State Report of the Seas of Republic of Korea

Korea Ocean Research & Development Institute

Ministry of Land, Transport and Maritime Affairs

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Ⅰ. Overview

1. Purpose

The efforts to understand and improve marine environmental state have been carried out by some developed countries and international organizations in the circumstance of growing degradation in marine environmental state such as, excessive catch of fishes, increase of pollutants, decrease of habitats, ecosystem change caused by climate one, increase of natural disasters, decrease of fishes stocks, etc at the world level. However, credible information with scientific facts and integrated assessment of marine environment at the global level to support policy-makers' decision-making is not sufficient.

In 2002, the world summits on Sustainable Development (WSSD) supported actions at all level to “establish by 2004 a Regular Process under UN for global reporting and assessment of the state of the marine environment including socio-economic aspects, both current and foreseeable, building on existing regional assessments”. “Assessment of Assessment” (AoA) as a preparatory stage towards the establishment of the ‘Regular Process’ is being implemented.

This report aims to support policy-makers' decision-making to conserve and manage integrated marine environment in ROK by providing credible and scientific information through assessing marine environmental state and its progress and to provide data to assess integrated marine environmental state at a global level.

Assessment gaps will be identified through analyzing data related to status and assessment of marine environment in ROK. Strategies to fill the gaps and improve marine environmental state will be suggested as well as to improve appropriate capacity-building which meets the requirements from UN Regular Process.

2. Participants

The experts from various institutions in Korea participated in this effort to assemble the information on the availability of coverage of existing data relevant to the assessment of marine environments in the Korean seas. They represent:

- Korea Ocean Research & Development Institute
- Korea Maritime Institute
- National Fisheries Research & Development Institute
- Pukyung National University
- University

3. Scope of the survey

There are 21 regions defined in the AoA. The geographical coverage of this survey includes the three marginal seas in the Northwest Pacific: the Yellow Sea, the East China Sea, and the East Sea (Sea of Japan). These seas correspond to AoA region No 5 (East Asian Seas: Yellow Sea, East China Sea) and No 12 (North-West Pacific oceans: East Sea).

The data searched in this survey include variables pertaining to climate, oceanographic, biological, chemical, fisheries, and socio-economic properties:

- Climate variables: air temperature, air pressure
- Oceanographic variables: sea temperature, sea level
- Chemical variables: nutrients, heavy metals, organic pollutants
- Biological variables: phytoplankton, zooplankton, larval fish, benthos
- Fisheries: major commercial fish
- Socio-economic aspects: population statistics, marine tourism statistics, marine litters, fisheries and aquaculture, legislation, management policies

4. Results of the survey

4.1 Hydrographical conditions and climate

- Sea surface temperature (SST) has been increasing with a rate of 0.019 °C/yr in the Korean coastal waters for the past 30 years. The SST increase in winter was 0.035 °C/yr for the same period. In the upper layer of the East Sea (down to 1,000m), a temperature increase of 0.1-0.5 °C/yr has been observed.

- Extrapolation of the past 39 year trend indicates that SST will be increased to 18.9 °C by the year 2100.

- The sea level rise has also been observed in the coastal regions of Korea. Jeju Island shows a sea level rise rate of 0.5 cm/yr, which is the maximum rate in Korea.

4.2 Chemical components and pollutants

- Point sources of pollutants such as metals, nutrients, PAHs, and other contaminants have been reduced in number since late 1990s.

- The infrastructure of sewage treatment has been improved with better compliance with water quality standards, except some specialized areas.

- Some persistent chemicals are not routinely monitored and diffuse sources may pose a problem near urban and industrial areas.

4.3 Biological communities

- Frequency and intensity of red tides in the coastal waters of Korea have greatly increased over the last three decades, causing significant economic damages to aquaculture industry. Toxic red tides have occurred since 1990s, leading to massive deaths of fish and shellfish. The area of red tide occurrence has also extended from the southern coastal waters to the entire coastal waters.

- Habitat loss due to reclamation mostly in the western coast, massive oil spill accident in 2007 in the western coast, and hypoxia by eutrophication in the inner bays of the southern coast affect benthic community.

- The number of wintering bird, Baikal teal, has continued to increase since 2002 in the western coast. This trend would be due to the environmental changes in the tundra area of main wintering ground by global warming.

4.4 Fisheries

- CPUEs of major fish species have been decreased, and the proportion of small fish has been increased.

- Coastal nursery areas and sea weed areas are reduced, so that bad recruitment of major fish species was often found. Restoration of original habitat and pollutants control are required.

- The composition of fish species in catch has been changed from time to time depending on changes in climate.

4.5 Socio-economic aspects

- As of 2007, 26.6% of the Korean population live in the coastal areas with 32.4% of the cities is located in the coastal area. Of the coastal populations, 88.9% reside in the cities. Urbanization in the coastal areas is still continuing with an increase of 0.57% per year.

