavily urbanised and industrialised shelf sea, will complement existing conservation activities.

From 1994 to 2007 the buyback programs were implemented in two ways: one was a general buyback program and the other was an international one. In the first year (1994) of the program, 54 vessels were decommissioned but by 1999 this figure had increased to 730 boats. They were removed from the fishery by the general and the international buyback program.

However, the law regarding the international buyback program was initiated to deal with the fisheries problems between Korea-Japan (1999) and the Korea-China (2001) fisheries agreement, so the international buyback program was in operation for a limited period from 1999 to 2002. The total number of fishing vessels reduced in 1994-2007 was 14,364 (in-shore 11,458 and off-shore 2,806) and the public fund of 1,067 billion Korean won was used for decommissioning the boats.

The Yellow Sea is the name given to the northern part of the East China Sea, which is a marginal sea of the Pacific Ocean. It is located between mainland China and the Korean peninsula. In South Korea it is only known by its historic name: the West Sea.

Most of the fish species that live around the Korean peninsula are occurring in the Yellow Sea, East China Sea and the East Sea area. Following feed, temperature and currents, they migrate widely in the East Asian seas. Off-shore fishing vessels operate in the entire Korean seas.

However, vessels from other regions land and sell at their catch at ports surrounding the Yellow Sea so catch statistics in the Yellow Sea are not 100% accurate. Analysis was conducted for hair tail, sea bass, mackerel, brown croaker, anchovies, pomfrets, monkfish, yellow croaker, blue crab, and common squid occurring largely in the Yellow Sea regardless of regional landings. Vessels targeting these species in the Yellow Sea include large pair trawls, large otter trawls, large Danish seines, west southern pair trawls, off-shore stow nets, large purse seines, west southern Danish seines and offshore angling.

Regarding the stock status by species, the assessment results suggest that (i) red fish (*Doederleinia berycoides*), monkfish (*Lophius* sp.), anchovy (*Engraulis japonicus*), sea bass

(*Collichthys* sp.), yellow tail (*Seriola quinqueradiata*), pen shell (*Atrina*(*Servatrina pectinata*), and Spanish mackerel (*Scomberomorus niphonius*) are not in overexploitation/overcapacity, (ii) hair tail (*Trichiurus lepturus*) and skate ray are in overexploitation but in non-overcapacity, and (iii) yellow croaker (*Larimichthys polyactis*) and flounders are in non-overexploitation but in overcapacity. However, considering stock fluctuations and assessment uncertainties, the average optimal fishing effort over the last three years (2005-2007) on E_{MSY} and $\frac{2}{3}E_{MSY}$ criteria was evaluated at 73.4 – 90.2. This result suggests that the current level of total fishing capacity in the Yellow Sea should be reduced by 9.8 – 26.6%.

A survey of buyback program effectiveness on stock restoration showed that 70% of the respondents thought that the programs had a significant effect on resource recovery. This indicates that fishermen recognise the buyback programs as a useful policy instrument in restoring fish resources.

Where the government implements the buyback programs in parallel with TAC (total allowable catch) schemes, 70% of the respondents replied that implementing the two policies at the same time would be more effective in resource restoration than the buyback programs alone.

The results showed that (i) the average annual catch from the Yellow Sea ecosystem in 1975-2004 was 130 thousand mt (CV 16.8) which was 4.5-6.5 times less than that of the Southern Sea, (ii) the fishing effort increased gradually over time from the 1990s, (iii) the ratio of adults to small fish has increased since1997 mainly due to an increase in the ratio of adults to small anchovy and (iv) reproduction indices were still at a low level because of overcapacity in the fleets.

Other sources by which the ecosystem change could have been described is the observation data on the size of major fish species. The sizes of hair tail and yellow croaker after 1995 tended to be shorter more or less than those in 1995, but since 1995 their sizes appear to be pretty much stable at 19.7cm and 16.1cm, respectively. Other fish species have tended to increase in size.

Following the national low carbon/green growth initiative, the central and provincial governments should be able to develop integrated green policy packages, including buyback, resource enhancement, subsidy re-orientation, generation of non-fishing income and self (or co-management) programs. The measures should be supported by a new R&D programme focused on enhancing and maintaining the Yellow Sea's environment and ecosystem. This will require far closer co-operative work among South/North Koreas, China, and related international bodies.

Results

The following section presents a sample of the data and results.

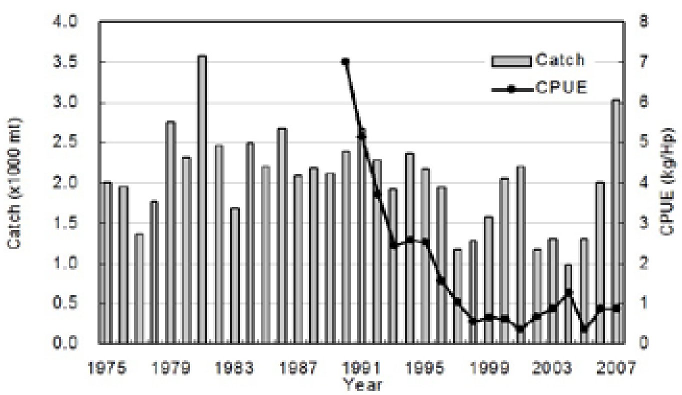


Figure 1 Catch and CPUE trends: brown croaker

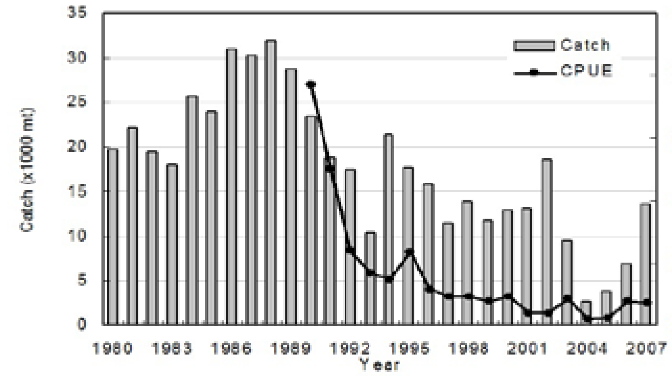


Figure 2 Catch and CPUE trends: blue crab

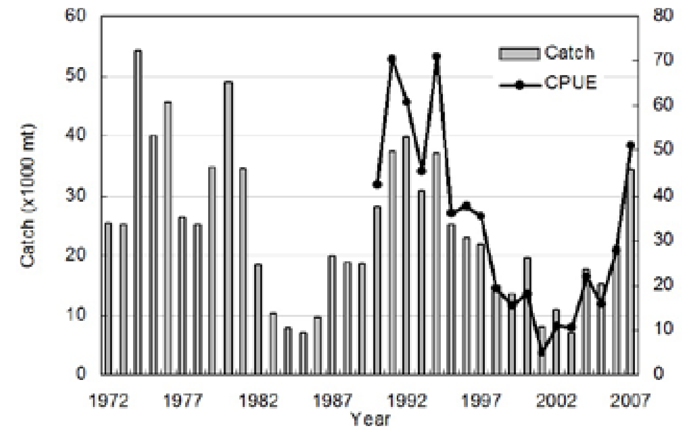


Figure 3 Catch and CPUE trends: yellow croaker

Resource Status

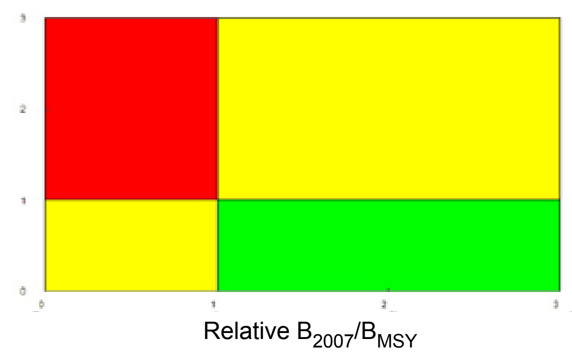
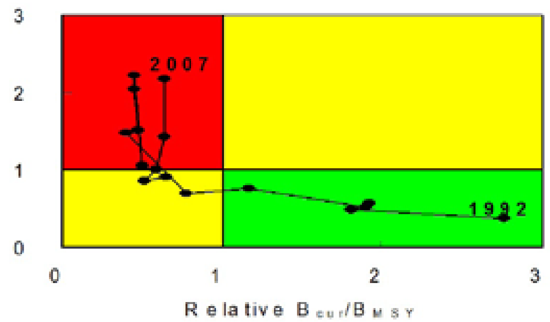


Figure 4 Traffic light display methods have been used to visualize the status of the stock (Caddy 1999, Caddy 2002, ICCAT 2008). This display method classifies the resource status into three stages and colors: green is safe, yellow is middle, and red is risky. Red means that the stock is overexploited, green signifies not-overexploited and from the fishing effort perspective, red is "overcapacity" and green is "non-overcapacity." For both relative stock and the relative fishing effort, upper yellow is non-overexploited/non-overcapacity" and lower yellow is overexploited/non-overcapacity

Figure 5 Stock status of the brown croaker in the Yellow Sea



The Yellow Sea's contribution to the total Korean brown croaker catch in the entire Korea waters(*cr*) accounted for 28.4% in 2007 and its relative weight of the total Yellow Sea's catch of all species (*w*) was 0.29%. The brown croaker's status, based on the resource management criterion (B_{2007}/B_{MSY}) was estimated to be 0.64 which indicated overexploitation. In terms of fishing effort or capacity, the ratio of E_{2007}/E_{MSY} was 1.27 which suggested overcapacity (Figure 5).

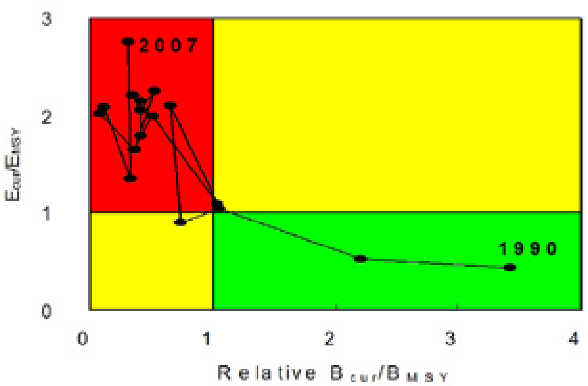
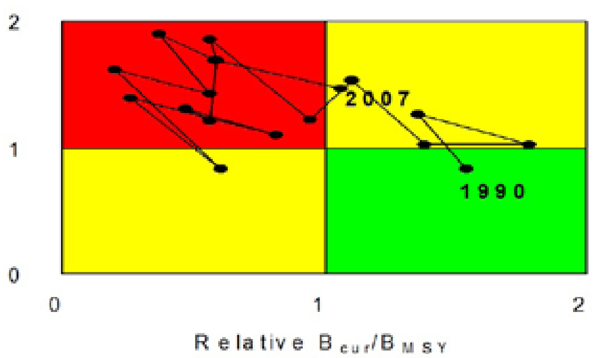


Figure 6 Stock status of the blue crab in the Yellow Sea

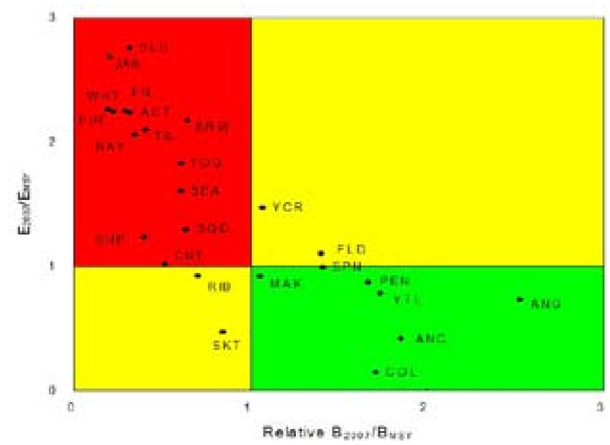
The blue crab catch has shown an increasing trend. The Yellow Sea's contribution to the total Korean blue crab catch in the entire Korea waters (*cr*) accounted for 91.4% in 2007 and its relative weight of the total Yellow Sea's catch of all species (*w*) was 4.24%. The blue crab's stock status, based on the resource management criterion (B_{2007}/B_{MSY}) was estimated to be 0.32 which suggested overexploitation. In terms of fishing effort or capacity, the ratio of E_{2007}/E_{MSY} was 2.75 which indicated overcapacity.

