Draft Final Report of the Regional Synthesis of Data and Information for the Ecosystem Component of the UNDP/GEF Yellow Sea Large Marine Ecosystem Project

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I. Background

The Yellow Sea is a semi-enclosed sea bordered by Republic of Korea (ROK), People's Republic of Korea (DPRK), and People's Republic of China (PRC). It has a total area of 380,000km^2 and an average depth of 44m (Song, 1997). High primary productivity of the Yellow Sea ecosystem has led researchers to conclude that the Yellow Sea ecosystem could provide a fertile fishery ground.

It was, however, classified as one of the most polluted seas in the world in an article in *Worldwatch* in 1995. According to the article, the number of types of marine animals decreased from 141 types in 1963 to 24 types in 1988. Rapid economic growth and coastal development in PRC, economic development plans of DPRK, concentrated socioeconomic activities in coastal areas of ROK, and increase in maritime transportation in the region pose threats to the already deteriorated ecosystem of the Yellow Sea (Kang and Nam, 2002).

Even though in average the general water quality of coastal areas of the Yellow Sea have been improving due to environmental investment in the region, the coastal ecosystems of the Yellow Sea have disappeared or deteriorated rapidly under heavy development pressure for short-term economic profits. This has been one of the major factors in the reduction of fishery resources. The marine environmental statistics of PRC shows that since 1999 polluted sea areas have decreased, but the number and areal extent of red tide events and the degradation of marine ecosystems have increased (SOA, 2006). In the period of 1950~1985, a third (2.94 million ha) of tidal flats of PRC had been reclaimed for other uses. Occurrences of red tides in the coastal area of ROK have also increased over the last decade, causing increase in economic loss of the fishery industry (Kang and Nam, 2002). Reclamation of the Korean tidal flats for industrial, agricultural, and urban purposes since 1960s has contributed to the loss and deterioration of productive coastal habitats for marine organisms. It was estimated that about 810 km^2 (25% of total area) of tidal flats had been lost to reclamation from 1988 to 1998 (MOMAF, 1998). There is not much information on the status of coastal ecosystem of DPRK. DPRK, however, has been reclaiming its coastal wetlands mostly in the west coast since 1981, as a part of a national project for economic development, further contributing to the destruction and deterioration of coastal ecosystems of the Yellow Sea (Kang and Nam, 2002).

The open sea ecosystem of the Yellow Sea seems to be in better condition compared to the coastal ecosystem. Its structure and function are, however, threatened mostly by ocean dumping of wastes and offshore oil spills, though limited to specific areas. There have been some reports on the pollution of seawater and bottom sediments in dumping sites of the

Yellow Sea. Possibility of oil spill accidents has been increasing as the economy of the Northeast Asian countries is growing. ROK, PRC, and Japan accounted for 20.9% of world GDP and 15.2% of trade in 2003. Some reports forecast that these countries are expected to produce 27% of the world GDP and 30% of the world trade in 2010 (PCNACI, 2005). This means that the Yellow Sea region could become a major economic centre in the 21st century, which would increase pressure on the Yellow Sea ecosystem.

Sustainable utilization of the Yellow Sea ecosystem requires a comprehensive cooperative management action plan which takes into account ecological information and socioeconomic characteristics of the surrounding countries. The starting point for the establishment of sound management strategies and measures is to analyze and understand the historical trajectory and current status of the Yellow Sea ecosystem.

In the approved Implementation Plan of the UNDP/GEF Yellow Sea Project, “Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem,” one of the agreed activities of the Ecosystem Component is to prepare a regional synthesis of the data and information collected from PRC and ROK, to input into the ecosystem chapter of the Transboundary Diagnostic Analysis (TDA). The regional synthesis will compile and analyse the information collected from national reports to provide a regional picture of the Yellow Sea ecosystem problems. The format and types of data and information to collect from the countries were agreed by the members of the Regional Working Group-Ecosystem (RWG-E) at its first meeting (Goeje, Korea, 10—13 May 2005).

This project aims at 1) assessing the national ecosystem data and information collected by experts in PRC and ROK and the national reports, 2) synthesizing the national data and cooperative study cruise results to provide a regional picture of the Yellow Sea ecosystem, 3) suggesting recommendations to fill the gaps in ecosystem information to be used for better understanding of the system and establishing management strategies and actions, and 4) providing a draft ecosystem chapter for the Transboundary Diagnostic Analysis (TDA) of the Yellow Sea.

II. Project Scope and Methods

II.1. Project scope

II.1.1. Geographic Scope

The Yellow Sea Large Marine Ecosystem is defined in the Project Document as the body of water delineated at the south, by a line connecting the north bank of the mouth of the Chang Jiang (Yangtze River) to the south side of Cheju; to the east, by a line connecting Cheju Island to Jindo Island along the coast of the Republic of Korea; and to the north, a line connecting Dalian to Penglai (on the Shandong Peninsula). This line separates Bohai Sea from the Yellow Sea (Figure 1).

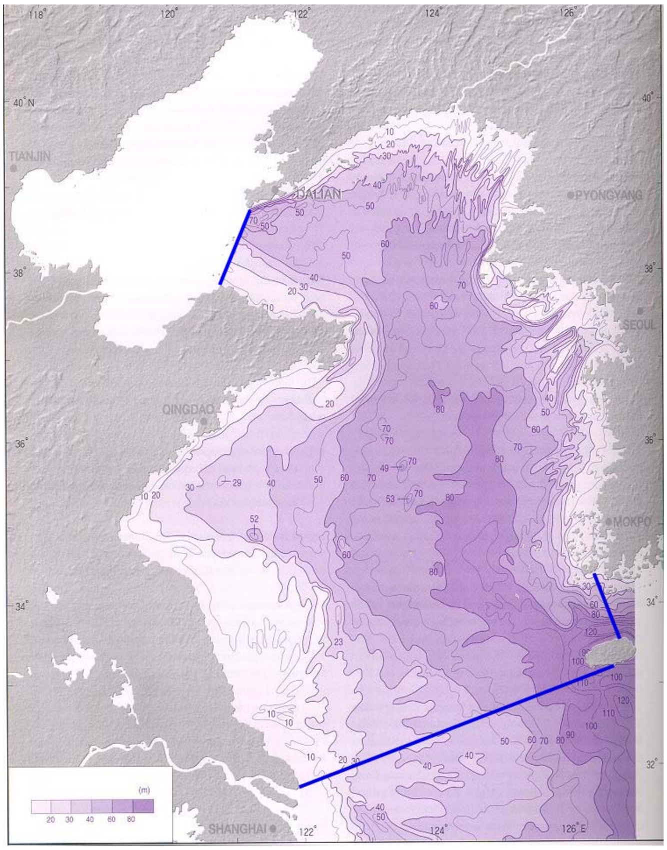

Figure 1. Geographic scope of the project (based on OSTI and IOCAS, 1998).