- Urbanization of coastal areas has been resulted from industrialization as coastal areas have advantages in transportation and accessibility. Urbanization and industrialization of coastal areas inevitably have incurred environmental problems and five special management regions are designated to protect from further degradation and to promote restoration.

- Sewage treatment rate has increased from 66% in 1996 to 70% in 2006. By 2011, the treatment rate will be increased to 87%.

- About 20% of the mudflat areas have been reclaimed since 1987 with damages in the habitats and ecosystem functions. Introduction of conservation policy has significantly reduced reclamation since 1996.

5. Gaps

- Monitoring conducted by different agencies in Korean waters is irregular in terms of spatial and temporal coverage. Uneven data coverage makes the analysis of trend and status evaluation difficult.

- Although signs of climate change are evident in Korean waters such as the rise in sea temperature, its impacts on the ecosystem is not clear. Monitoring schemes including variables and frequencies should be revised to aim to assess the impacts of climate changes as well as anthropogenic changes in the coastal waters.

- Some crucial information is not regularly collected, such as fisheries stock assessment. Current information required for fisheries management relies heavily on catch statistics. Scientific stock assessment needs to be a part of monitoring scheme. This information can be used for setting the total allowable catch with other oceanographic information.

- While stressors of ecosystem or direct drivers are monitored, the link with indirect drivers is less understood quantitatively. Current understanding of the processes of the ecosystem changes is rather fragmentary. To have better management policies, a better understanding of the causal chains leading to the root causes.

6. Recommendations

- Although monitoring is conducted by various agencies, the efforts need substantial re-organization and improvement. The variables to monitor need to be reviewed and adjusted to include common core variables and the methodologies of conducting observation and sample analysis should be harmonized.

- In selecting the variables to be monitored, indicators of ecosystem status need to be considered. At present, there is no evaluation system with status and stress indicators. Therefore, such evaluation system should be developed. The geographical and temporal scales of monitoring need to be adjusted so that monitoring network can provide comprehensive datasets that feed the evaluation system.

- Socio-economic analysis linking indirect drivers and direct drivers of ecosystem changes needs to be performed to aim a full causal chain analysis. To this end, socio-economic analysis should be a part of the marine ecosystem management system side-by-side with a comprehensive monitoring network.

Ⅱ. Climate variability in the neighboring seas of Korea

1. Introduction

The Korean Peninsula is located where the Siberian High and the subtropical Pacific Low collides producing cold-dry winter and a warm-wet summer. North and northwest winds in the autumn and winter are strong, and wind speed easily reaches 10 m s^{-1}. Winds reverse the direction and become weaker in the spring and summer. Typhoons developed in the west subtropical Pacific bring heavy rains in the summer and autumn. On the average, about nine typhoons pass the region every year (Kim and Khang, 2000). The trend in temperature over the Korean Peninsula has been increasing by 0.23℃ $decade^{-1}$ since 1950s. Also, it was found that unusual wet and dry periods alternate over Korea. For example, a wet period appeared in Seoul during the 1950s to the early 1970s, a dry period during the mid 1970s to the mid 1980s and turned to a highly wet period after the 1990s.

Seas around the Korean Peninsula are the Yellow and Bohai Seas to the west, and the East/Japan Sea (the East Sea, hereinafter) to the east that is connected to the East China Sea through the southern sea of Korea (Fig. 1). The Yellow Sea is geographically separated from the East China Sea by the line connecting the Jeju Strait and the mouth of the Yangtze River, and the Bohai Sea is considered as a bay separated from the Yellow Sea by the line between the Liaodong and Shandong Peninsula. The Yellow, Bohai, and East China Seas covering a total area of about $9x10^5$ km^2 lie on the continental shelf shallower than 200 m except the Okinawa Trough, which reaches 2700 m deep, west of the Ryuku Islands that is the border between the East China Sea and the North Pacific. On the other hand, the East Sea covering a total area of about 1.01×10^6 km^2 is a semi-enclosed deep marginal sea with an average depth of 1684 m. It consists of three deep basins greater than 2,000 m deep: the Japan Basin in the northern half that is almost 4,000 m deep, the Ulleung Basin to the southwest, and the Yamato Basin to the southeast The East Sea is connected with the East China Sea through the Korea Strait, with the North Pacific through the Tsugaru Strait, and with the Sea of Okhotsk through the Soya Strait. The Korea Strait splits into the western and eastern channels with Tsushima Island in between them. As these straits are shallower than 200 m, water exchanges in the East Sea with adjacent seas are very limited in the East Sea, and there exist deep water formation and deep circulation in the East Sea independent of those in the North Pacific. General upper circulation of the seas around Korea is shown in Fig. 2, which will be described in sections 4 and 5. Reviews of physical oceanography of the seas around Korea can be found in Preller and Hogan (1998), Ichikawa and Beardsley (2002), Lie and Cho (2002), and Chang et al. (2004).