Figure 7 Stock status of the yellow croaker in the Yellow Sea



The Yellow Sea's contribution to the total Korean yellow croaker catch in the entire Korea waters (*cr*) in 2007 accounted for 27.0% and its relative weight of the total Yellow Sea's catch of all species (*w*) was 3.2%. The yellow croaker's stock status, based on the resource management criterion (B_{2007}/B_{MSY}) was estimated to be 1.07 which implied non-overexploitation. In terms of fishing effort or capacity, the ratio of E_{2007}/E_{MSY} was estimated to be 1.47 which indicated a state of overcapacity.

Figure 8 Species distribution relationship between B_{2007}/B_{MSY} and E_{2007}/E_{MSY} in 2007.



Hair tail , HT; Rays, RAY; Flounders, FLD; Cuttlefish, CTL; Sea bass (*Collichthys* sp), COL; Sharp toothed eel (*Muraenesox cinereus*), SHP; Chub mackerel, MAK; Blue crab, BLU; File fish, FIL; Anchovy, ANC; Brown croaker, BRW; Yellow tail, YTL; Pomfrets, POM; White croaker (*Argyrosomus argentatus*), WHT; Puffers, PUF; Sea eel, SEA; Spanish mackerel, SPN; Tongue fish (*Cynoglossus* sp.), TOG; Monkfish (Anglerfish) ANG; Common squid, SQD; Tile(file) fish (*Thamnaconus modestus*), TIL; Jack mackerel, JAK; Acetes shrimp, ACT; Yellow croaker, YCR; Pen shell, PEN; Skate ray, SKT.

Regarding the stock status by species, the assessment results suggest that (i) red fish, monkfish, anchovy, sea bass, yellow tail, and Spanish mackerel were not in over-exploitation/ over-capacity, (ii) hair tail were not in over-exploitation but in non-overcapacity, and (iii) yellow croaker was not in over-exploitation but in over-capacity①. However, considering stock fluctuations and assessment uncertainties, the average optimal fishing effort over the last three years (2005-2007) on $\frac{2}{3}E_{MSY}$ and E_{MSY} criteria was evaluated at 73.4 – 90.2. This result suggests that the current level of total fishing capacity in the Yellow Sea should be reduced by 9.8 – 26.6%.

However, accurate quantitative evaluations of the buyback program effects on the stocks was extremely difficult. The main reason for this was that there were many contributing elements to fishery resource status, such as over-capacity, climate change and pollution. In addition, there was no regulation on vessel engine power, even though the government has tried to substantially reduce the number of fishing boats. Separating the Yellow Sea exploitation from the entire fishing mortality in Korean waters was extremely difficult, because most off-shore fisheries operate their vessels in all off-shore seas.

Field Survey Results

Recently, a study on the effectiveness of the buyback programs in R. Korea (Lee et al. 2003) was conducted. The research results showed that, in spite of vessel reductions, the overall fishing capacity still exceeded the optimal level. The prime sources of resource decline included factors such as overexploitation, tideland reclamation, ocean pollution and climate change. 50% of the respondents considered overexploitation as the most important reason for resource stock decline, 30% climate change, and 10% tideland reclamation and ocean pollution, respectively. This implied that overcapacity was considered to be the most important source of stock decline and that a reduction of fishing effort was necessary.

①The case of non-overexploitation/overcapacity represents a dynamic adjustment process of stock status and fishing capacity. This indicates that stock is under recovery but still requires further reduction in fishing effort to realize the target level of fishing capacity.

A survey of the effectiveness of the program on resource restoration showed that 70% of the respondents thought that the programs had a significant effect on resource recovery. This suggests that fishermen recognized that buyback programs are useful policy instrument in managing fish resources.

Where the government implements the buyback programs in parallel with TAC (total allowable catch) schemes, 70% of the respondents thought that implementing the two policies at the same time would be more effective on resource restoration than the buyback programs alone.

In addition, more than fifty-three percent of those surveyed considered that there was a need for a regulation on vessel engine power. There is a serious trade off between reductions in fishing capacity and increases in engine power when the number of vessels only are controlled (Kim et. al. 2006). Ceilings on engine power were established for 4 fisheries - the eastern Danish seine, west-southern Danish seine and anchovy drag vessels.

A further survey of self managed fisheries was conducted to analyse (i) if the SMF was perceived to be successful and if so what were the contributing factors and (ii) changes in resource status and income within the SMF. In addition, we examined the effect of SMFs on fisheries sustainability. Ninety-five percent of the respondents considered their communities were successful as SMFs. The remaining of five percent felt that their SMFs achieved some success. Fifty-nine percent considered solidarity and co-operation as the most important factor in a successful SMF. Leadership (10.3%) and members' effort (10.3%) were next most important factors.

The total number of fishing vessels reduced in 1994-2007 was 8,324 (in-shore 6,357 and off-shore 1,967) and the public fund of 1,067 billion Korean won was used for decommissioning the boats. The results of a study by Lee et al., 2003, showed that the buyback programs did not make a positive net contribution to resource recovery, but it helped reduce the rate of decline. He predicted that the stock status and fisheries management would be improved significantly in the long run, if the buyback programs were implemented with resource enhancements, input controls and TACs.

Other management measures

In 1999 the Chinese government placed a moratorium on the Southern Sea. At the same time it extended the moratorium period over the Yellow Sea so that fishing time was significantly reduced. Also, in 1999 it established a zero-growth goal for the quantity harvested. This policy was a practical step to resource conservation and the sustainable development of fisheries. In addition, China strengthened the regulations for limiting new boat construction. The government increased the number of ocean-administrative officials and strengthened the rules of implementing vessel reduction policies in a unified manner. The policy package helped Chinese capture fisheries production and resources which stabilized and increased by 9.5 thousand mt between 1998 and 1999 (Cho *et al*. 2003).

Even though the large number of fishing vessels has been reduced over the last 15 years, the effective fishing capacity (i.e. engine power) has tended to increase during the period. Thus, there has been a serious trade-off between the number of decommissioned vessels and the expanded engine power②. Such trade-off was brought up mainly due to a lack of effective institutional arrangements. Now, the ministry of food, agriculture, fisheries and forestry (MFAFF) from here is searching for ways to effectively control vessel engine power.

② During the buyback period there is no additional new-boat construction. Since however higher engine power was allowed where two existing boasts were put together into one, engine power has much increased without construction of extra new boats. Most of the decommissioned boasts were scraped or used for artificial reef establishment. A small number of the boats were given to a few Asian developing coastal states.

Conclusions

In addition, it is known that fisheries resource management problems are compounded by land-based pollution and climate change. The Korean government has begun to actively manage land-based pollution through the intergovernmental co-operative mechanism. In order to respond to climate change, the government declared a low carbon/green growth strategy as a new national policy for the next six decades. In particular, dealing with land-based pollution problems in the Yellow Sea is much more important than other seas in the Korean peninsular since most of large industrial complexes and metropolitan cities are located on the east coast of China and in the west coast of Korea.

Following such national initiatives, the central and provincial governments should be able to develop integrated green policy packages including buyback, resource enhancement, off-fisheries income promotion, fuel subsidy reorientation and self (or co)-management programs. Effective fisheries management will require far closer co-operative work among South/North Korea, China, and related international bodies.

Figure 9 Fishing operations in the Yellow Sea

Calculation of Nutrient Loads in The Yalu River Estuary

Prepared by

The National Marine Environmental Monitoring Center
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December 2009

Introduction

The Yalu River is one of the most important rivers in the Yellow Sea Region and its estuary is one of the 'high-eutrophication-level areas' defined by the "UNDP/GEF Yellow Sea Large Marine Ecosystem Project (YSLME). Due to the upgrade of the wastewater treatment capacities in the region, the water quality of the Yalu River has improved significantly compared to 1990s. However, there is still no systematic study of the total loads of pollutants to the Yalu River Estuary from land-based point sources, non-point sources, sea-based discharges and atmospheric deposition.

This project "Demonstration activity to Calculation Nutrient Loads in the Yalu River Estuary," details the activities relating to the monitoring and assessment of nutrient loads from various sources, which is the basis for management actions to control the total loading of nutrients in this region. The methodologies established here will be applicable to other hot spots in the Yellow Sea Region.

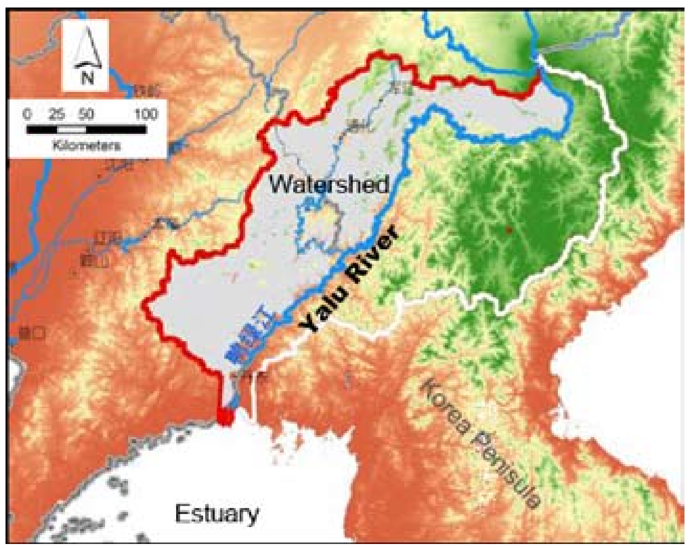

Figure 1 Map of the Yalu River watershed

The project was implemented from August 2008 to December 2009. Historical data collection and a full year of field surveys were accomplished on schedule. Long term co-operative relations with the Dandong environmental monitoring departments were established and two rounds of expert consultation and discussion meetings were held in Dandong in October 2008 and May 2009, during which management and technical problems were discussed.

In brief, the annual total loads of nitrogen (N) and phosphorous (P) in the study area were 37,669.7t and 3,370t, among which the Yalu River was the major source with annual loads of 37,340t and 649t. For directly discharged wastewater effluents to the sea, N and P annual loads were 8.05t and 0.61t, while mariculture contributions were 321.9t and 130.1t respectively. However, large amounts of pollutants from land-based wastewaters are first discharged the into Yalu River and then into the sea. About 13.3~52.0 of total P and 16.5%~57.7% of ammonia in the Yalu River are from land-based wastewaters. Non-point sources in the Yalu River watershed are also important, contributing to about 30% of TN and TP of the annual loads of the Yalu River watershed.

Background information

Physical. The Yalu River is 795 km long, covers a watershed area of about 63,700 square kilometers, including Changbai, Linjiang, Kuandian and Dandong cities within China's border and a large area of the Korean Peninsula. The largest tributaries of the Yalu River are the Ai River and the Pushi River in China and the Changjin, Herchun and Tokro rivers in North Korea. The average annual flow rate of the Yalu River is 926m^3/s. The flood season is usually from June to August, discharging about 60% of the annual flux, and the ice period is usually from December to April, according to historical data. Based on statistics from 1971 to 2000, the average annual temperature and humidity in Dandong were 8.9°C and 69%, respectively. The annual precipitation was about 925.6 mm, with maximum precipitation usually from May to September with average precipitation of 754.6 mm.

The Socio Economic Environment. The downstream i.e. Dandong part, of Yalu River is one of the most developed areas of the industrial and agricultural the watershed, which collects most of the point sources to the Yalu River Estuary. Up to 2004, the land area of Dandong Municipality was about 15,000 square hectares, with a population of 2.42 million. The pillar industries in Dandong are automobile, cotton spinning, paper making and aquaculture; food supplies are corn, rice and soya; main economic crops are oil plants, tobaccos, medicinal plants, strawberry, and chestnut. Other cities such as Changbai, Linjiang and Kuandian are dominated by agriculture which contributes to the total loads of nutrients mainly from non-point sources.

Environmental quality status. Historical reports show that the pollution sources mainly came from the downstream area of the Yalu River watershed. In 2005, 68.9% of industry and domestic wastewater from the downstream area were discharged to the river; 312 enterprises directly discharged wastewater into the Yalu River or the Estuary, among which 69 enterprises were discharging wastewater of over 100 tons per day. For example, in 2005, 0.227 billion m^3 wastewater and 0.253 million tons pollutants were discharged directly to the Yalu River from 23 direct discharge outlets in Dandong city, and the main pollutants were Chemical Oxygen Demands (COD) 112,000t, suspended substance (SS) 106,000t, ammonia nitrogen 33.1t and volatile phenol 82.2t (Liu Fuxiang, et al.; Guan Awei, et al.).