II.1.2. Subject scope

The regional synthesis of data and information of the Yellow Sea ecosystem covers the lower trophic levels of the ecosystem as agreed in the Ecosystem Working Group meetings: phytoplankton and harmful algal blooms (HABs), zooplankton, and benthos (Figure 2).

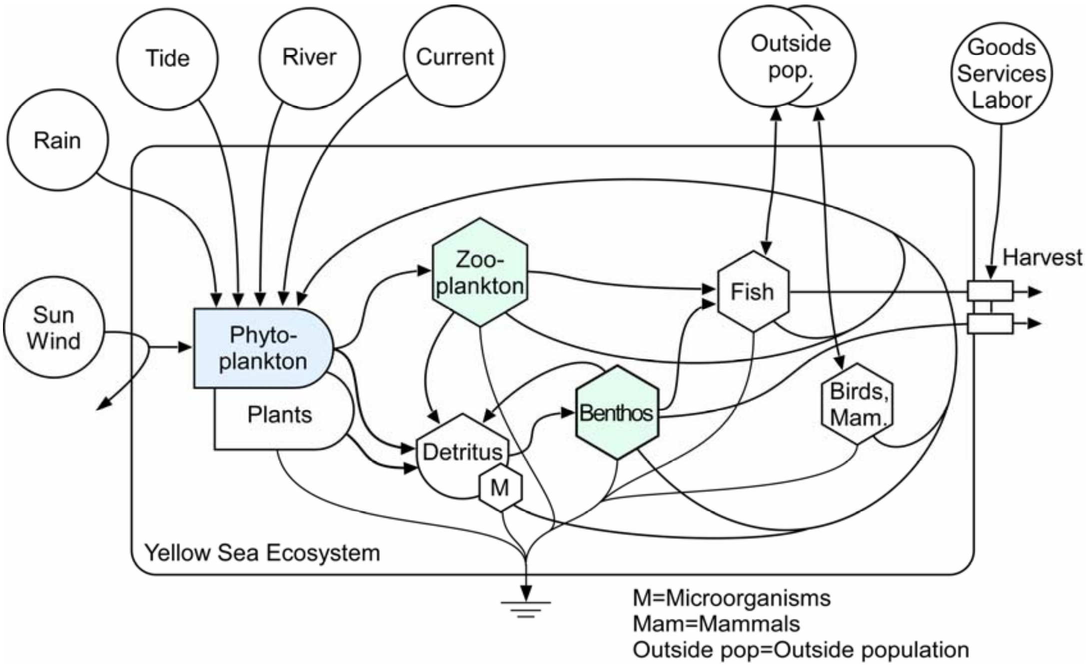

Figure 2. Subject scope of the project.

II.2. Methods

- Compilation of ecosystem data and information of the Yellow Sea
  - National data collections and their reports will be used to compile regional ecosystem data and information for the Yellow Sea ecosystem on a regional level.
  - Data and information collected will be input in spreadsheet database format for temporal analyses and GIS map construction.
  - GIS maps will be produced to show spatial distribution of ecosystem characteristics of the Yellow Sea.
- Review of available documents on the previous analyses and syntheses of the Yellow Sea ecosystem on a regional scale
- Review of environmental/ecosystem status reports for other regional marine ecosystems
- Analysis of the temporal and spatial changes of ecosystem variables of the Yellow Sea

III. Regional synthesis of data and information

III.1. Phytoplankton

III.1.1. Species composition

There are very few basin-scale studies that provide detailed information on the species composition of phytoplankton in the Yellow Sea. The Chinese national report on ecosystem data and information collection did not provide this information, thus the number of species and their composition are based on the Korean report.

A total of 273 species of phytoplankton were observed in the Yellow Sea in September 1992 (Noh, 1995; Table 1). Diatoms and dinoflagellates accounted for about 97% of the total number of species identified, with diatoms comprising 76.0% and dinoflagellates 30.4%. The proportion of diatoms decreased from coastal areas to central part of the Yellow Sea with stratified water, while that of dinoflagellates increased. Fourteen warm water oceanic phytoplankton species were observed in September 1992, indicating the influence of the Kuroshio Current in the Yellow Sea (Noh, 1995). In a study which covered the coastal water of ROK and the central part of the Yellow Sea, a total of 253 phytoplankton species were reported (Chang, 1990).

Table 1. Species composition of the phytoplankton community in the Yellow Sea in September 1992 (data from Noh(1995)).

Group	Number of species	Percentage
Bacillariophyceae	183	67
Dinophyceae	83	30.4
Cyanophyceae	3	1.1
Chrysophyceae	2	0.7
Chlorophyceae	1	0.4
Cryptophyceae	1	0.4
Total	273	100.0

More diverse phytoplankton species occurred in the coastal waters of PRC and ROK than in the central part of the Yellow Sea, with the most species number in the coastal water off the Taean Peninsula of ROK (Figure 3). Stations off the Yangtze River Estuary also showed higher species number than those in the central part.