Observations and modeling investigations suggest distinct scales of temporal climate variability in oceanographic variables such as temperature and currents – from subannual (e.g., Lee and Cornillon, 1996) through seasonal (e.g., Schott and Molinari, 1966) and interannual Mizuno and White, 1983), and all the way to interdecadal (e.g., Deser et al., 1996). These can be either forced or free (e.g., Chang et al., 2001) variability, the latter due to system's instability and nonlinearity. Furthermore, due to the recent increases in greenhouse gases in the atmosphere, the world's climate is rapidly changing. IPCC report (2007) suggests that the global warming will cause not only the oceanic temperature and sea level rises but also impact the overall oceanic environments comprising changes in ocean circulation system, biogeochemical cycles, and the related fisheries resources. The ocean's meridional overturning circulation is known to play a pivotal role in earth's climate and its changes because it controls oceanic heat and materials transport including CO_2, and air-sea heat and gas exchanges.

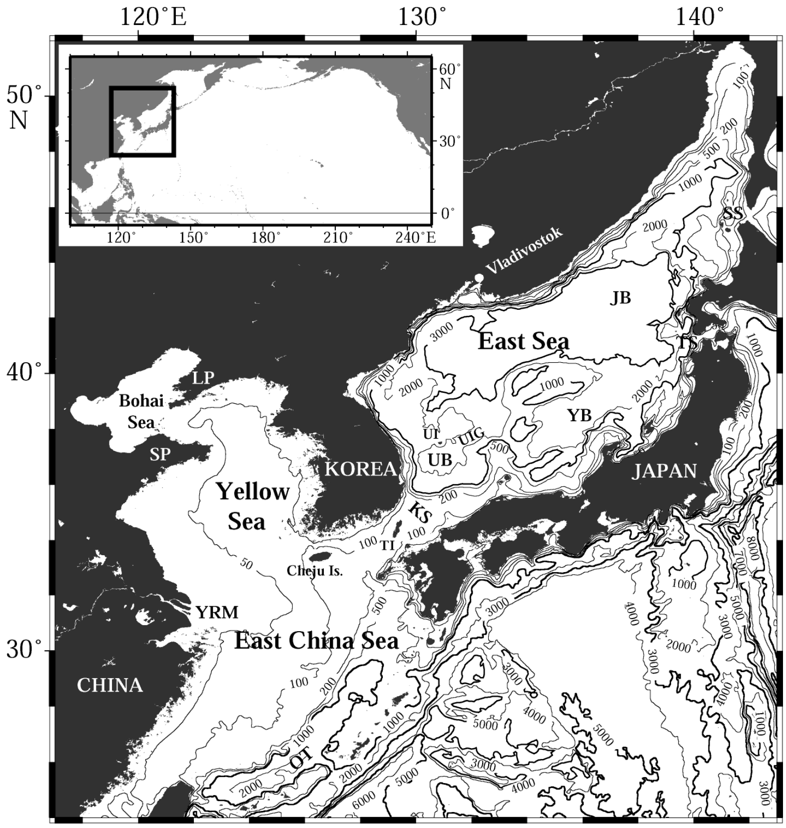


Fig.1. A topographic map of the seas around Korea with isobaths of 50, 100, 200, 500, 1000, 2000, 3000, 4000, 5000, 6000 m. SP, LP, YRM. OT, KS, TI, UB, UIG, UI, YB, JB, TS, SS denote the Shandong Peninsula, Liodong Peninsula, Yangtze River Mouth, Okinawa Trough, Korea Strait, Tsushima Island, Ulleung Basin, Ulleung Interplain Gap, Ulleung Island, Yamato Basin, Japan Basin, Tsugaru Strait, Soya Strait, respectively.