Furthermore, the increased demands of chemical fertiliser and pesticide and the development of large-scale livestock and poultry farms in recent years, have caused serious non-point pollution throughout the Yalu River watershed. According to statistics, the pesticide and fertiliser used in the whole watershed was about 1325 and 174,500 tons in 2005, almost a 30% increase has been observed compared to 2000. Soil erosion by run-off also plays an important role in non-point pollution discharges, the area of soil erosion in Dandong is up to 3908.6 square kilometers, which is about 27% of the total area of Dandong municipality. This is based on satellite remote sensing general survey data from the Water and Soil Conservation Bureau (Liu Fuxiang, et al.).

The marine environment quality status in the Yalu River Estuary is a serious problem from the past, especially eutrophication. Some of the latest research showed that from 2001 to 2005, concentrations of oil and phosphate in the coastal waters were declining, but the concentrations of inorganic nitrogen and COD were increasing (Wang Jigang, et al.).

As a result of serious pollution by nutrients, harmful algal blooms (HABs) occurred frequently over the past decade in the Yalu River Estuary. Figure 2 shows that HAB events were mainly seen after 1996. The largest HAB reported there was nearly 1,100 square kilometers, which occurred from 24th August to 14th September 2001 (Bulletin of Marine Environmental Quality of China, 2002).

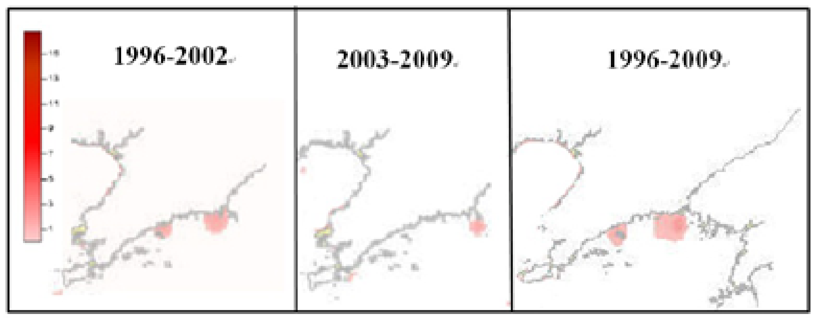

Figure 2 Number and area of HAB events in Yalu River Estuary (1996-2009)

Objective and Research Contents

Objectives. The Yalu River Estuary was selected as the demonstration area for the calculation of nutrient loads in the Yellow Sea region, with field surveys conducted from July 2008 to the July 2009. It was expected that the demonstration activity could meet the following objectives/ outputs:

1) To establish effective calculation models for the total loading control of nutrients applicable for coastal areas of the Yellow Sea.
2) To identify the main nutrient sources, especially land-based sources.
3) To assess impacts of eutrophication on the marine ecosystem of the Yalu River Estuary.
4) To establish a forum to begin discussing and improving understanding of environmental capacity.
5) To make preliminary steps towards incorporating a total loading control into national development plans with the aim of reducing by 10%, the total N loading in 2010, using 2006 as the baseline.
6) To propose advice on appropriate nutrient control schemes for the local government agencies, and to evaluate the applicability, effectiveness, efficiency, and appropriateness of the proposed management actions.

Research contents. The main research contents of this demonstration activity in the Yalu River Estuary are as follows:
1) Collection of historical data and statistical information for the Yalu River Estuary from the database of NMEMC and other related statistical information sources.
2) Monitoring of discharging sources of nutrients into the Yalu River Estuary.
3) Establishment of a calculation model for the total loading of nutrients from various land based and sea-based sources, especially nutrients discharged from land-based point sources.
4) Seasonal field surveys and validation of the calculation model by data obtained from the seasonal surveys in the Yalu River Estuary and adjacent areas, and data obtained from additional monitoring actions of the local government agencies.
5) Identification of the major nutrient sources for the Yalu River Estuary.
6) To propose management actions for local government agencies for the total loading control of nutrients.

Field surveys

Site selection. Four seasonal field surveys were conducted from October 2008 to July 2009. 17 sampling stations were established in the Yalu River and estuary, in which:
- ●8 sampling sites were in the downstream of Yalu River from Dandong City to the estuary, with the sample salinity from 0 to 20;
- ●One 24h-continuous monitoring station was established at A4 station, where water samples were collected every two hours;
- ●9 monitoring stations were established in the Yalu River Estuary with the sample salinity from 20 to 28;
- ●14 Direct Discharge Outlets (DDOs) along the river and coastline in the study area were monitored to obtain nutrient loads from municipal wastewaters

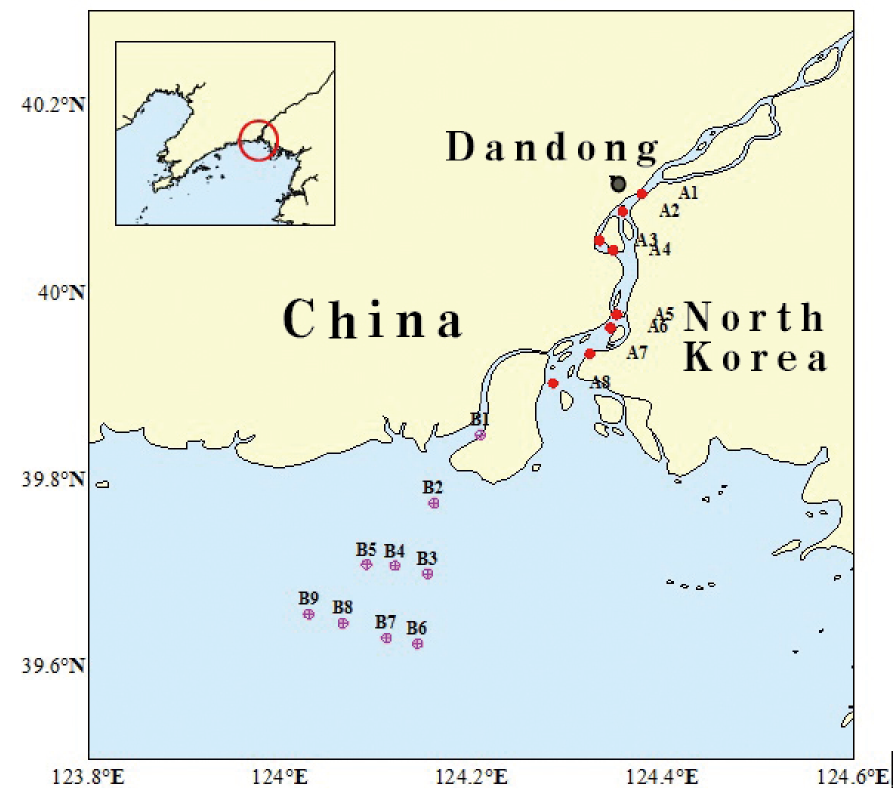

Figure 3 Sampling sites in the Yalu River and Estuary

Environmental variables. The environmental variables determined for the Yalu River and DDOs used for the calculation of total loads of nutrients were:

- Water or wastewater flux,
- Water temperature, pH, salinity, and
- Concentration of nitrates, nitrites, ammonia, phosphates, and silicate.

The variables determined for eutrophication and water quality assessments in the Yalu River Estuary were:

- Water temperature, pH, salinity,
- Concentration of Chl-a, nitrates, nitrites, ammonia, phosphates, dissolved oxygen, and
- Plankton.

Methods

Estimation of nutrient loads from land-based non-point sources.

In some cases, nutrient loads from land-based non-point sources contribute more than half of the total amounts of nutrients received by coastal waters, such as in Chesapeake Bay. Therefore, it is very important to quantify estimates for nutrient loads from land-based non-point sources, before effective management actions can be carried out to control the total loading. Land-based non-point sources mainly included part of domestic sewage, farmland surface runoff, soil erosion, and livestock farming sewage.

To estimate nutrient loads from non-point sources, the Yalu River watershed was divided into 36 catchment cells, according the topographic map of the watershed. For each of the catchment cell, non-point discharges of nutrients were calculated. These included;

(1) Domestic sewage production estimation
(2) Livestock- farming sewage production estimation
(3) Chemical fertiliser pollutant production estimation
(4) Soil erosion pollutant production estimation
(5) Land-based non-point sources pollutant production estimation

Estimation of nutrient loads from mariculture.

Mariculture is one of the main industries in the Yalu River Estuary. According to the data collected from the local government agencies in Dandong, the major mariculture species are fish (mainly *Sebastes schlegelii*), prawn (including *Feneropenaeus chinensis Osbeck* and *Feneropenaeus japonicus*), crab, shellfish and algae. The fish and shellfish are cultured in the open sea or tidal flat area so no feed or fertiliser is used in this process, therefore there should be no additional pollutants discharged into in the estuary. In this project, the calculation of the pollutant loads from mariculture only focused on the pond prawn pollutant loads as the main sea-based non-point sources.

Eutrophication level assessment method. In this study, the assessment of the eutrophication level in the Yalu River Estuary was calculated by the Eutrophication Index (EI) method, as shown in equation (1).

$$EI=(COD \times DIN \times DIP) \times 10^6/4500 \qquad (1)$$

COD − the chemical oxygen demand, mg/L;
DIN − the dissolved inorganic N, mg/L;
DIP − the dissolved inorganic P, mg/L;
EI > 1 indicates that the study area is experiencing eutrophication.

Results and discussion

Water quality of the Yalu River. The concentration of NH_3-N in the Yalu River showed a decline from 2003-2009. The annual average was 0.12-0.41 mg/L, with a maximum value in 2003 and minimum in 2009. There was no obvious trend for TN and TP, partially due to the very low concentration and insufficient data series.

Pollutant loads from Yalu River

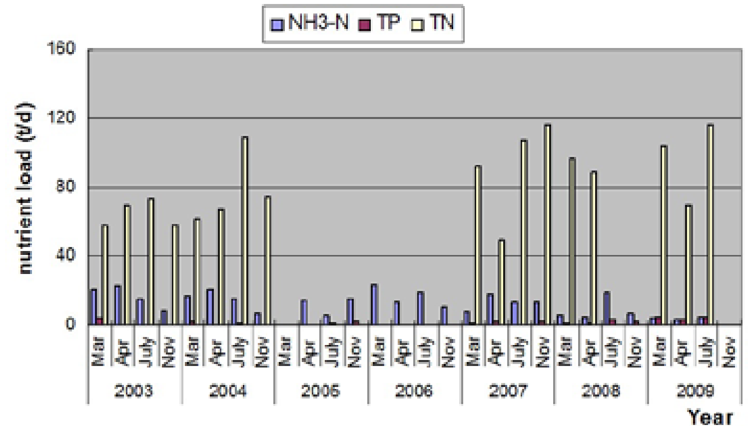

Figure 4 Daily loads of NH_3-N, TP, TN from the Yalu River

Results for nutrient loads from the Yalu River in this work are much higher than previous studies, because annual loads of TN and TP were focused here while annual loads of DIN and active phosphate were in the previous work. For example, the Bulletin of Marine Environmental Quality of China in 2008 showed that annual loads of inorganic nitrogen from the Yalu River into the Yellow Sea were about 4,415 tons, which was similar to annual loads of NH3-N in this work.

Nutrient loads from DDOs. In the present study, all the DDOs monitored were categorised as two types in the study area: type I - wastewater discharged directly to Yalu River, and type II - wastewater discharged directly to the sea. Loads of DDOs were calculated. The loads of NH_3-N and TP from 14 type I DDOs to the Yalu River were 999.4~2692.4 t/yr and 52.3~318.6 t/yr respectively from 2003 to 2008 and both of the loads of NH_3-N and TP showed an obvious increasing trend according to calculation results

Nutrient loads from non-point sources. In this present work, annual loads of nutrients in 2008 from non-point sources were calculated by nutrient generation and discharging coefficients and experimental models with GIS tools.

Nutrient loads calculation. (1) The rural domestic sewage and livestock farming coefficient was identified by the empirical discharge coefficient used in literature (Hong Huasheng *et al*),

(2) The discharge coefficient of chemical fertiliser. The use of chemical fertiliser in agriculture was one of the major sources of TN and TP to the river. In this study, the loss rate coefficient of 5% was used to calculate the load of the TN and TP from nitrogenous fertiliser and phosphorus fertiliser.

(3) The discharge coefficients of soil erosion. For soil erosion, most of the coefficients were cited from previous research in the Liaohe River watershed, which is adjacent and similar to the Yalu River watershed (Huang Jinliang, et al.); other localised coefficients were obtained from the

Digital Elevation Model (DEM) and LANDSAT (TM) remote sensing images, according to soil compositions, land-use types, precipitations, terrain and landform.