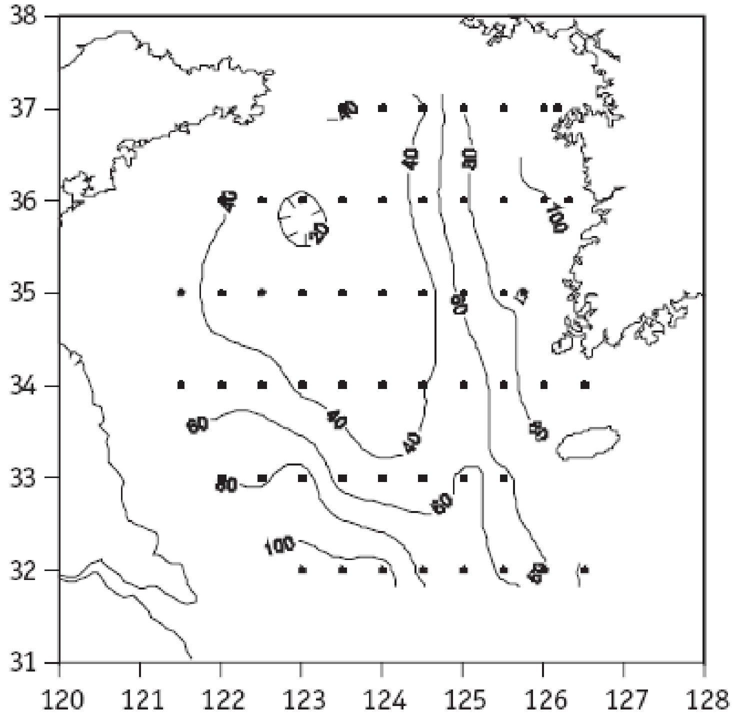

Figure 3. Spatial distribution of phytoplankton species numbers in the Yellow Sea in September 1992 (PICES, 2005).

III.1.2. Abundance

Phytoplankton abundance in the Yellow in 1990s varied greatly in the range of 5,570~856,025 cells/L, temporally and spatially (Table 2). Blooms are known to occur in late winter to early spring, and summer to early autumn (YSLME, 2000; Figure 4).

Table 2. Phytoplankton abundance in the Yellow Sea (data from KEWG(2006)).

Period	Standing crops (cells/L)
Sep-1992	5570~343400 (58930)
Apr-1998	6640~702558 (202890)
Aug-1998	6890~270085 (204320))
Oct-1998	17564~856025 (127717)

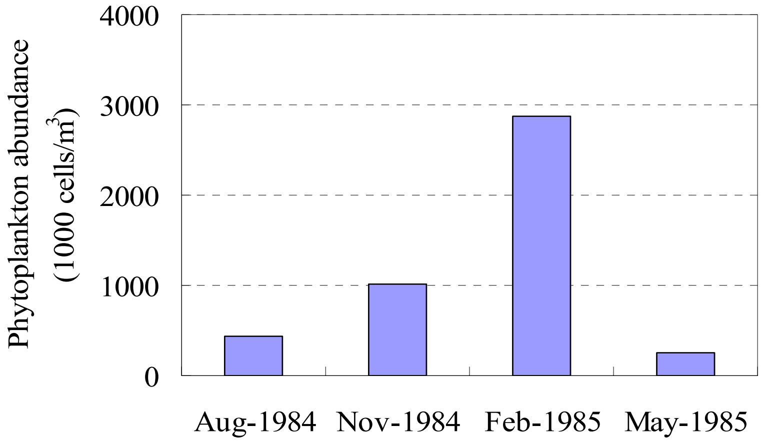

Figure 4. Phytoplankton abundance in the surface water of the Yellow Sea in 1984~85 (data from CEWG(2006)). Phytoplankton samples were made vertically from bottom to top using a net with a mesh size of 77㎛.

High phytoplankton density was found in the southwestern part of the Yellow Sea off the Yangtze River Estuary and in the tidal front area between coastal and central waters of the Yellow Sea. Phytoplankton abundance showed a decreasing gradient from the coastal waters to the central water (KEWG, 2006; OSTI and IOCAS, 1998). The average phytoplankton abundances in the surface water in September 1992 were 81,470 cells/L, 31,610 cells/L, 91,420cells/L for stations from the coastal waters of ROK, the central part of the Yellow Sea, and the coastal waters of PRC, respectively (KEWG, 2006).

The phytoplankton community of the Yellow Sea is mainly composed of neritic diatoms (YSLME, 2000). Dominant species in terms of cell abundance were. *Skeletonema costatum*, *Coscinodiscus*, *Nitzschia, Rhizosolenia*, *Chaetoceros*, *Paralia sulcata*, etc (OSTI and IOCAS, 1998; CEWG, 2006; KEWG, 2006). There was a change in the dominant species along the coastal to central waters gradient, with tychopelagic species such as *Paralia sulcata* being dominant in the coastal water and small dinoflagellates*, Chatoceros*, and *Rhizosolenia* being the dominant species in the central part (KEWG, 2006).

Chlorophyll-a concentrations in the surface water of the Yellow Sea in spring and autumn were in the range of 0.426~17.425 mg/m^3 (KEWG, 2006). In most cases, chlorophyll-a concentrations in the surface were the highest in the southern part of the Yellow Sea off the Yangtze River Estuary (OSTI and IOCAS, 1998; KEWG, 2006. High chlorophyll concentrations were also found in the tidal front area between coastal and offshore waters. The concentrations in the coastal waters were generally higher than those in the central part of the Yellow Sea as in the abundance distribution (Figure 5). The average chlorophyll-a concentrations in the coastal water of ROK, the central part, and the coastal water of PRC in September 1992 were 0.74 mg/m^3, 0.50 mg/m^3, 1.01 mg/m^3, respectively.

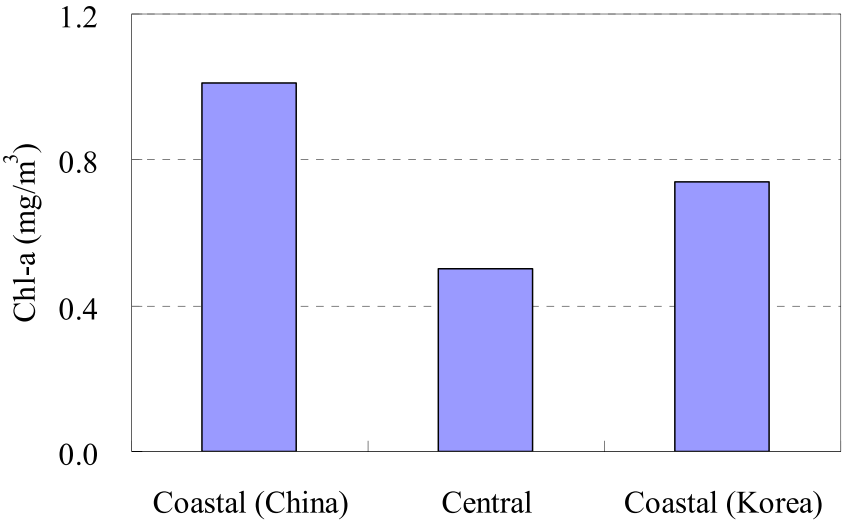

Figure 5. Chlorophyll-a concentration gradient across the Yellow Sea in September 1992 (data from KEWG(2006)).