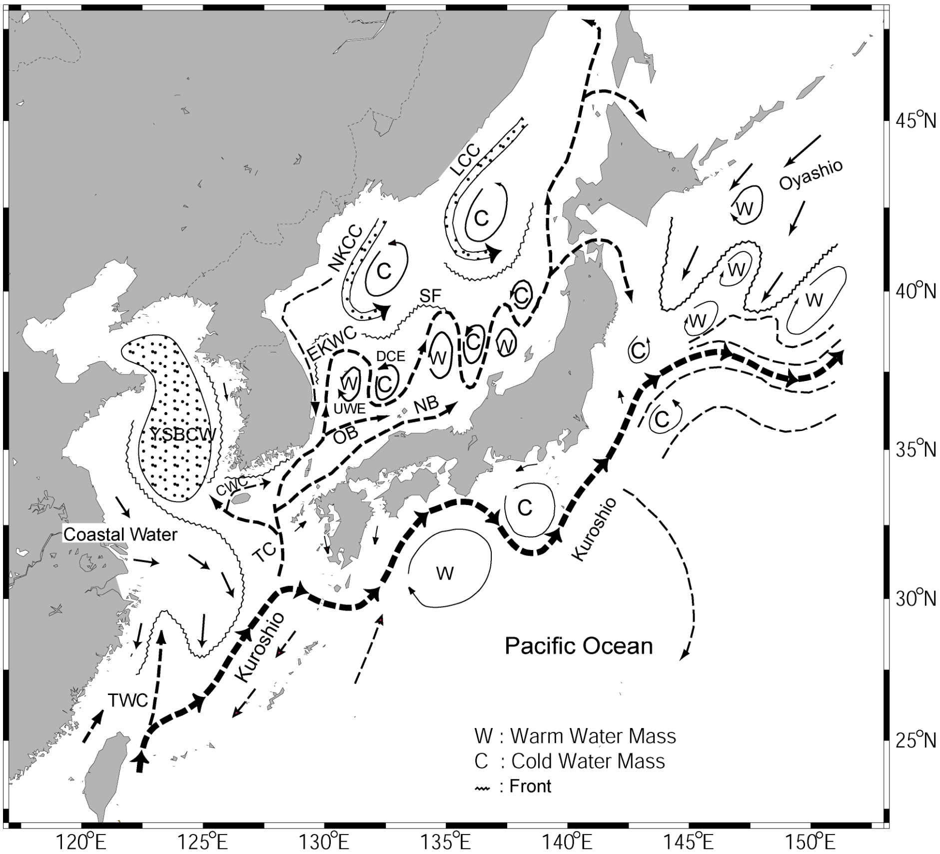


Fig. 2. A schematic surface circulation in the seas around Korea. YSBCW, TWC, TC, CWC, NB, OB, EKWC, UWE, DCE, SF, NKCC, LCC denote the Yellow Sea Bottom Cold Water, Taiwan Warm Current, Tsushima Current, Cheju Warm Current, Nearshore Branch, Offshore Branch, East Korean Warm Current, Ulleung Warm Eddy, Dok Cold Edd, subpolar front, North Korean Cold Current, and Liman Cold Current, respectively

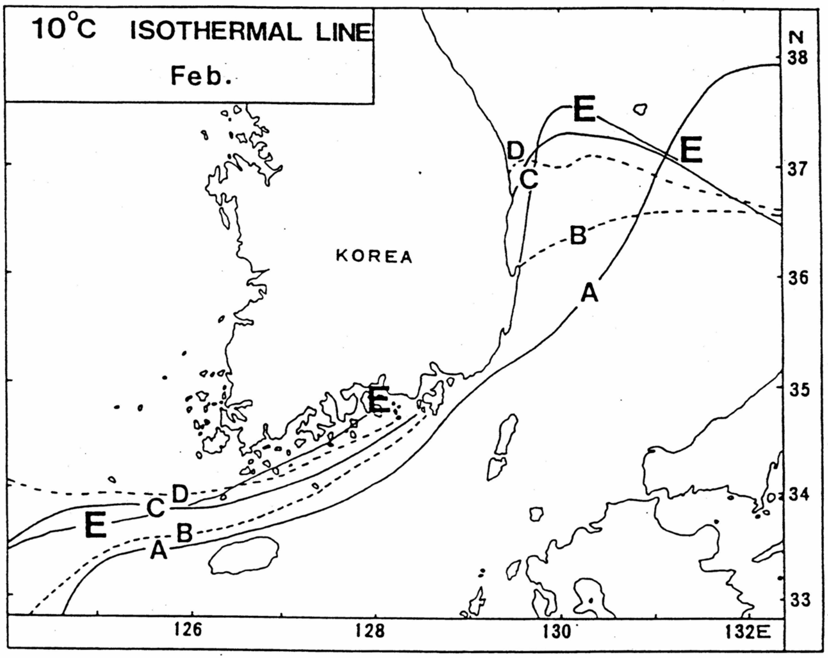
2. Monitoring oceanic environment for climate change in Korea

2.1 Thermal variation in the neighboring seas of Korea

The sea surface temperature (SST) in the East Sea has risen approximately by 2℃ over the past century, which is especially clear near North Korean coastal region.

Based upon the relationship between SST anomalies and ENSO signal in the East Sea, El Nino summer is colder than the previous summer and El Nino winter is warmer than the previous winter (Hong et al., 2001), which is vice versa for La Nina. Long-term variability of water temperature in the East Sea (Park et al., 2000; 2002) shows that it had decreased from 1960s and increased since 1980s in the southern region while it had persistently increased fro 1960s to late 1980s in the northwestern region.

Hahn's reports (1994, 2000) shows the long-term variation of SST around Korea from 1881 to 1990; Fig. 3 represents the northward migration of the isothermal distribution of 10℃ in February, which is especially remarkable in the coastal regions of the South and the East Seas. There is also a similar trend of thermal variability in August, but the E line (average position of the isotherm between 1976 and 1990) is closer to the coasts by 30 to 60 knautical miles in the South and Yellow Seas (Fig. 3) Through the total period, there is a thermal rise by 2℃ in February and 1℃ in August.