TN and TP loadings. The annual load of TN and TP from non-point sources in the Yalu River watershed was 13,431 tons and 1,121 tons, respectively. Soil erosion was the main non-point source in the Yalu River watershed, which contributed to 56.2% TN and 72.0% TP of the total loads, in which Kuandian and Baishan municipalities mostly contributed.

For other non-point sources, TN from rural sewage, livestock and use of chemical fertiliser use was 1,588, 3,185 and 1,109 tons respectively, and accounted for 11.83%, 23.71% and 8.26% of the total loads from non-point sources; TP from rural sewage, livestock and use of chemical fertiliser use were 115, 101 and 97 tons respectively, accounting for 10.27%, 9.00% and 8.68% of the total loads from non-point sources. Livestock farming and use of chemical fertiliser in Baishan and Benxi municipalities were the major sources, which is consistent with the highly developed agricultural sector in the two municipalities.

Nutrient loads from mariculture. The mariculture load from the pond prawn cultivation was calculated. The feed used amount *i*, prawn production *G*, the N, P content in the feed *Cl* and the N, P content in the prawn *Gf* was 23,067 t/a, 34,477 t/a, 5.76% and 1.0%, 2.91% and 0.29% respectively. Then, loads of TN and TP were calculated to be 321.9t and 130.1t respectively.

Annual loads of nutrients to the Yalu River Estuary. As the Yalu River Estuary is a relatively small area, atmospheric deposition of nutrients over the coastal waters could be ignored compared to atmospheric deposition over the Yalu River watershed, which can be carried to the Estuary as non-point sources. Therefore, the total loads of nutrients in the Yalu River Estuary mainly consisted of three fractions: nutrient loads from the Yalu River, directly from DDOs, and from mariculture. The annual total loads of N and P in the Yalu River Estuary was 37,669.7t and 3370t respectively in recent years.

The results also showed that the Yalu River is the major source of nutrients discharged into the Yalu River Estuary, contributing to total N and P loads with proportions of 99.1% and 96.1% respectively (Table 1).

Table 1 Annual loads of N and P in the Yalu River Estuary

pollutants		Annual loads (t/a)		Subtotal(t/a)		Proportion (%)	
		Yalu River	mariculture	effluent		Yalu River	Mariculture effluent
TN	37,340	321.9	8.05	37,670	99.1	0.85	0.021
TP	3,240	130.1	0.61	3,370	96.1	3.86	0.018

Contribution of DDOs to the nutrient loads of Yalu River. According to the loads from type I DDOs, they contributed about 13.3%-52.0% of TP and 16.5%-57.7% of NH_3-N to the total loads of the Yalu River.

Contribution of non-point sources to nutrient loads of the Yalu River. Monitoring and assessment results showed that the non-point sources were the first-order pollution sources for the Yalu River Estuary, which contributed to 35.6% TN and 33.2% TP of the total loads. If the whole watershed is considered, the contribution of non-point sources is much higher.

Eutrophication level in the Yalu River Estuary. The Eutrophication Index value was 0.48-1.33 in 2005-2009 with an increasing trend, indicating that the Yalu River Estuary is facing the risk of eutrophication. According to the report of Bulletin of Marine Environmental Quality of China, the latest harmful algal blooms (HABs) to develop in this area was from 24th August to 14th September 2001. Furthermore, analysis of the species composition and distribution of plankton in the Yalu River Estuary showed that, the dominant species in the study area was the typical species in the north of China. There were no red tide organisms to be found in field surveys. Therefore, it may be safe to conclude that the risk of HABs in the Yalu River Estuary is currently relatively low, but the eutrophication status should be frequently checked because the Eutrophication Index and the annual loads of nutrients from DDOs are increasing.

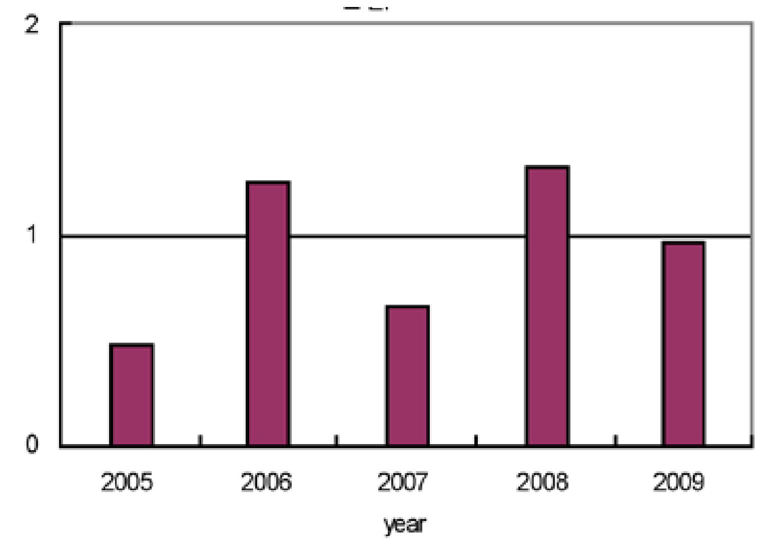

Figure 5 The eutrophication index (EI) in the Yalu River Estuary, 2005~2009

Conclusion

The nutrient loads of N and P were monitored and evaluated in this project. Nutrient loads from the Yalu River, DDOs, land-based non-point sources and mariculture were calculated. According to the monitoring and assessment results, the Yalu River was the major nutrient source of the Estuary, annually discharging 37,669.7t N and 3,370t P to the sea in 2008, with a proportion of 99.1% and 96.1% of the total loads of N and P. Annual nutrient loads from DDOs directly to the sea were 8.05t N and 0.61t P and the annual loads from mariculture were 321.9t N and 130.1t P.

As far as the Yalu River, (the major nutrient source,) was concerned, 14 DDOs along the river contributed 13.3%-52.0% of TP and 16.5%-57.7% of TN to the whole nutrient load of the river, from 2003 to 2008. Non-point sources in the watershed were even more important contributors to the Yalu River. About 30.2% of TN and 32.0% of TP of the total loads were from non-point sources in the watershed of China. However, this work was an original research for the load calculation of N and P in the northern Yellow Sea. The lack of the historical data, especially TN in the study area, was a big problem for the assessment of TN load trends. Nutrient loads from non-point sources were calculated mainly based on empirical parameters and models, which should be verified by on-site monitoring results.

In May 2009, the second expert meeting was held in Dandong City to discuss the establishment of a local forum and long-term co-operation between NMEMC with the local government agencies for protecting of the Yalu River Estuary. It was agreed that the Yalu River is the most important nutrient source for ecosystems in the Yalu River Estuary, or even in the northern Yellow Sea; on the other hand, excess nutrients should be reduced to hold back the increasing trend of total loadings to the sea.

Monitoring and Assessing Sea-based Sources of Nutrients

Prepared by

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December 2009

Background

China is the world's largest producer of aquaculture products and the Yellow Sea is one of the major mariculture areas of China. In 2004, mariculture production in the Yellow Sea coastal areas of China reached 6.03 million tons or 45.8% of total national mariculture output.

On the one hand, mariculture has produced plenty of food and especially additional protein for the Chinese people; on the other hand, the high level of mariculture activity has brought about many environmental issues. One of the largest impacts of mariculture on the ocean environment is pollution produced by the farming activities. Effluents, excess feeds, and excretions of organisms in hatchery culture, shrimp in pond culture, molluscs in raft culture, and fish in cage culture, are the major pollution sources. Excess phosphorous and nitrogen compounds from these sources have generated serious eutrophication and may even trigger red tides. As one of the most important aquatic producers, the Yellow Sea is likely to play an even bigger role in seafood production in the future.

Qingduizi Bay is located at the northern part of the Yellow Sea within the boundaries of Zhuanghe City, which is famous for mariculture in the northern Yellow Sea. In Qingduizi Bay, there is a large area dedicated to mariculture ponds. In order to achieve the target identified in the SAP "reduce total loading of nutrients from 2006 levels", Qingduizi Bay was used as a demonstration area to model nutrient loads and manage nutrient input from the mariculture area, and demonstrate the possible actions that resource managers could take to reduce any potential impacts.

The natural environment of Qingduizi Bay. Qingduizi Bay is located at the northern part of north Yellow Sea within the boundaries of Zhuanghe City, Nanjian peninsula is in the east of Qingduizi Bay, and Heidao peninsula is in the west. The total area of the bay is 156.8 km^2, the tidal flat area is 130 km^2, accounting for total area 83%, and the reef area is 1.8 km^2. The bay mouth is very wide, the average water depth in the bay mouth is 2.3m, and its capacity for water exchange is strong. The Yingna and Huli Rivers both flow into Qinduizi Bay, bringing much silt and sand and the shallow seas and tidelands expand and thicken toward the bay mouth continuously.

Figure 1 Location of Qingduizi Bay

Socio-economic aspects.

Zhuanghe City has a land area of about 4039 km^2. The total population is 900,900 among which 171,600 people are engaged in non-agricultural industries and 729,200 people are involved in agriculture. The population density in urban areas averages 223 persons/km^2. The implementation of the construction strategy “Zhuanghe on the Sea,” has promoted the co-ordinated development of marine industries, marine protection, marine technology and marine culture. Prawn culture and shallow sea culture has helped to develop new studies of oceanic chemistry, seawater use, harbour transport and tourism.

In 2006, the output value of the fishery sector was 3.06 billion RMB, up by 13% over the previous year, accounting for 38.3% of the total output value of agriculture in Zhuanghe. In addition, the output value of the fishing economy was 55.1 billion RMB, up by 19.5% over the previous year. The total coastline length of Zhuanghe City is 285 kilometers, including 267 thousand hectares of Yellow Sea areas, 27 thousand hectares of intertidal shoals, 7 thousand hectares of breeding ponds. In relation to mariculture it has 322 hectares of fish, 1782 hectares of prawn and crab, 44095 hectares of shellfish, 8599 hectares of sea cucumber, 1557 hectares of jellyfish and 521 hectares of other species. There are 139 thousand square meters for seawater breeding cages and 370 thousand cubic meters of water bodies for factory farming. There are 95 fish seedling raising rooms, 78 fishery processing factories, 9 fishery feed processing factories and 37 fishing harbours.

Table 1 Fishery production in Qingduizi Bay in 2006 (tons)

Town	Ocean fishery	Mariculture	Inland waters culture	Total
Lizifang	19210	28698	510	48418
Anzishan	300	11250	20	11570
Qingduizi	9995	6845	130	16970

The distribution of the mariculture regions in Qingduizi Bay. The coastline length of Qingduizi Bay is 85.7 kilometres, one third of Zhuanghe City. There are 5 cultivation shallow seas and tidelands areas, amounting to 600 hectares, where cultured species mainly include *Mactra veneriformis*, *Meretrix meretrix*, *Ruditapes philippinarum* and *Ostrea plicatula Gmelin*. There are 56 pond culture facilities encompassing 4544 hectares. At present, the cultured species mainly include jellyfish, sea cucumber, clam and Chinese Shrimp. The major culture mode of clam, Chinese Shrimp and jellyfish is in mixed pond breeding.

Figure 2 Mariculture in Qingduizi Bay

Indoor ponds grew juvenile sea cucumbers, while outdoor ponds raised adult sea cucumbers. Chinese Shrimp, jellyfish and clam from juveniles was also grown to maturity. Plankton was used as feed for juvenile sea cucumber, but artificial feeds were also added for higher production. Juvenile sea cucumbers required more feed and water exchange than adult sea cucumbers which may have produced a greater nutrient outflow (during water exchange).

Methods

The water body of Qingduizi Bay experiences nutrient pollution from various sources, sea-based (mariculture activities, diffusion across the sediment-water interface), rivers and sewage outlets. To assess the contribution of sea-based discharges of nutrients to total loadings, we quantified the nutrient load from mariculture activities, the diffusion across the sediment-water interface and additions from main rivers and sewage outlets, which flow into the water body of Qinguizi Bay. Meanwhile the pollution discharge coefficient was applied in calculating nutrient discharges from mariculture activities, so that information can be supplied to the mariculture industry from where major sources of sea-based nutrients are released. Additionally, the temporal and spatial distribution of nutrients in Qingduizi Bay was investigated and the numerical model that was developed was used to predict the transport of pollutants in the water body of Qingduizi Bay.