III.1.3. Primary productivity

Primary productivity in the Yellow Sea varies greatly in the range of 235~894 mgC/m^2/day, depending on season and area in the Yellow Sea (Table 3). With very few scattered productivity measurements or estimations based on different methods, it is difficult to have meaningful temporal and inter-annual changes.

Primary productivity was the lowest in winter, and highest in summer to early autumn (KEWG, 2006; OSTI and IOCAS, 1998). Spatially, high productivity was found in the southern area off the Yangtze River Estuary and the central area of the Yellow Sea. High primary productivity was also measured in the tidal front area between the central and coastal waters (Choi et al., 2003). Coastal waters of the Yellow Sea have lower productivity than the central area (KEWG, 2006; OSTI and IOCAS, 1998; Son et al., 2005). The average primary productivities in the Korean coastal waters, the central part of the Yellow Sea, and the Chinese coastal water in September 1992 were 529 mgC/m^2/day, 765 mgC/m^2/day, and 712 mgC/m^2/day, respectively (KEWG, 2006). Decrease in the euphotic depth due to increasing turbidity in the coastal water was the main factor in the low primary production in the Korean coastal water (Son et al. 2005).

Table 3. Primary productivity of the Yellow Sea.

Period	Number of stations	Primary productivity ($mgC/m^2/day$)	Source	Remark
May 1992	40	196.86 (11.78 ~ 424.92)	OSTI and IOCAS, 1998	Estimation based on chlorophyll-a concentrations, assimilation number, day length, and thickness of euphotic zone
Sep 1992	31	330.91 (65.10 ~ 972.29)	OSTI and IOCAS, 1998	
Sep 1992	40	716 (147 ~ 1694)	KEWG, 2006	^{14}C and P/I data
Apr 1996	23	645 (51 ~ 3461)	KEWG, 2006	
Feb 1997	21	95.25 (10.81 ~ 334.55)	NFRDI, 1998	
Apr 1997	25	872.12 (120.27 ~ 2359.94)	NFRDI, 1998	
Aug 1997	20	893.56 (272.59 ~ 2358.79)	NFRDI, 1998	
Oct 1997	14	616.85 (81.43 ~ 1421.49)	NFRDI, 1998	
Dec 1997		235	KEWG, 2006	
May 1983~2000		835.6	Son et al., 2005	Estimation using satellite data
Sep 1983~2000		672.4		

The Yellow Sea was classified as a Class I LME with high primary productivity (>300gC/m2/yr) (Sherman and Hoagland, 2005). Some estimations on the annual productivity (165gC/m2/yr by KORDI(1993) and 210gC/m2/yr by Son et al.(2005)), however, provide conflicting information, requiring efforts to better estimate the annual productivity.

III.2. Zooplankton

Copepods were the most dominant zooplankton group in the Yellow Sea in terms of abundance (OSTI and IOCAS, 1998; CEWG, 2006; KEWG, 2006), followed by chaetognaths or thaliaceans depending on season and area covered. On the Korean side of the Yellow Sea, the fraction of copepods in the zooplankton abundance has been increasing since the mid-1980s, while that of chaetognaths is decreasing (Figure 6). The highest zooplankton abundance was found in the southern part of the Yellow Sea in October 2004, with relatively high abundance near the Chinese coastal water (KEWG, 2006).

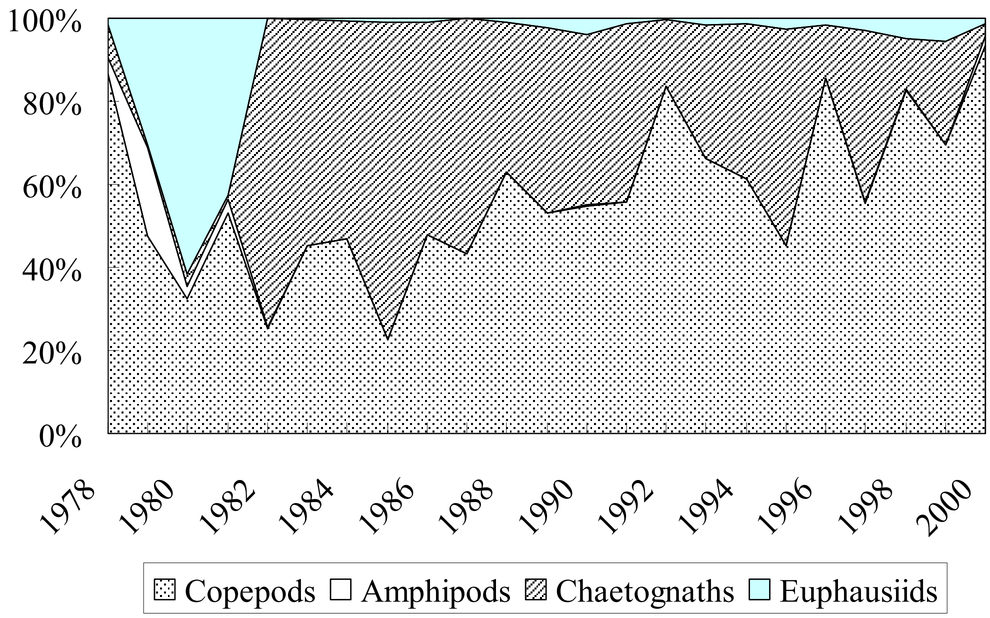

Figure 6. Long-term change in relative composition of four major zooplankton groups during 1978~2000 (KEWG, 2006). A net with a mesh size of 330㎛ was used to sample zooplankton.

Dominant species were *Calanus sinicus*, *Sagitta crassa*, *Euphausia pacifica*, *Themisto gracilipes*, *Acarcia pacifica*, *Corycaeus affinis*, *Paracalanus indicus* (OSTI and IOCAS, 1998; Tang, 1989; CEWG, 2006). Bioindicator species of the warm current such as *Sagitta crassa*, *S. enflata*, *S. nagae* appeared in the Yellow Sea (OSTI and IOCAS, 1998; CEWG, 2006).