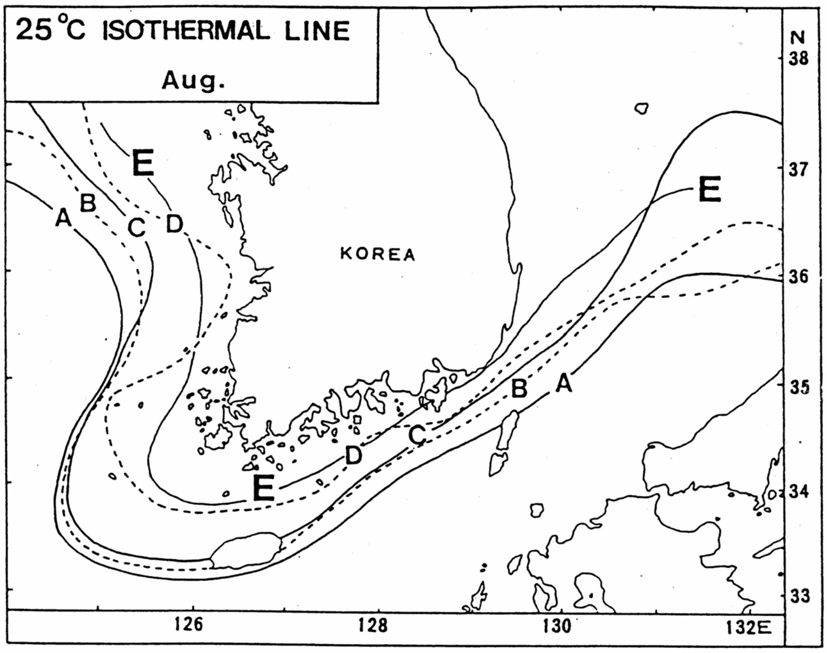


Fig.3. Distributions of the 10℃ and 25℃ isotherms in February and August, respectively, in the coastal areas of Korea. The averaging periods are; A: 1881-1910, B: 1911-1925, C: 1926-1940, D: 1961-1975, E: 1976-1990. (Hahn, 1994)

Table 1 represents the linear trend of SST anomalies from daily measurements around the Korean Peninsula (Kang, 2000); 9 out of 12 stations show the increasing trend with the average rate of +0.008℃/year for the last 60 years, while 17 out 18 stations show the faster increasing trend with the rate of +0.019℃/year for the last 30 years. The increasing rate in winter is even faster, which is +0.019℃/year for the last 60 years and +0.035℃/year for the last 30 years.

Table 1. Various estimations of long-term linear trends of SST in the seas around Korea. (NA: not available)

Area		Linear trend	Reference	Data period	Data used	Data source
Bohai Sea		0.011℃yr^{-1}	Lin et al. (2001)	1960~1997	Annual mean SST	6 coastal stations
Yellow Sea		0.01℃yr^{-1}	Lin et al. (2001)	NA	NA	NA
East China Sea		0.01℃yr^{-1}	Lin et al. (2001)	NA	NA	NA
East Sea	Japan Basin	0.0885℃yr^{-1}	Kwon (1998)	1945~1991	Wintertime SST (Dec.~March)	Various sources of basin-wide hydrographic data
	Yamato Basin	-0.0199℃yr^{-1}	Kwon (1998)	1950~1991		
	Ulleung Basin	0.0419℃yr^{-1}	Kwon (1998)	1953~1991		

Neighbouring seas around Korea		0.023℃yr $^{-1}$ (February)	Hahn (1997)	1881~1990	15-year mean SST for 5 periods	Various sources of SST charts
		0.013℃yr $^{-1}$ (August)				
Neighbouring seas around Korea		0.024℃yr $^{-1}$ (annual mean)	Kang (2000)	1966~1995 (30 years)	Low-pass filtered daily SST, subsampled every 5 days	18 coastal stations
		0.035℃yr $^{-1}$ (Feb.~March)				
		-0.010℃yr $^{-1}$ (Aug.~Sept.)				
Neighbouring seas around Korea		0.007℃yr $^{-1}$ (annual mean)	Kang (2000)	1936~1995 (60 years)	Low-pass filtered daily SST, subsampled every 5 days	12 coastal stations
		0.019℃yr $^{-1}$ (Feb.~March)				
		-0.014℃yr $^{-1}$ (Aug.~Sept.)				
Neighbouring seas around Korea (annual mean, winter, summer)	East coast	0.035℃yr $^{-1}$, 0.058℃yr $^{-1}$, 0.005℃yr $^{-1}$	Re-estimated from Kang (2000)	1966~1995	Low-pass filtered daily SST, subsampled every 5 days	18 coastal stations
	Southern coast	0.016℃yr $^{-1}$, 0.015℃yr $^{-1}$, -0.038℃yr $^{-1}$				
	West coast	0.022℃yr $^{-1}$, 0.032℃yr $^{-1}$, -0.043℃yr $^{-1}$				

Measurements from CREAMS program show that there is a thermal increase by 0.1-0.5℃ in the upper layer from sea surface to 1,000 meters and by 0.02℃ in the layer below 2,000 meters in the East Sea (Kim, 1996). The variation of deep water temperature is coincident with that of other tracers such as dissolved oxygen and chlorofluorocarbons (CFC), which implies that the continuous change of the vertical structure of water masses for several tens of years is greatly associated with global warming (Kim et al., 2001).