Survey Stations. 5 ponds were selected to represent mariculture farms near Qingduizi Bay for seawater sampling. Pond 1 was used for mixed breeding of Chinese Shrimp and jellyfish, Pond 2 for mixed breeding of jellyfish and clam, Pond 3 for mixed breeding of Chinese shrimp, clam and jellyfish, Pond 4 for sea cucumber culture hatchery, Pond 5 for sea cucumber breeding. 5 survey cruises in total were conducted.

Summer and autumn cruises were organised in August and November, 2008. Winter and spring cruises were organised in April and May, 2009. In addition, another survey was carried out in July, 2009.

In order to survey diffusive fluxes across the sediment-water interface and distribution character of nutrients in Qingduizi Bay, 12 survey stations were used for seawater samples, of which 6 were for sediment sampling. The sediment survey stations were chosen because of the effect of the river and their even distribution in the Bay. They included 9 monitor stations inside and 3 reference stations outside the Bay and 3 measuring stations for ocean currents.

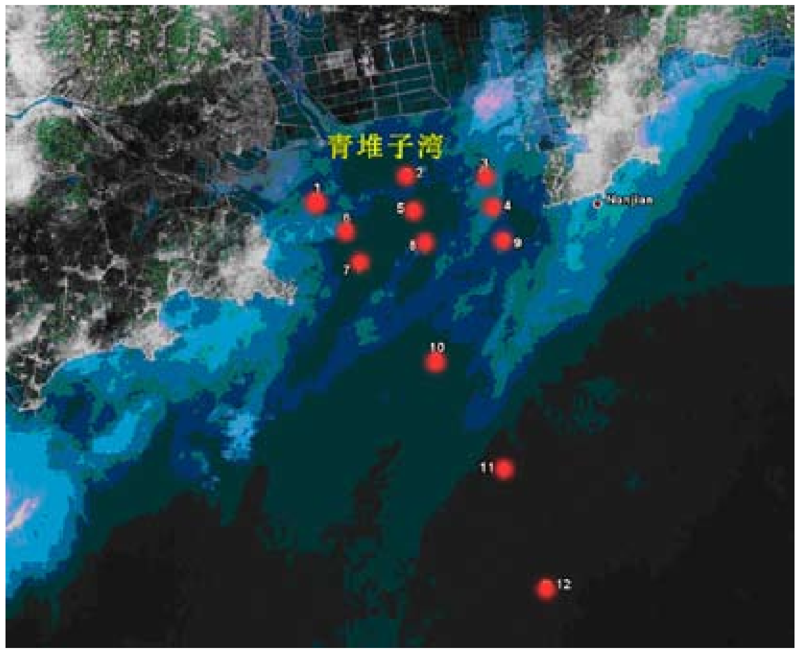

Figure 3 Location of survey stations of sea water and sediment samples

Seawater was sampled for common environmental variables: temperature, salinity, pH, DO, COD; and nutrients: nitrogen (nitrate, nitrite and ammonia), phosphate, silicates, TN, TP. Sediment was sampled for common environmental variables: porosity, TOC, type of sediment and nutrients: forms for transferable nitrogen, silicate, phosphate, TN, TP, NO_2^-, NO_3^-, NH_4^+. The ocean current was measured for velocity and direction.

Results

Based on the mariculture production figures from 2009 provided by the Zhuanghe Ocean and Fisheries Bureau, the overall pollution discharge was calculated from the mariculture industry, which showed that DIN was released at a rate of 6.24 ton/year and phosphate, 1.22 ton/year, into the body water of Qingduizi Bay.

Table 1 The amount of nutrients discharged from main rivers and sewage outlets in 2009 (ton/year)

Name	Ammonia	Nitrate	Nitrite	Inorganic nitrogen	Phosphate	COD
Qingduizi sewage outlet	0.14	39.07	2.50	41.72	1.46	471.17
Anzishan sewage outlet	0.53	56.90	2.56	60.00	0.49	798.57
Huli River	2.01	60.10	2.46	64.57	1.04	4299.22
Yingna River	1.10	127.33	4.03	132.46	1.93	225.44

A comparison of nutrient concentrations in the interstitial water and in the overlying water, showed that the level of nutrients in the interstitial water was higher than that in the overlying water. There was a trend in the amount of nutrients diffused from sediment to the overlying water across the sediment-water interface.

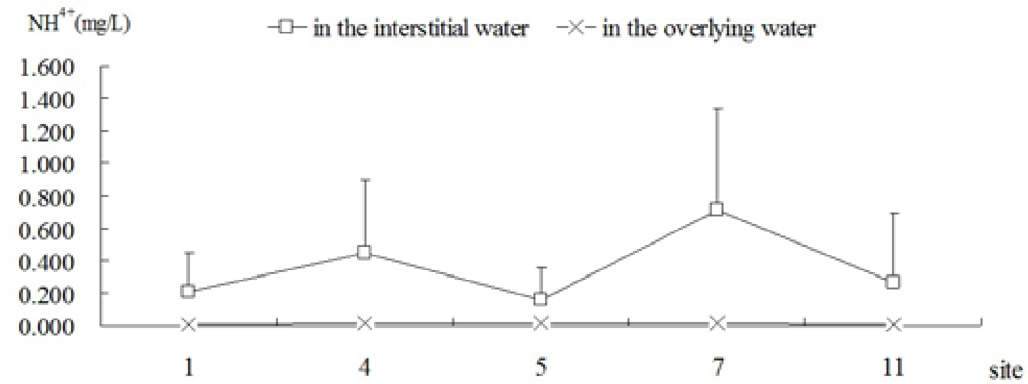

Figure 4 Spatial distribution of NH4+ in the interstitial water and in the overlying water

The significantly larger flux of SiO_3^{2-}, NH_4^+ and NO_3^- was observed in the sediment-water interface of Qingduizi Bay. The content of SiO32- ranged from 11.73 to 146.77 mg/(m^2*d), NH_4^+ from 204.88 to 608.70μg/(m^2*d) and NO_3^- from 98.05 to 761.16μg/(m^2*d), respectively. The level of NO_2^- was the lowest. NH_4^+ and NO_3^- diffusion across sediment–water interface was the dominant process of DIN exchange. The results show that the nutrients were released by sediment.

Table 2 The amount of nutrients discharge from various sources into Qingduizi Bay

Nutrient discharge sources	Amount (ton/year)	Contribution ratio (%)
Qingduizi sewage outlet	43.17	13.52
Anzishan sewage outlet	60.48	18.94
Huli River	65.61	20.54
Yingna River	134.39	42.08
Diffusion across sediment-water interface	8.35	2.61
Marine industry	7.36	2.31
Total	319.36	100.00

Temporally, summer and autumn were not only the rainy seasons but also the best culture periods in the Bay. Huge quantities of runoff and aquatic wastewater were discharged into the Bay. For that reason, the concentrations of total nitrogen and nitrate were significantly higher in summer and autumn than those in winter and spring.

The currents in Quigduizi Bay have a steady, weak circulation. The circular velocity was smaller in the bay mouth, thus one high-speed deposition region was formed. Therefore, the high concentration of nutrients in the interstitial water near the bay-mouth (station 7) may be caused by this high-speed deposition. Inside the Bay is wider than the mouth. However, the Qingduizi Bay-mouth is not narrow, so the water exchange is good. Pollution in the water can be easily be transported outside Qingduizi Bay. Thus, the water in Qingduizi Bay is not at risk from the adverse effects of land-based and sea-based nutrients inputs. The results obtained indicate that the present method was useful for the investigation of transport phenomena by shallow water flows in complex geometries and practical flow problems.

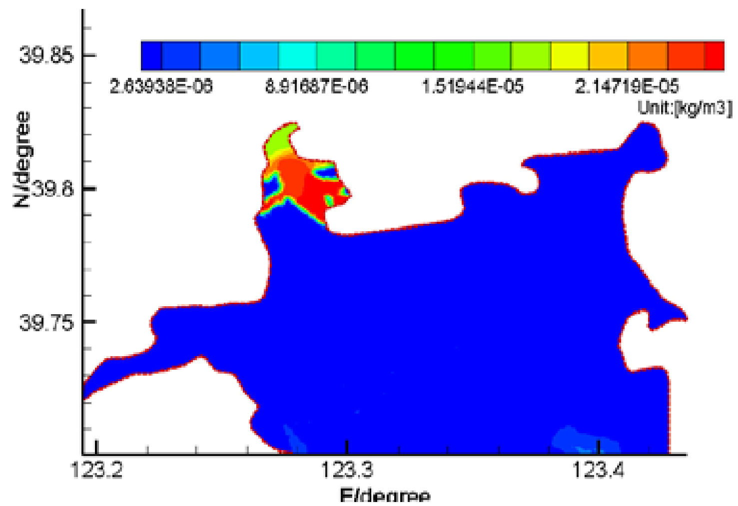

Figure 5 Simulated field distribution of ammonia concentration at neap tide

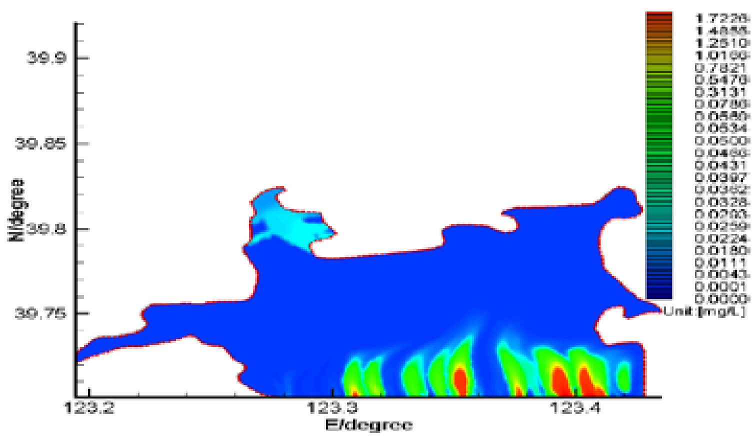

Figure 6 Simulated field distribution of ammonia concentration at spring tide

Discussion and conclusion

The results indicated that the amount of nutrient emission per unit production of cultivated juvenile sea cucumber during one culture cycle was the largest among the breeding species in Qingduizi Bay. Plankton was used as juvenile sea cucumber feed, but artificial feeds were also added for higher production. Feed and exchange water were also needed more frequently for growing juvenile sea cucumber than adult sea cucumber and other breeding species in outdoor ponds. Therefore there could be higher nutrient outflow from the indoor ponds during water exchange. If Qingduizi Bay is to be used as a model to control nutrients, then it also needs to control the scale of the juvenile sea cucumber farms.

In addition, the contribution of sea-based discharges of nutrients to total loadings was estimated to be about 4.92%, of which marine industry supplied an estimated 2.31%, diffusion across the sediment-water interface supplied an estimated 2.61% of total loadings. However, the contribution of nutrients discharged by main rivers was estimated to be 62.62%, the contribution of nutrients discharged by sewage outlets was estimated to be 32.46%. At present, the mariculture industry in Qingduizi Bay has a low impact on the environment, because there are many ponds with no artificial feeding or fertilisation and the major culture model of clam, Chinese Shrimp and jellyfish, is mixed pond breeding. However, 95.08% of the total nutrient loadings were from land-based sources, such as agriculture and municipal sewage. There were many nutrient discharge sources in the Bay head, mariculture farms, sewage outlets and the Huli and Yingna Rivers, so nutrients concentrations were usually higher in the Bay head.

Management recommendations

Mariculture has the potential to supplement world seafood supplies and generate livelihoods and income. The goal was to find an effective or optimal culture model that will not only yield high quality aquatic products, but also provide ecological and socio-economic benefits as well. The goal can be achieved though the following ways: first, long-term monitoring and emergency monitoring by local government should help in determining the impact of aquaculture and other forms of pollution on the environment, and form the basis for decision-making. Second, the government must put more effort into aquaculture legislation. Policymaking and enforcement are also important in keeping the industry on the right track. In particular, there is a need to establish comprehensive mariculture policy frameworks that streamline mariculture development into national development and environmental management plans and that adequately define the legal and institutional frameworks governing mariculture development. Third, technological improvement is vital to pollution control for aquaculture. Studies on carrying capacity, environment remediation, effective micro organisms and polyculture techniques have all contributed to enhancing productivity as well as protecting the environment. Finally, other factors that support a sustainable aquaculture include: the establishment of easily accessible information systems and public awareness for the aquaculture community and fishermen and the importance of harmonised development relating to the economy, social culture and the environment.