Zooplankton biomass on the Korean side of the Yellow Sea showed an increasing trend with more fluctuations since late 1980s, after remaining stable since the mid-1960s (Figure 7). A Chinese source, however, revealed a noticeable decrease in the biomass from 1959 to the mid-1980s (Figure 8).

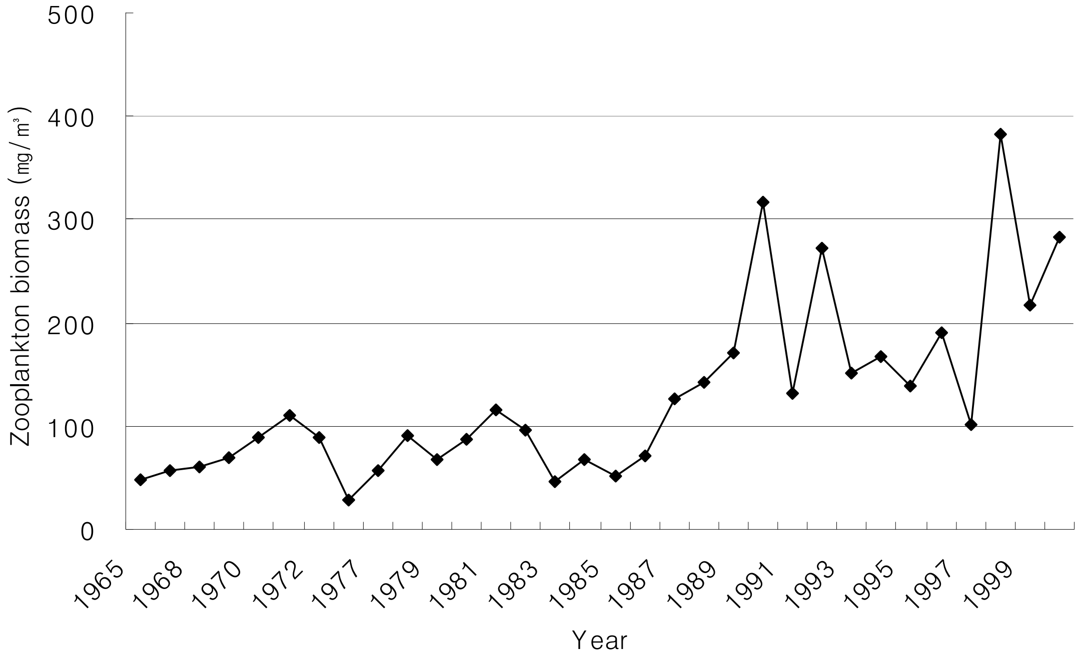

Figure 7. Long-term change in zooplankton biomass in wet weight in the Yellow Sea (KEWG, 2006). A net with a mesh size of 330㎛ was used to sample zooplankton.

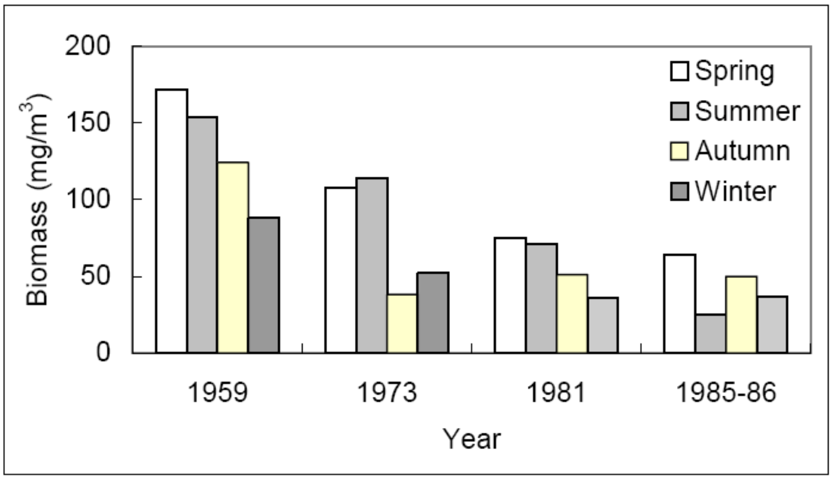

Figure 8. Changes in zooplankton biomass in the Yellow Sea (Sherman and Hoagland, 2005). No mesh size information was available.

Spatial distribution of zooplankton biomass showed the highest biomass in the southern area off the Yangtze River estuary (OSTI and IOCAS, 1998; KEWG, 2006). In many cases, zooplankton biomass was higher in coastal waters of PRC and ROK than in the central part of the Yellow Sea.

Zooplankton biomass showed two peaks in a year in the Yellow Sea. On the Korean side of the Yellow Sea, a larger peak was in June and a smaller one in October on average during 1965~2000 (Figure 9).

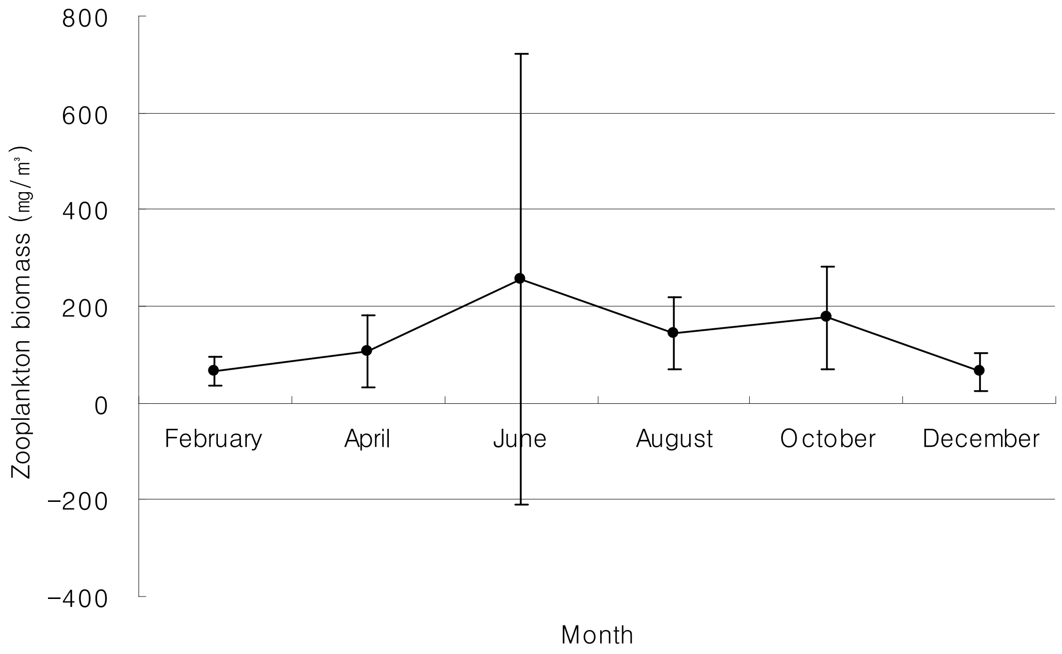

Figure 9. Seasonal change of zooplankton biomass in wet weight in the Yellow Sea during 1965~2000 (KEWG, 2006). A net with a mesh size of 330㎛ was used to sample zooplankton.