2.2 Sea level change

Sea level rise in the East Sea appears to have increased faster than the global average and to have been predominantly caused by the effect of thermal expansion, which implies that she is more affected by climate change.

Yi(1966, 1967, 1969), Choi (1983), and Kang and Lee (1985) analyzed annual and semiannual characteristics of the average sea levels along the Korean coasts. Oh et al.(1993) reported that sea levels in the East Sea have risen in summer and fall and fallen in winter and spring except at Sakhalin, and that annual component is predominant and semiannual component is also clearly shown. Oh et. al (1997) showed that short-term variability less than 6 months is dominant along the southern Chinese coasts and at Hokkaido while longer-term variability is dominant along Korean and Japanese southern coasts where Tsushima Warm Current and Kuroshio are influential. Sea level pressure has affected approximately 30 percents of sea level change in this region.

Choi et. al (1999) analyzed long-term variation of tides and atmospheric factors such as sea level pressure and wind stress from 56 tide-gauge stations in the East Sea and in the

Yellow and East China Seas; the variability of sea level pressure has affect 25 % of monthly-mean sea levels, which is comparable with the result by Oh et. al (1997). They suggested the linear trend of annual mean sea levels. The sea levels are falling at the Pohai Bay (-0.1 ~ -1.1mm/year) and at Inchon (-1.5mm/year) and along the Japanese coasts (-0.4 ~ -2.4mm/year) in the East Sea while they are rising along the western and southern coasts of Korea and along northwestern coasts in the East Sea (1.0 ~ 4.7mm/year). Kang et. al (2002) reported that the rising trend of sea levels were not clear at Wando and at Yeosu.

The factors of long-term variability of sea levels are 1) land level uplift or fall, 2) thermal expansion by the increase of water temperature, 3) the increase of water volume by melting of ice in the Antarctic and Greenland etc., 4) interior volume change of the basins, and 5) change of wind and current systems. Yanagi et. al (1993) reported that the linear trend of monthly-mean sea levels between 1953 and 1980 from the tide-gauge stations except at the stations with abrupt submergence by earthquakes or by over-usage of ground water; it is -1.0mm/year along the coasts of the East Sea and 0~0.5mm/year along the eastern coasts of Japan in the Pacific. The linear trend of sea levels at selected 6 stations, where the data is about 100 years long (1894~1990), shows falling at a rate of 0~0.5mm/year along the northern coasts of Japan in the East Sea and along the coasts of Kyushu and rising at a rate of 1.0~2.0mm/year along the eastern coasts. The primary factor of the variability of mean sea levels is tectonic motion around Japan. That is, there is a submergence along the south and east coasts of Japan due to subduction of the Philippine Sea Plate and the Pacific Plate under the Urasian Plate and North Asian Plate, and uplift of land levels along the coasts in the East Sea.

3. Prospective of climate change in the neighboring seas of Korea

NFRDA (National Fisheries Research & Development Agency) has measured the oceanic properties such as temperature, salinity, and dissolved oxygen in the neighboring seas on a regular basis since 1921. If SST is assumed to be persistently increased in the future at the same rate as that during the last 39 years (1968~2006) in the neighboring seas of Korea, then annual mean SST reaches up to 18.9℃ at the end of 21 century (Table 2). It is expected to be submerged 1.4 times the area of Seoul when sea levels rise by 50cm (Table 3).

Table 2. Estimated annual SST in the neighboring seas of Korea (NFRDA)

	East Sea	Yellow Sea	South Sea	mean
present	16.43℃	14.65℃	18.55℃	16.50℃
2050 년	17.50℃	15.76℃	19.70℃	17.61℃
2100 년	18.71℃	17.03℃	21.01℃	18.87℃

Table 3. Estimated scenario of submerged area and population for sea level rise

Sea level rise	Submerged population	Submerged area (㎢)	cf.
0.5m	268,745	856.126	1.4 times Seoul area
1.0m	312,855	984.304	1.6 times Seoul area

※ Submerged population and area are based upon tides and storm surges

The increasing rate of sea levels is the greatest at the Jeju Island (+0.5cm/year). If it is applied simply by linear extrapolation method, then sea levels are expected to rise by 25cm in 50 years and by 50cm in 100 years. Horizontal area from mean sea levels to shorelines (vertical approx. ~1.5m) is approximately 11,866 m^2, and the estimated submergence area is 5,680 m^2 for the rise of 50cm and 21,707 m^2 for the rise of 100cm at the eastern beach area of the Jeju Island. The scenario of sea level rise by 100cm shows the submergence over the human-living area and coastal facilities past present shorelines (Lee et. al, 2006). This estimate is based only upon tidal rise at high tide, not upon the expansion of submergence area by the attack of storm surges or waves.