However, the major sources of nutrients discharged to Qingduizi Bay are agriculture and municipal sewage. Some management suggestions targeting the main sources of pollution are proposed as follows a) national planning as a basis for a management regime that takes environmental considerations into account, is of prime importance. Such planning should cover all aspects of the coastal and marine activities and should encompass land-use practices, plans for sewage treatment facilities, management plans for waste disposal sites and the removal of outdated industrial facilities, b) while the national government has the overall legal responsibility, the capability of implementing and supporting institutions and organisations must be strengthened, c) infrastructure and technical facilities have to be improved. This includes improving existing facilities for municipal and industrial waste treatment and the construction of new facilities, d) international cooperation will have a significant positive impact on efforts to reduce the nutrients discharged. International cooperation may be an important contributor to the process, which can provide access to financial, technological, scientific and human resource assistance.

Figure 7 Local communities are directly dependant on the mudflats for their livelihoods

Monitoring and Assessment of the Atmospheric Deposition of Pollutants in the Yellow Sea

Prepared by

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November 2009

Objectives and Methods

Major urban and industrial centers increase loadings of atmospheric pollutants, such as heavy metals, nutrients and semi-volatile organic compounds (SVOCs), to nearby coastal waters through riverine transport, atmospheric deposition (via dry particle deposition), wet deposition and air-sea gas exchange (McVeety and Hites, 1988; Bidleman et al., 1995; Park et al., 2002; Fang et al., 2008). In addition to acting as sinks for these pollutants, the sea can act as a source of some SVOCs to coastal atmospheres and play important roles in the global biogeochemistry (Hinckley et al., 1991; Dachs et al., 1999, 2002). Particle-sorbed pollutants can settle on the ocean surface by dry particle deposition, a uni-directional advective transport process from the atmosphere to the water, the removal rate by which is a function of the physical and chemical properties of the aerosols and bound pollutants, meteorological conditions and surface characteristics (Wania et al., 1998; Odabasi et al., 1999).

The northern Yellow Sea ecosystem has suffered severely from the land-based pollution, as a result of anthropogenic inputs of a wide variety of toxic chemicals. Heavy metals, nutrients and some typical persistent organic pollutants (POPs) have been discovered in the sea water, sediment and fish, in the Yellow Sea region. Thus, it is essential to assess the magnitude of atmospheric deposition of these contaminants, and quantify both local (urban-influenced) and regional (background) concentrations of air toxins by locating monitoring sites. Atmospheric deposition monitoring networks in the coastal areas of the northern Yellow Sea were designed to capture the regional deposition signal and were focused in rural areas away from local sources.

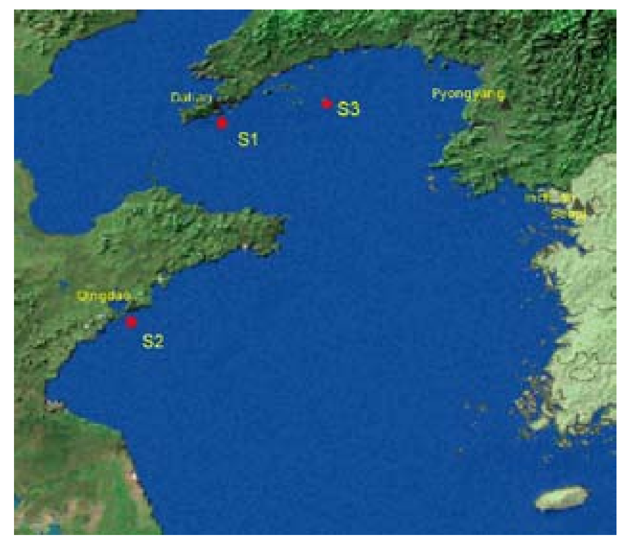

Figure1 Location of three observation stations. (S1: Laohutan Station; S2: Xiaomai Island; S3: Changhai Island)

The objectives of this research were to (i) estimate the importance of atmospheric deposition of these pollutants to the north Yellow Sea surface waters; (ii) identify the local and regional sources of atmospheric contaminants; (iii) quantify current concentrations and deposition fluxes of targeted contaminants; and (iv) assess their spatial and seasonal trends.

Analysis methods

The targets analysed in this study include 15 PAHs, 6 metals and 4 nutrients, the analysis methods were listed in Table 1.

Table 1 Target analytes and analysis methods

No.	items	analysis methods
01	TSP	gravimetric analysis
02	nitrate	ion chromatography
03	nitrate	ion chromatography
04	ammonium salt	ion chromatography
05	phosphate	ion chromatography
06	Cu, Pb, Zn, Cd, Fe	atomic absorption spectrophotometry
07	Hg	cold atomic absorption spectrophotometric method
08	PAHs*	GC/MS

Sampling duration

This study commenced from October 2008. The data presented here are the results from October 2008 to September 2009. Samples of Total Suspended Particulates were collected every two weeks, and samples for PAHs were collected once per month. Precipitation samples were collected only when it was raining.

Results and discussion

Nutrients

Table 2 Mean and standard deviations (SD) of nitrate, ammonium salt, phosphate and nitrite in particle samples collected from the three sites (μg/m^3)

Nutrients	Zhangzi Island		Laohutan		Xiaomai Island	
	Mean	SD	Mean	SD	Mean	SD
Nitrate	10.5	5.8	15.4	12.6	13.5	8.4
Ammonium salt	6.0	5.4	17.3	17.9	15.4	13.0
Phosphate	0.035	0.023	0.131	0.110	0.139	0.095
Nitrite	0.039	0.014	0.073	0.052	0.072	0.044
Total suspended particaltes	16.6		32.9		29.1	

The average concentrations and standard deviations of nitrate, ammonium salt, phosphate and nitrite at the three sites are listed Tables 2. The total nutrients (nitrate + ammonium salt + phosphate + nitrite) at Laohutan was the highest (32.9 μg/m3), followed by Xiaomai Island (29.1 μg/m3) and Zhangzi Island (16.6 μg/m3). Among the four nutrients, ammonium salt is the most abundant component in samples of Laohutan and Xiaomai Island, while nitrate possesses a higher proportion of the total nutrients at Zhangzi Island (Figure 3).

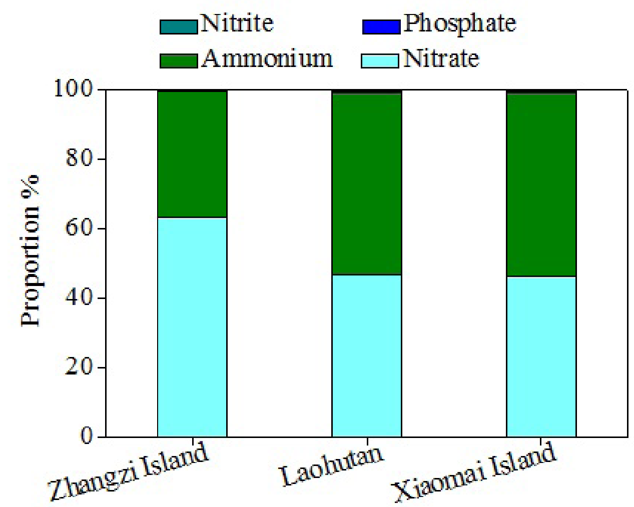

Figure 3 Proportion of four nutrients in samples of all three site

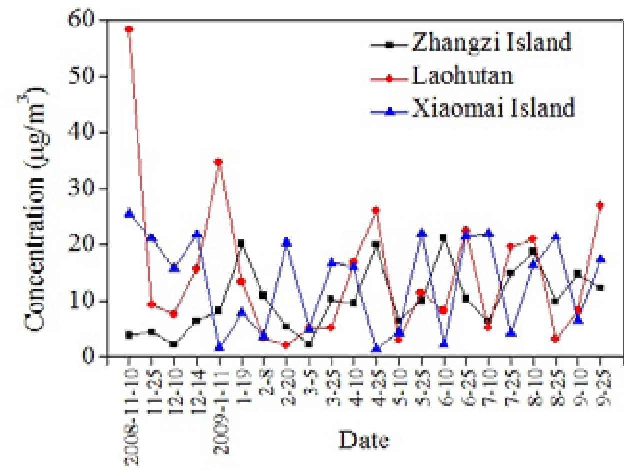

Figure 4 Time trends of nitrate concentration for the three sites

Heavy metals

The summarised concentrations of Cu, Pb, Zn, Cd, Fe and Hg in particles are presented in Figure 5. The highest mean concentrations of Cu (17.6 ± 7.8 ng/m^3), Pb (84.5 ± 37.1 ng/m^3), Cd (6.0 ± 1.9 ng/m^3) and Hg (0.44 ± 0.29 ng/m^3) were observed at Xiaomai Island; the highest concentrations of Zn (255.1 ± 189.4 ng/m^3) and Fe (5162.9 ± 925.7 ng/m^3) were observed at Laohutan. Meanwhile, mean concentrations of Cu (13.0 ± 5.8 ng/m^3), Pb (63.2 ± 35.6 ng/m^3), Zn (89.6 ± 50.2 ng/m^3), Fe (3539.7 ± 2111.6 ng/m^3) and Hg (0.16 ± 0.08 ng/m^3) at Zhangzi Island were the lowest, and the mean concentration of Cd (1.18 ± 0.76 ng/m^3) at Laohutan was the lowest. The results implies that Xiaomai Island, which is located near Qingdao City, has suffered heavy pollution with trace metals. It must be noted that, although it is far away from the urban/industrial areas, Zhangzi Island has been polluted with trace metals too, especially the pollution of Cd. A relative high concentration of Cd was observed at Zhangzi Island, in fact, the concentration of Cd in precipitation collected at Zhangzi Island was also high compared with Xiaomai Island and Laohutan. To date, the reasons of having a high Cd concentration at Zhangzi Island have not been well understood. One possible explanation is that there exists a potential point source near/at the island.

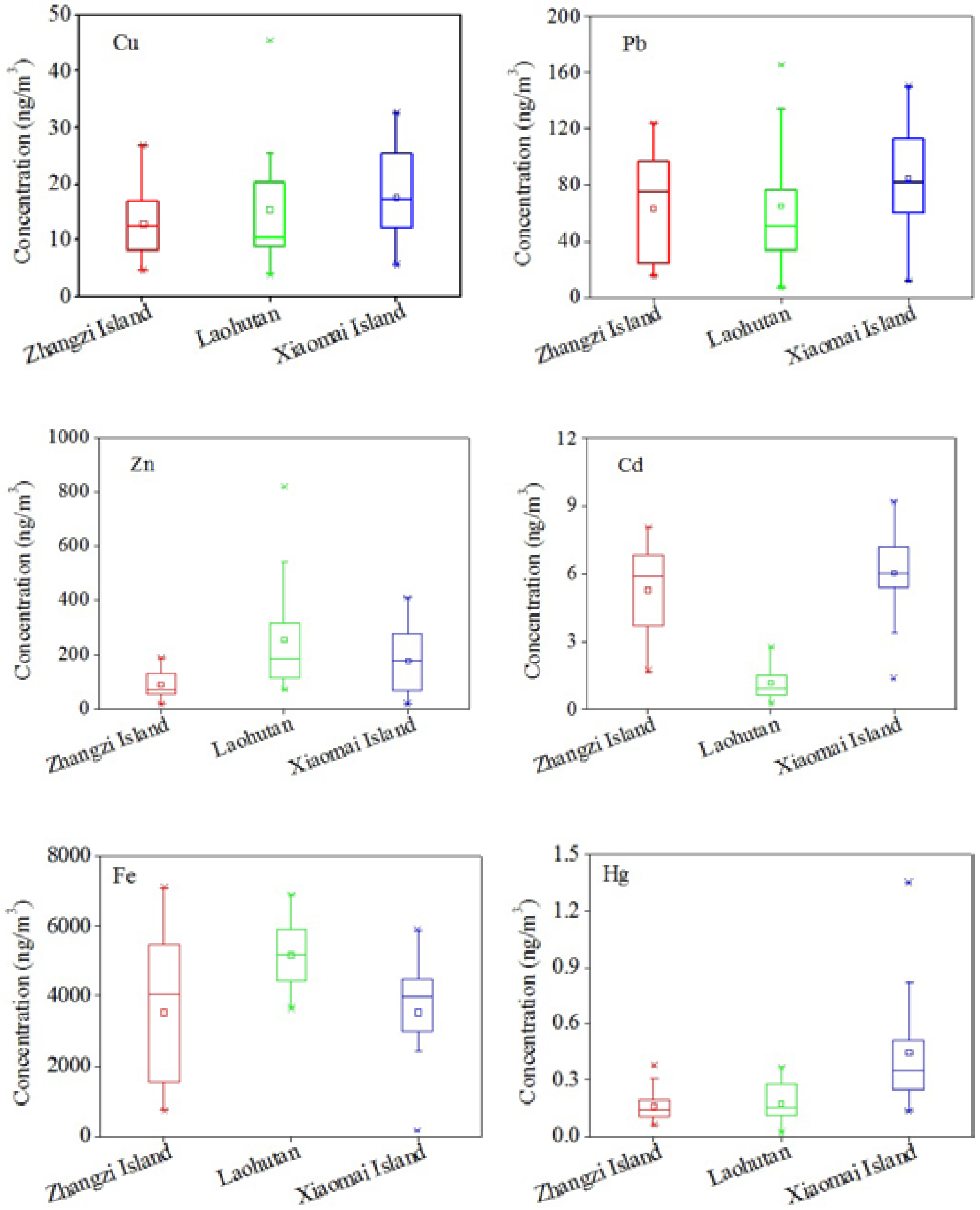

Figure 5 Box and whisker plot of 6 metals (Cu, Pb, Zn, Cd, Fe and Hg) at Zhangzi Island, Laohutan and Xiaomai Island for samples collected from October 2008 to September 2009.