III.3. Benthos

Polychaetes were the most dominant benthic group in terms of species richness and abundance in the Yellow Sea (Figure 10, Table 4). Out of 384 species identified in September 1992, polychaetes occupied 48.4% (186 species), followed by molluscs (88 species, 22.9%), crustaceans (84 species, 21.9%), others (17 species, 4.4%), and echinoderms (9 species, 2.3%). Polychaetes comprised 59.2% on average of the benthic abundance in the Yellow Sea in 1990s.

In terms of biomass, however, echinoderms and polychaetes were the dominant benthic group in the Yellow Sea. Echinoderms and polychaetes accounted for 29.2% and 28.5%, respectively, in 1990s.

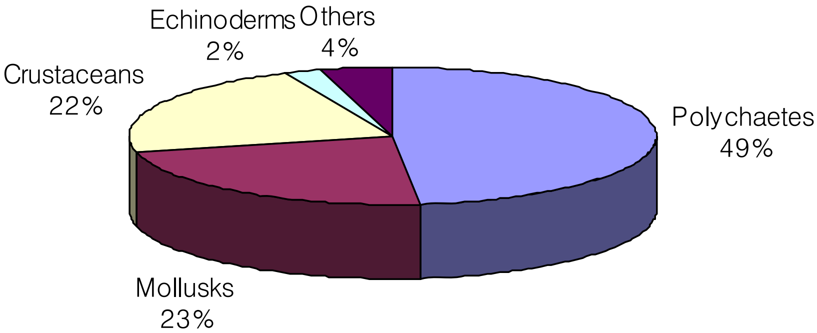

Figure 10. Relative composition of the major benthic groups in September 1992 (data from KEWG(2006)).

Table 4. Relative composition of major groups of benthos in the Yellow Sea (data from KEWG(2006) and CEWG(2006)).

Period	Polychaetes (%)	Molluscs (%)	Crustaceans (%)	Echinoderms (%)	Others (%)
Abundance					
Sep-1992	61.0	18.1	12.6	7.0	1.3
May-1998	53.8	15.6	22.0	6.9	1.6
Dec-1999	49.9	10.3	16.5	3.3	20.0
Aug-2000	53.3	9.5	32.2	3.6	1.4
Sep-2000	77.8	4.9	9.1	6.2	2.0
Average	59.2	11.7	18.5	5.4	5.3
Biomass					
Sep-1992	42.9	19.9	10.9	15.6	10.6
May-1998	20.1	16.9	8.5	36.4	18.1
Dec-1999	20.2	12.1	6.0	36.4	25.4
Aug-2000	30.3	9.0	20.8	20.4	19.5
Sep-2000	29.0	6.0	8.8	37.1	19.1
Average	28.5	12.8	11.0	29.2	18.5

The biomass of the Yellow Sea benthos remained relatively stable at a long term average of 23 mg/m^2 from 1959 through 1992 (Sherman and Hoagland, 2005). Recent investigations had higher biomass than the long term average until 1992 (Figure 11). Data and information on the biomass is not sufficient to conclude any meaningful change in the benthic community in the Yellow Sea.

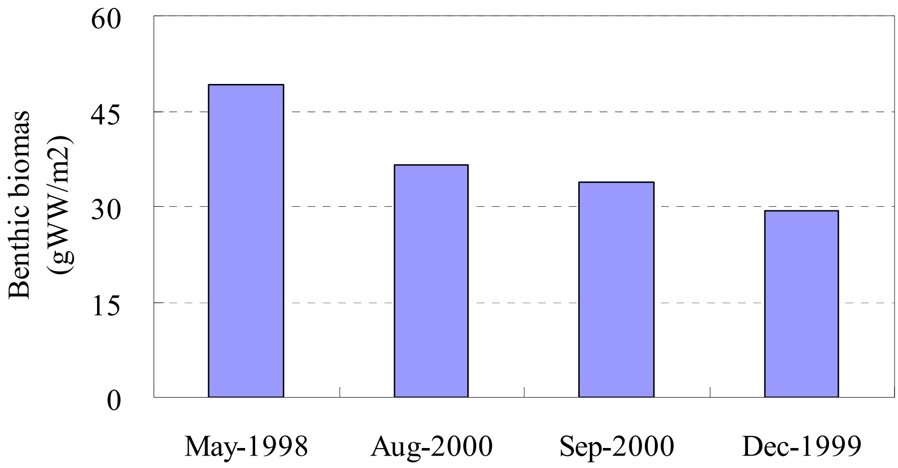

Figure 11. Benthic biomass of the Yellow Sea in late 1990s (data from CEWG(2006)).

In most cases, benthic abundance and biomass were the lowest in the central area of the Yellow Sea in 1980s and 1990s.

Spatial distribution of diversity index and benthic community productivity in September 1992 also followed the general spatial distribution in abundance and biomass. The average diversity index of the benthic community was 2.42, with higher values in the coastal water of ROK and the southern part of the Yellow Sea than in the central part. Benthic community productivity was the highest in the Korean coastal water, with an average of 4.67 g/m^2/yr in ash free dry weight (a range of 2.29~6.91g/m^2/yr).

Benthic macrofaunal communities may be divided into two large-scale assemblages: Yellow Sea coastal shelf assemblage dominated by eurythermal and low salinity species and Yellow Sea central clayey bottom assemblage dominated by low temperature and high salinity fauna (KEWG, 2006; OSTI and IOCAS, 1998). The coastal shelf assemblage is much higher in most benthic community parameters such as abundance, biomass, diversity, and productivity than in the central bottom water. The southern part of the Yellow Sea that is influenced by the compositionally southern elements showed different species composition and abundance from the two assemblages (KEWG, 2006). Warm water tropical species were found in the southeastern region of Jeju Island in ROK (OSTI and IOCAS, 1998).