The expenses for application in coastal areas with respect to long-term sea level rise is expected to increase exponentially. DIVA (Dynamic Integrating Vulnerability Assessment) produces the submergence areas and the additional expenses for application as Table 4 for the rise of sea levels by 22, 47, 96cm within next 100 years (Hwang, 2007)

Table 4. Estimates of submerged area and expenses for application

year	Submerged area (㎢)			Expenses for application (100million wons)		
	22cm	47cm	96cm	22cm	47cm	96cm
2020	0	10.23	37.65	0	53.27	634.01
2040	24.57	60.71	139.90	390.87	346.83	2,147.36
2060	59.21	130.15	271.26	1,019.77	1,411.05	3,265.85
2080	99.68	214.73	430.50	1,289.22	2,345.87	4,824.76
2100	151.46	309.80	621.52	2,106.74	2,806.77	6,868.37

※ Tides and storm surges are included for KEI estimates and tides only for DIVA estimates.

4. Oceanic survey system of Korea

4.1 NORI (National Oceanographic Research Institute)

NORI has operated 35 tide-gauge stations along the coasts to supply sea level and SST data
near the stations. At a few coastal stations, surface tidal currents are measured with HF radar and forecasted by tidal current model. Internet service is carried from 35 tidal stations, 150 tidal current locations, real-time current maps in 3 different types (Fig. 4 and 5).

6 data buoys will be installed in the northwestern Pacific Ocean with respect to DART (Deep ocean Assessment & Reporting Tsunami), and 53 national marine observatories including Eardo Station will be established for real-time oceanic data supply (Fig. 6 and 7).

Fig.4. Tidal stations

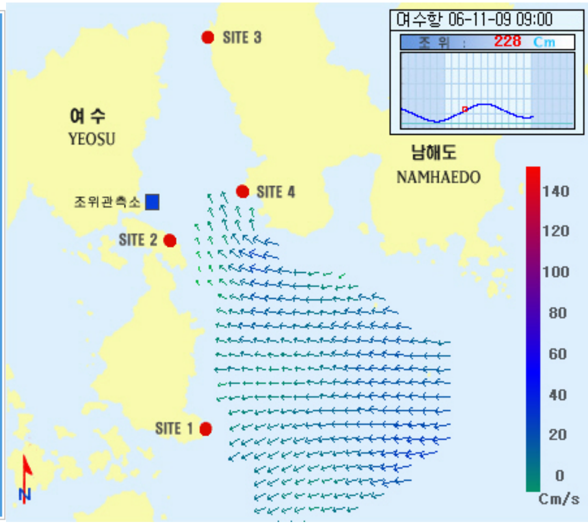


Fig. 5. Surface currents in the Yeosu Bay

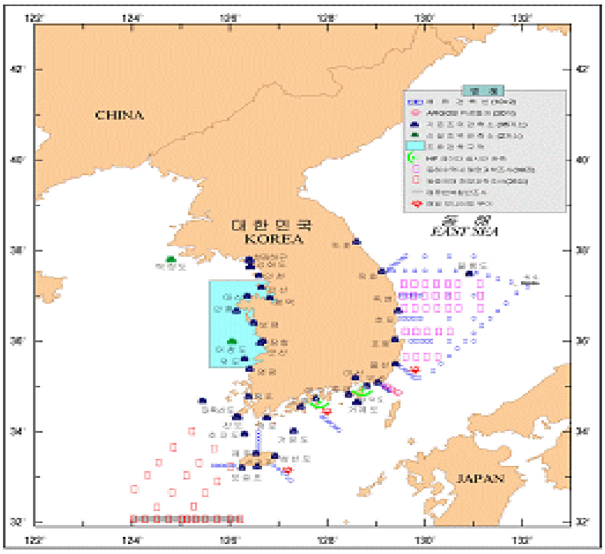


Fig. 6. Ocean survey plan by NORI

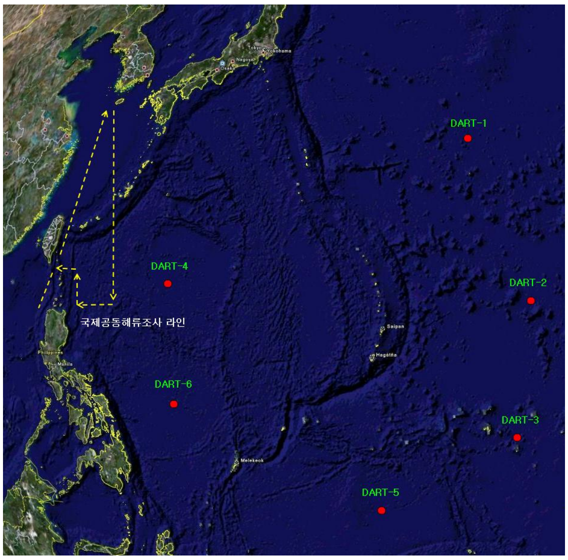
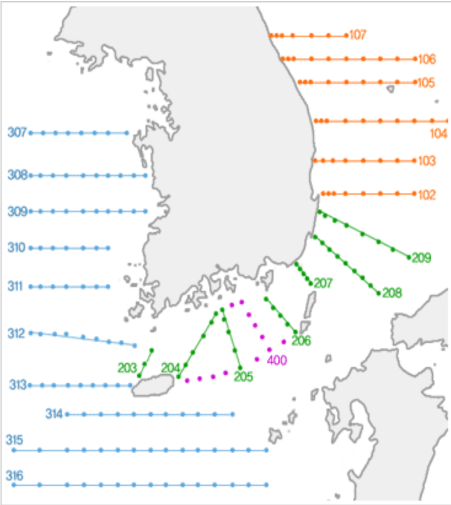