PAHs

The gas-phase PAH distribution (Figure 7) is dominated by the total PAH concentrations for all three sites. Although the average concentrations vary spatially across the north Yellow Sea, the average PAH profiles at all sites are similar, indicating that while the source strength is different at each site, the mix of sources is similar. The proportions of the gas phase PAHs to the total PAHs (gas + particle) are 62%, 81% and 54% for Zhangzi Island, Laohutan and Xiaomai Island, respectively, which indicates that the gas phase PAHs are the main component of atmospheric PAHs in the north Yellow Sea. It is interesting to note that, at Xiaomai Island, the proportion of particle phase PAHs are higher compared with the proportions at Laohutan and Zhangzi Island, confirming that there are more particle emission sources in the urban areas. Nevertheless, various PAH compounds display different gas-particle distribution profile. The gas-phase PAH distribution is dominated by low to medium molecular weight PAHs (Nap to An) and relatively depleted in higher molecular weight PAHs (BaA to InP). This pattern is determined in part by vapor-particle partitioning, although emission patterns also play a role.

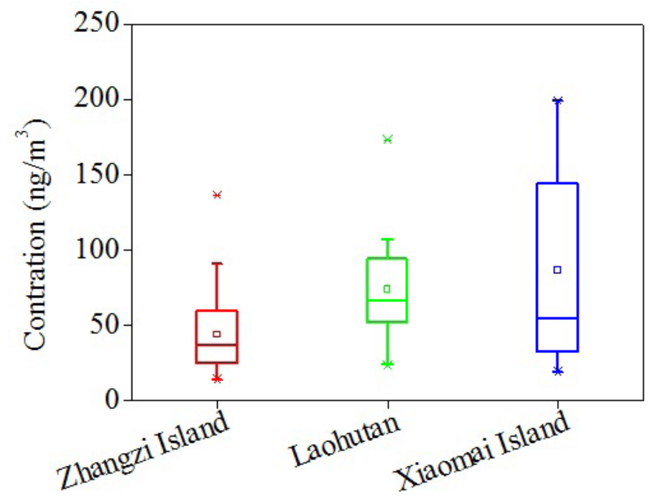

Figure 6 Box and whisker plot of PAHs at Zhangzi Island, Laohutan and Xiaomai Island for samples collected from October 2008 to September 2009

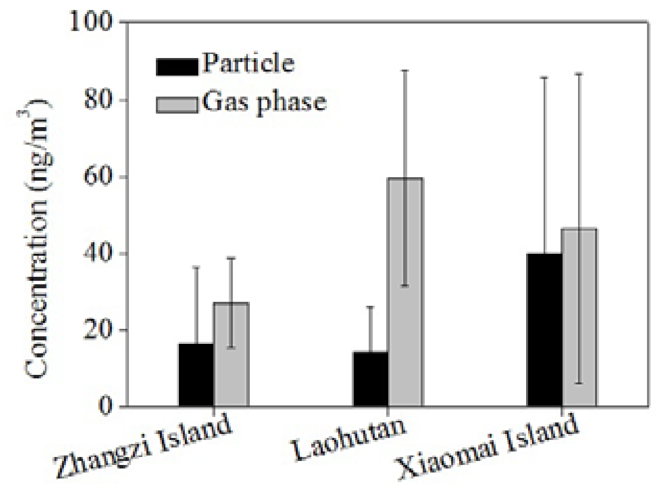

Figure 7 Distribution of particle and gas PAHs at the three sites

Summary of findings

The results of the present study give an important overview of contaminant concentrations and deposition fluxes in the north Yellow Sea and provide benchmark levels for the assessment of spatial and temporal trends and the evaluation of emissions control strategies. Higher concentrations and deposition fluxes of nutrients, trace metals and PAHs were observed in the study area compared with the other areas of the world. The composition of atmospheric pollution has its own characteristics. The main findings included:

For nutrients:

- Nitrate and ammonium were two main components of nutrients in the northern Yellow Sea.
- Wet deposition of nitrate played an important role in the input of nutrients into the northern Yellow Sea.
- Seasonal variations of nutrient deposition fluxes were not obvious.
- Ratios of N/P measured were much higher than the appropriate N/P ratio for the production of phytoplankton in the marine environment.

For heavy metals:

- Local spatial trends in atmospheric trace element concentrations were observed in the northern Yellow Sea, but these trends varied by elements.
- Deposition fluxes of some metals (Cu, Zn, Fe and Pb) in urban areas (the Xiaomai Island, Laohutan) were elevated with respect to the regional background levels.
- Higher atmospheric concentrations and deposition fluxes of Cd were found at Zhangzi Island than the sites near the urban/industrial areas.

For PAHs:

- Atmospheric ΣPAHs deposition fluxes (gas absorption + dry particle deposition) increased with proximity to urban areas.
- PAH concentrations and deposition fluxes varied spatially across the sites with the highest occurring at the most heavily urbanised and industrial locations. PAH profiles are similar at the three sites. However, the primary sources are not the same.
- Deposition fluxes of PAHs to the north Yellow Sea are estimated to be higher than those in coastal areas of America, indicating PAH pollution is heavy in China.

Suggestions for management

The above results and discussions indicated that the atmospheric deposition of the pollutants of nutrient, heavy metals and PAHs are serious in the Yellow Sea. Thus, it is important to develop relevant policies and actions to reduce the sources of these pollutants; and relieve the pollution and ecological pressure of the Yellow Sea. Based on the findings of the study, suggestions for management to reduce the emissions of the target pollutants into atmosphere are presented as follows:

For nutrients:

- Reduce the amounts and improve the efficiency of fertiliser use in agriculture and prevent the unnecessary discharge of fertilizer
- Reduce the consumption and improve the combustion efficiency of fossil fuels
- Increase treatment of municipal wastewater and animal waste

For heavy metals

- Reduce the emission of industrial dusts and vehicle exhausts
- Control the total suspended particles of the region
- Reduce the consumption of coals and control emissions of industrial waste gas

For PAHs

- Reduce the consumption and improve the combustion efficiency of fossil fuels
- Cease the incomplete combustion of waste
- Reduce the discharge of vehicle exhausts
- Reduce the combustion of wood in rural areas

Recommendations for further study

The sampling period of this program was 12 months, and frequency of sampling was twice per month. Due to the limited data, some uncertainties in the results may exist especially as the results have not been compared and integrated with data from other relevant programmes, e.g. pollution loadings from non-point sources and mariculture, which may also be significant sources. Therefore there should be some additional studies focused on the evaluation of the watershed retention and runoff and ecosystem impacts of atmospheric contaminants, to evaluate the real impacts of atmospheric deposition as a major non-point source of contaminants to surface waters. In addition, the following studies are recommended to depict the whole pollution status more clearly.

- Basic research is needed to provide more robust understandings of the physics of dry particle depositions, which can account for significant deposition fluxes of organic and inorganic contaminants;
- Local transport modeling and source apportionment studies should be supported and used to identify the major emissions sources of nutrients and trace metals to the atmosphere;
- The quantification and identification of organic N and its sources in the atmosphere is needed to complement extensive research and monitoring of inorganic N;
- The isotopic tracer (such as 13C and 15N) is a useful and direct tool in determining the sources and transport routes of nutrients in the environmental media. More research is needed to develop the methods and models on apportioning atmospheric nutrient sources by employing the isotope tracers; and
- Assessments of the concentrations and deposition fluxes of emerging atmospheric contaminants such as brominated compounds are needed in the north Yellow Sea region.

The Management of Recreational Waters

Prepared by
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December 2009

Introduction

Situated on the south coast of the Shandong Peninsula, Qingdao is a city of picturesque red-tiled roofs nestled between green hills and blue sea. The mild climate, the bathing beach, and Mount Laoshan, make Qingdao a popular resort, particularly in summer when visitors come in droves for sightseeing and escaping the heat. In 2007, Qingdao received more than 1 million overseas tourists and 30 million domestic tourists. The total tourism revenue exceeded 40 billion RMB. Coastal recreational waters are a valuable resource for the development of the local economy.

Figure 1 Location of monitoring areas

In recent years, in order to mitigate the impact of marine pollution, the local government took a series of measures to control sewage discharges. Water quality in the coastal areas has been greatly improved since 2005. In this study, the No.1 Bathing Beach, Shilaoren Bathing Beach and the Olympic Sailing Area was selected as target demonstration sites.The aims of this study were to;

- ●identify gaps in existing monitoring systems and management actions, based on analysis of the data and information
- ●explore the primary factors affecting water quality in the target areas through field surveys
- ●put forward recommendations on the management of recreational waters

The project centered on the following activities; field surveys (summer 2009) including high frequency sampling and observation which revealed the status and trends in water pollution, spatial and temporal forecast modelling of microbial contaminants, suggestions for future monitoring and management recommendations. A beach clean-up activity was also organised to improve public environmental awareness. A list of the data collected is shown in table 1.

Table 1 Data and information collected from the target areas

Items	Details
Water Quality	Faecal coliform /Dissolved oxygen/Water color/ pH value/ Water transparency
Hydrology	Water temperature/Wave height
Meteorology	Air temperature/Wind scale/Visibility/Weather condition/ Rainfall/ Wind speed and direction/ Total cloud cover
Floating Material	Hazardous organisms/Marine litter/Red tide

From the data and analysis, the dominant risks and issues found to occur in recreational waters were;

1) *Faecal pollution* -the primary problem of water quality in the target areas was faecal contamination which can lead to health problems because of the presence of infectious microorganisms. Microbial indicator bacteria, for example, faecal coliform and enterococci, were used for assessing water quality status.

2) *Dangerous organisms*- jellyfish were often observed during the bathing season in the coastal recreational waters of Qingdao. Through interviews with staff it was discovered that up to 200 swimmers suffered painful stings from the jellyfish in one day. Primary symptoms were inflamed skin and itching.

3) *Floating microalgae*-in July 2007, along Huiquan Bay, small quantities of floating microalgae appeared but did not aggregate on a large-scale. However in the summer of 2008, vast mats of floating Enteromorpha were seen along the Qingdao coast. This type of seaweed can affect the sediment underneath at low tide and reduce the visual amenity of recreational beaches. All of the bathing beaches along the Qingdao coast were closed from June to July that year.

4) *Marine litter*- bathing beaches attract a great number of tourists who produce significant amounts of marine litter. This can be dangerous to wildlife and tourists as well as being aesthetically degrading. It can also propagate bacteria.

Analysis of the existing management actions

Gathering information on the evolution of management actions helped evaluate the current regulatory environment and assess the scope of potential future actions. The result of the analysis are presented in the following table.