III.4. Harmful algal blooms (HABs)

Occurrences of HABs in the coastal waters of the Yellow Sea have dramatically increased in frequency, intensity, and geographical extent over the last three decades, resulting in significant economic losses to the aquaculture industry in the region (Figure 12). In the coastal water of ROK, there have been 70 cases of HABs over the last 22 years (1984~2005), with a peak of 10 cases in 1998. Over the same period, 59 HAB events (65 cases since 1972) were observed in the Chinese coastal water, with peaks in 1990, 1999, and 2001 (CEWG, 2006; KEWG, 2006). HAB occurrences in the last 6 years (2000~2005) have reached 68% (38 cases) in the Korean coastal water and 81% (21 cases) of those in 1990s. Construction of dams and barriers that inhibit circulation in coastal water was suggested as the cause of HABs in the coastal area of ROK, and eutrophication due to mariculture activities in the coastal water of PRC (PICES, 2005).

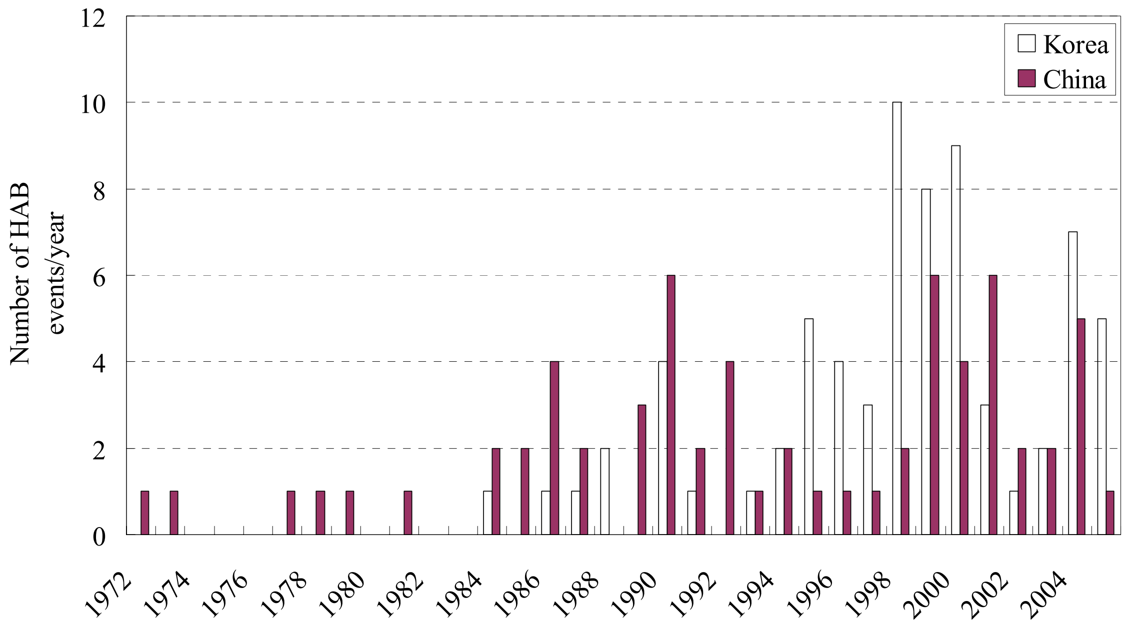

Figure 12. HAB occurrences in the coastal waters of PRC and ROK (data from KEWG(2006) and CEWG(2006)).

HAB occurrences reached the peak from June to August for the Korean side of the Yellow Sea and from July to August for the Chinese side. HABs have started earlier in the coastal waters of PRC and ROK over the last three decades. In the Chinese coastal water, HABs were observed in April since 1980s. With increasing HAB events, the HAB season lasted longer in 1990s than in 1980s in the coastal water of ROK. Most HAB events ended in August in 1990s in the coastal water of PRC, but some events lasted until September in 2000s.

More than 20 species of algae were responsible for the HABs in the coastal water of ROK, with diatoms and dinoflagellates accounting for most of the species identified (Table 5).

Blooms caused by fish-killing dinoflagellate *Cochlodinium polykrikoides* were observed in Kunsan in 1998 and 1999, but no fish damage reported without fish farms in the area. HABs were caused by more than 10 species in the Chinese coastal water (CEWG, 2006), with more frequent HABs in the vicinity of the Yangtze River Estuary (PICES, 2005).

Table 5. HAB causing species in the Yellow Sea (data from KEWG(2006) and CEWG(2006)).

Period	ROK	PRC
1970s		*Mesodinium rubrum, Skeletonema costatum*
1980s	*Noctiluca scintillans*	*Heterosigma akashiwo*, *Skeletonema costatum*, *Thalassiosira nordenskioldi*, dinoflagellate
1990s	*Ceratium* sp., *Chaetoceros* sp., *Chroomonas salina, Coscinodiscus gigas, Guinardia flaccida, Cochlodinium polykrikoides, Heterosigma akashiwo, Mesodinium rubrum*, *Microcystis* sp., *Noctiluca scintillans*, *Prorocentrum minimum, Skeletonema costatum, Thalassiosira* sp.	*Biddulphia aurita*, *Chaetoceros*, *Chattonella marina*, *Eucampia zoodiacus*, *Gymnodinium*, *Heterosigma akashiwo*, *Mesodinium rubrum*, *Noctiluca scientillans*, *Phaeocystis*, *Skeletonema costatum*, *Thalassiosira nordenskioldi*, Pyrrophyta, Euglenophyta,
2000s	*Alexandrium* sp., *Ceratium fusus, Chroomonas salina, Dinophysis acuminata*, *Eucampia zodiacus*, *Eutreptiella gymnastica, Gyrodinium* sp., *Heterosigma akashiwo, Leptocylindrus danicus, Mesodinium rubrum, Nephroselmis* sp., *Noctiluca scintillans, Prorocentrum micans, P. minimum, P. triestinum, Pseudo-nitzschia pungens, Skeletonema coatatum, Thalassiosira* sp.	*Chaetoceros socialis*, *Eucampia zoodiacus*, *Heterosigma akashiwo*, *Mesodinium rubrum*, *Noctiluca scientillans*, *Skeletonema costatum*, dinoflagellate

IV. Information gaps and recommendations to fill the gaps

IV.1. Information gaps

The synthesis of the Yellow Sea ecosystem data and information provided in the national reports prepared by experts in PRC and ROK has revealed severe lack of basin-scale ecosystem information for any meaningful analysis on the status of the ecosystem. There were no long-term data and information available for the basin-scale analysis, except for a couple of parameters. Even seasonal analysis of the ecosystem in a given year was not possible because most data and information were scattered and sporadic one-time investigations.

It seems that this lack of data and information has resulted from insufficient investigations in the past. Other factors might also have led to the current data and information problem, such as inadequate data and information mining and governmental restriction on the opening of and access to those data and information.

Different sampling methods and area covered in those investigations further limited the basin-scale analysis of the data and information collected in the national reports. For example, water samples were taken for phytoplankton analysis in Korean investigations, while a net with a mesh size of 77㎛ were used for Chinese samples. The mesh sizes of zooplankton nets were also different: 505㎛ for Chinese sampling and 330㎛ for Korean sampling.

In addition to the general gaps mentioned above, gaps in data and information on specific ecosystem components are listed in Table 6. These parameters should be included together with the data and information provided in the national reports in the future surveys on the Yellow Sea ecosystem.

IV.2. Recommendations to fill the gaps

IV.2.1. Systematic data and information collection

With the delays in the scheduled basin-scale surveys, the best available option for understanding the Yellow Sea ecosystem is to have as much past data and information as possible. More efforts should be made to dig out existing data and information on the Yellow Sea ecosystem. Because surveys done in PRC and ROK adopted different sampling methods and strategies, qualitative data and information may be more useful in understanding the ecosystem from a management perspective.

The YSLME Project Management Office (PMO) should act as a clearing house for all the data and information collected in the process so that diverse experts and managers have easy access to the data and information. By doing so, PMO would have a broader expert pool to turn to when needs arise.

Table 6. Gaps in data and information on the Yellow Sea ecosystem (KEWG, 2006).

Items	Gaps in data and information
Phytoplankton	Species composition - seasonal species composition except autumn - detailed species composition for each taxonomic group Abundance - winter data, - detailed data on diverse taxonomic group such as picoplankton - chlorophyll-a Primary production - winter and summer production
Zooplankton	Detailed species composition for all zooplankton groups Species composition in other seasons than May and December Depth distribution of zooplankton
Benthos	Species level identification for all taxonomic groups Seasonal data except September
HABs	Species composition Detailed abundance on other taxonomic groups such as picoplankton Detailed species composition of picoplankton groups

IV.2.2. Establishment of a basin-scale joint survey program

Basin-scale surveys are needed not only to better understand the current status of the Yellow Sea ecosystem for the Transboundary Diagnostic Analysis and the Strategic Action Programme (SAP) but also to have sufficient scientific data and information to evaluate the effectiveness of SAP implementation in the future. It is, therefore, very important to establish a long-term basin-scale survey program.

Appropriate frequencies of surveys are very important to have data and information for properly understanding ecosystem structure and processes. The ecosystem components in lower trophic levels such as phytoplankton and zooplankton require very frequent samplings. This may require monthly or even weekly sampling, which demand a huge funding resource. It is important to note that the survey program is not for pure scientific researches but for management purposes in the decision of appropriate balance among available fund, research personnel, and survey frequency.

In this regard, the joint survey program can be divided in two components of scanning survey and target survey. Essential parameters for management purposes are only measured in the scanning survey, while in-depth or contingent measurements for extended parameters are made in the target survey. The scanning survey should be made for at least four seasons every year, and the target survey be carried out every five years or when contingent environmental issues arise. This structure would provide both managers and scientists with necessary data and information on the Yellow Sea ecosystem.

Prioritization of survey items for each ecosystem components is required considering practical problems such as funding availability and research manpower. Again, the key point is that the first objective of the joint survey program is to get data and information and understand the ecosystem structure and processes for the management of the Yellow Sea ecosystem. In this way, we will have the most essential data and information on the ecosystem when there is insufficient funding for the program. This would also prevent random addition of survey items not relevant to the management purposes. Cooperation with existing marine ecosystem surveys in PRC and ROK is another way to overcome the funding and research manpower problems.

The joint survey program would provide a scientific basis for the sustainable management of the Yellow Sea ecosystem with long-term data and information using the same sampling methods, area, and time. Steady participation of the same experts for each ecosystem component is also an important factor for the survey in obtaining consistent data and information. For example, phytoplankton experts agree on that cell counting by different researchers may yield different results even with the same set of samples.

IV.2.3. Utilization of remote sensing technology

Organisms in low trophic levels in food webs have fast turnover time, which requires frequent sampling and observation for properly understanding their functioning in ecosystems. There are, however, some practical constraints on the number of surveys in a year to be made. Remote sensing technologies are a viable option to overcome the constraints to some extent. There has already been much progress in estimating chlorophyll and primary production in marine ecosystems with satellite data. Workshops on remote sensing technologies and their application are needed to exchange information and experiences and to work within the same framework regarding the application of those technologies to the Yellow Sea ecosystem.

IV.2.4. Collection of data and information on the coastal water of DPRK

As an integrated part of the Yellow Sea ecosystem, the ecosystem condition in the coastal water of DPRK will influence other parts of the ecosystem. Even though there are poor data and information on the basin scale, lack of data and information on the DPRK side is more severe than on the other parts of the Yellow Sea. It is, therefore, important to establish strategies to secure ecosystem data and information on the coastal water of DPRK.

V. Persons/Institutions visited or interviewed

An, Soonmo, Professor, Pusan National University (Benthos)
Choi, Heejung, Researcher (GIS maps)
Hong, Jaesang, Professor, Inha University (Benthos)
Kang, Junghoon, Researcher (Zooplankton)
Lee, Changhee, Professor, Myungju University (Synthesis)
Moon, Changho, Pukyung National University (Phytoplankton)
Nam, Jungho, Research Fellow (Synthesis)
Park, Jonggyu, Kunsan National University (Phytoplankton and HABs)
Yeo, Hwangu, Professor, Hanseo University (Phytoplankton and HABs)

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