Year	Environmental status	Management actions	Reference
2003	From July to September, higher faecal coliform concentrations were observed at No.1. The 95th value of annual faecal coliform concentration was up to 1779 MPN/100ml.	-	Qingdao Marine Environment Quality Bulletin （2003）
2004	In July and August, higher faecal coliform concentrations were monitored intermittently at No.1 Bathing Beach. 95th value of annual faecal coliform concentration was up to 1544 MPN/100ml.	Maidao secondary sewage treatment plant was constructed. Aquaculture facilities along the southern coast were cleaned.	Qingdao Marine Environment Quality Bulletin(2004), Qingdao Environment Quality Bulletin(2004)
2005	The water quality gradually improved. 95th value of annual faecal coliform concentration at No.1 Bathing Beach was 50 MPN/100ml. Water quality of the Olympic Center area and Shilaoren Bathing was classed as Good.	Enlarging project of Maidao sewage treatment plant and supporting network were carried out. 120 drainage pipelines of Tuandao sewage treatment project were laid. Rainfall-sewage separation project was implemented.	Qingdao Environment Quality Bulletin(2005)
2006	Water quality of Olympic Center area, No.1 Bathing Beach and Shilaoren Bathing Beach was classed as Good.	Maidao and Tuandao sewage treatment plants were established, and management of land-based sources of pollution were strengthened.	Shandong Marine Environment Quality Bulletin(2006)
2007	Water quality of the Olympic Centre area, No.1 Bathing Beach and Shilaoren Bathing Beach was classed as Good.	Management of pollution problems were strengthened, such as beach litter. Supervision and management of the coast along Fushan Bay was also strengthened.	Qingdao Environment Quality Bulletin(2007), China Marine Environment Quality Bulletin(2007)

Evaluation of the existing monitoring system

Regular monitoring is carried out by the local Oceans and Fisheries Bureau and although the monitoring system has been carried out for eight years, inevitably gaps still occur. During this phase of the activity, the existing monitoring system was evaluated and the following gaps were identified.

●Lack of research about microbial indicators
●Lack of pollution source surveys
●Time delay in forecasting water quality

Field surveys and laboratory analysis

The Qingdao Government has taken a lot of effective measures to improve water quality in the coastal environment. However, the presence of sewage outlets near the recreational waters still exists at the foremost bathing beach. Most visitors are not aware of the risk of contamination from sewage water and use the waters to wash and swim. Outlets around the No.1 Bathing Beach and Olympic Sailing Area are from a storm water pipe. Outlets on the east and west sides of Shilaoren Bathing Beach are combined storm water/sewer systems pipes.

Figure 2 Discharge outlets at No.1 beach, Olympic Sailing Area and Shilaoren Beach

Laboratory assay test results showed that water quality around the Olympic Sailing Area was of a good standard. During dry weather, water quality at the No.1 Bathing Beach maintained its good quality but during wet weather the flow of sewage increased, raising the levels of microbial activity. Restricted by the topography of the coastline, dilution (and dispersal) of pollutants is poor and water quality is difficult to restore immediately after rain.

Sewage discharges from outlets around Shilaoren Beach are larger than No.1 Beach. However, with the water body linking it with the open sea, the water exchange capacity is stronger so the water quality is better than the NO.1 Bathing Beach. In addition, in September 2009, an oil pollution incident occurred around the Qingdao coast, so Shilaoren, No.2 and No.6 Bathing Beach were closed.

Research in assessing and forecasting microbial pollution

From August 10 to 25, 2009, recreational water samples were collected at the No.1 Bathing Beach. The locations of sampling sites are shown below.

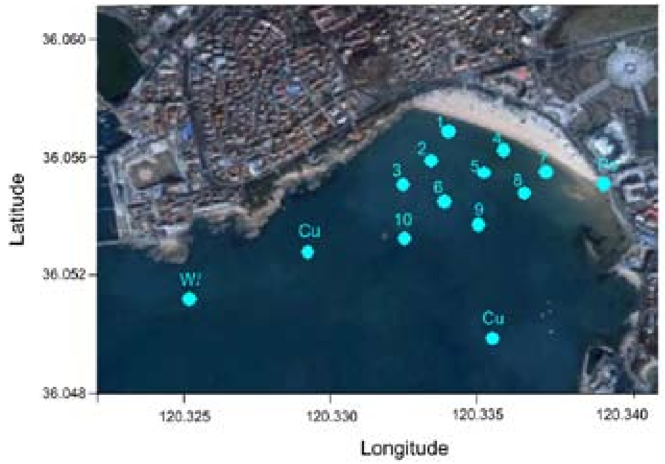

Figure 3 Location of sampling sites

Laboratory assay tests were conducted involving faecal coliforms and enterococcus. The fate and transport of faecal indicator bacteria in the environment was influenced by a number of factors such as sunlight, rainfall, tides, waves, wind, temperature and human bathers. Rainfall is one of the most important factors that it is currently used as the basis for the beach water quality health warning system in many countries. During wet weather, the sewage flow discharged directly into recreational waters and the concentration and flux of pollutants from sewage outlets is greatly increased. In addition, pollutants on the beach and the coast were washed out by the rainwater and carried into the seawater.

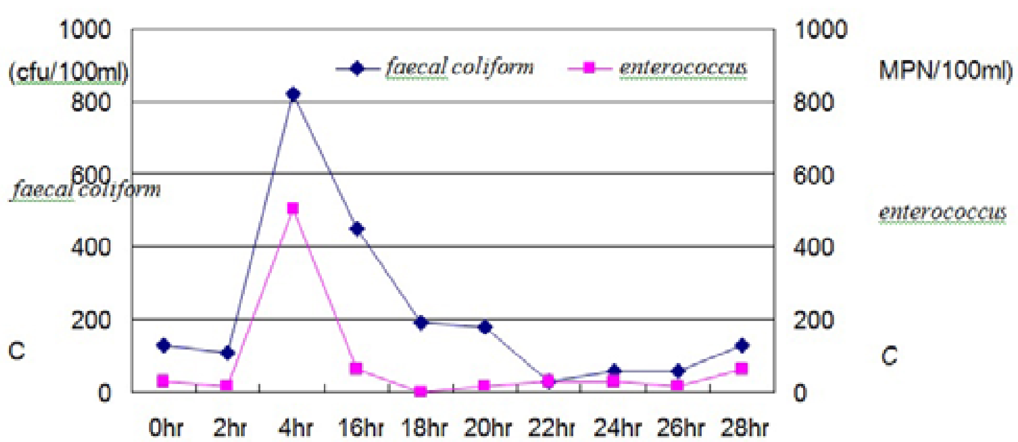

Figure 4 Temporal distribution trends of microbial indicators at station 4 after rainfall

Construction of a water quality forecasting model

A water quality model was developed for the project, the outputs from which are shown.

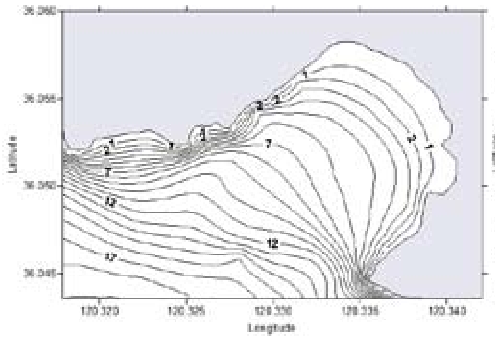

Figure 5 Isobaths in Huiquan Bay

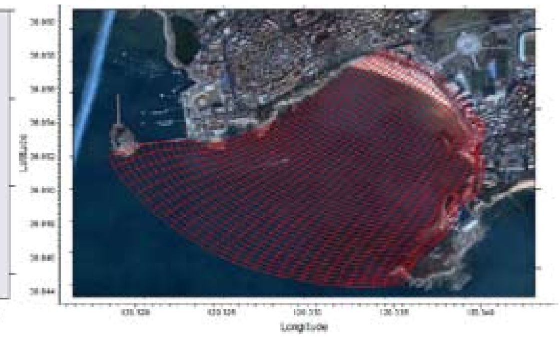

Figure 6 Simulation grid in Huiquan Bay

The forecasting model is based on the following assumptions;

- point source pollution has an impact on water quality
- the discharge of pollutants is continuous and steady
- decaying microbial indicator bacteria are affected by ultraviolet radiation;
- only two hydrodynamic forces, tide and current were considered in the simulation processes. Some of the outputs of the model are illustrated below.

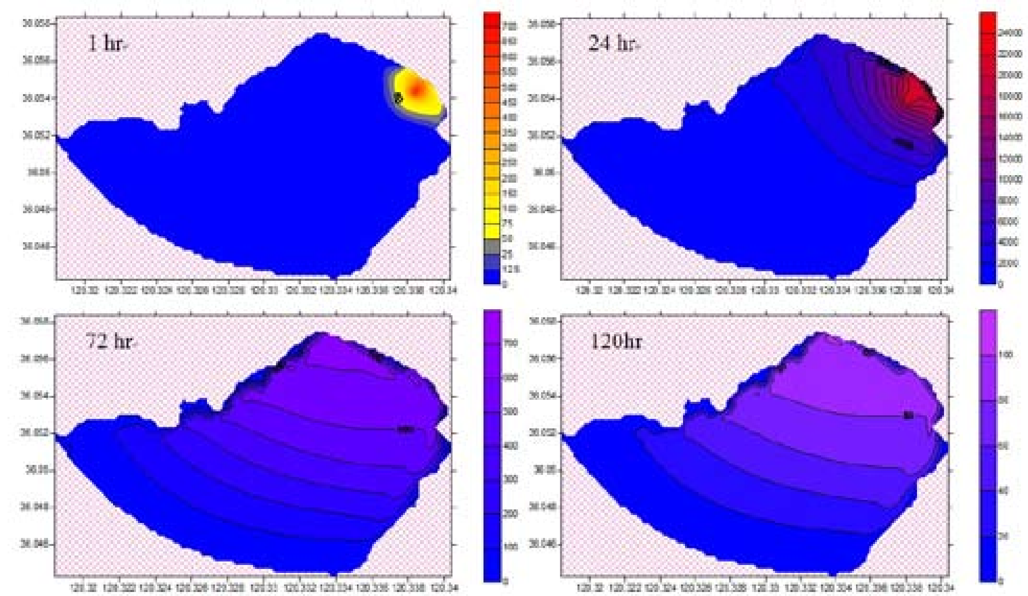

Figure 7 The isogrambaths of faecal coliform cells in Huiquan Bay (unit: cfu /100 ml)

Simulation results indicated that it might take about three days for the target area to its restore to original water quality status after exposure.

Suggestions for improvements to the existing monitoring programme

Effective monitoring data and information is the basis of scientific assessment and management evaluation. In addition to regular monitoring, causes of water quality deterioration should be surveyed. Surveys will help in the risk assessment of contamination 'events' and going pollution problems which will be useful to the management authorities.

In addition to the results of this study, ongoing monitoring of recreational waters and further improvements to the monitoring system should take into account the following aspects:

1）*pollution source surveys*

Before the start of the bathing season, potential pollution sources and other potential hazards should be monitored. These might include municipal sewage outlets, rainwater outlets, shower room and washroom outlets. Feedback mechanisms should be established that would guarantee that once the sewage treatment facility breaks down, the management department will undertake remedial management measures in time. When water quality deteriorates, pollution sources should be surveyed. Sewage discharging outlets in or around recreational waters should be monitored more carefully.

2）*adjustments to the sampling time and frequency*

For the regular monitoring programme, water quality aspects are monitored twice a week. However, basic information is not recorded automatically. During sampling, the monitoring time, tidal condition and location of the sampling site (longitude/ latitude) should also be recorded as this information would help to estimate changing trends in water quality. The distances of each sampling site from the coast or beach should be determined. If rainfall is shown to be having an impact on water quality, the sampling frequency should be increased after each rainfall period, until the water quality status has been restored to pre-rainfall levels.

3) *Incident monitoring and report*

When water quality suddenly deteriorates, monitoring of pollution sources should begin. In or around recreational waters incidents such as red tides, oil spills and macro algal blooms require emergency monitoring. Results and assessment reports should be presented to the management department as quickly as possible.

Publicity and education

Beach clean-up activities.

The variety of litter found in recreational waters or washed up on the beach is considerable and includes, for example, discarded food/wrapping, bottles/cans and cigarette butts. Some types of litter may be hazardous especially glass which if left on the beach, will injure walkers with bare feet. Actions should be taken to reduce these risks and control such activities through management measures and an increase in publicity and education.

In September 13, 2009, the Qingdao beach cleaning activity was organized by Qingdao Volunteer Association, NMEMC and YSLME, and sponsored by Coca Cola Co. Over 300 volunteers took part in the activity at No.1 Bathing Beach. Qingdao local media reported this activity through the newspaper and on internet, appreciating its active role in public education.

During the bathing season of 2009, the real-time monitoring results and assessment results were released by website and a beach closure/advisory system was established. Since 2009, beach safety flags (red, yellow and green flags representing different risk grades) are used for warning about environmental conditions and the presence of jellyfish.

Recommendations

Based on the survey and research of recreational waters, the following actions are recommended;

1) *to implement the improved monitoring programme*
2）*to improve regular monitoring and beach closure/advisory systems*
3）*to strengthen beach management*
4）*to improve legislation*
5）*to strengthen publicity and education*

The Yalu River is an important stop over for migrating waterfow. ©WWF China