Fig. 7. DART plan for tsunami monitoring)

4.2. NFRDA (National Fisheries Research & Development Agency)



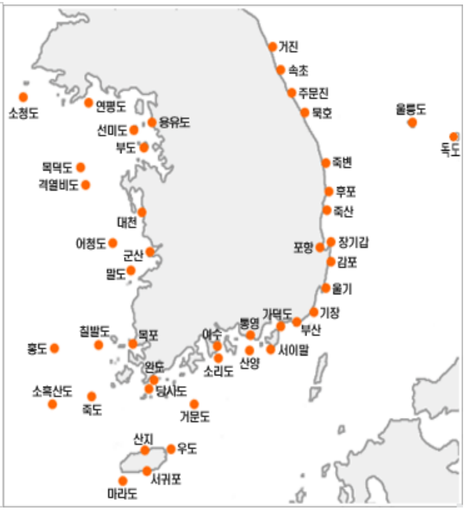


Fig. 8. bi-monthly survey lines **Fig. 9. costal temperature stations**

NFRDA has measured oceanic parameters such as temperature, salinity, dissolved oxygen, nutrients, phyto- and zoo-planktons, and meteorological data in the seas around Korea on a bimonthly basis, and published annual reports as well as supplied internet services (Fig. 8 and 9).

4.3. KMA (Korea Meteorological Agency)

KMA has performed a forecasting system for predicting weather over the seas such as air pressure, SST, sea surface winds, and significant wave heights on a real-time basis. She has also launched ARGO floats in the East China Sea and in the northwestern Pacific Ocean, which is shared with KORDI for global GOOS system (Fig. 10, 11, 12, and Table 5).

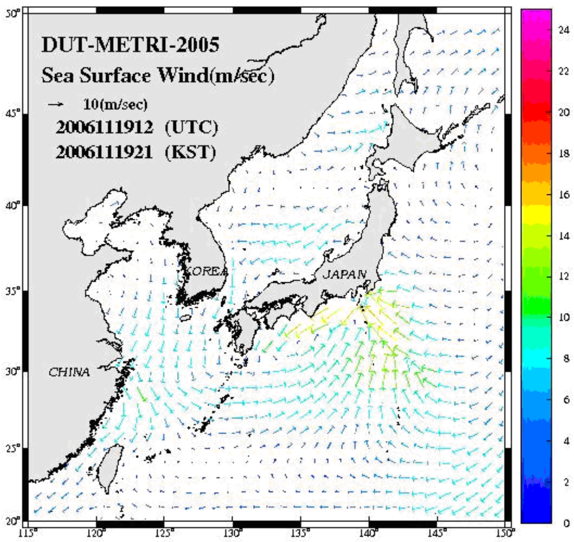


Fig. 10. DUT-METRI-2005 Real-Time Prediction System. Marine Meteorology & Earth Research Lab. METRI/KMA

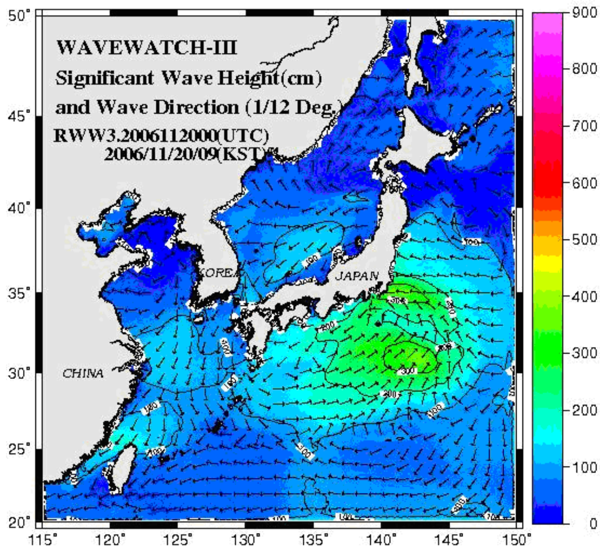


Fig. 11. WAVEWATCH-III Real-Time Prediction System. Marine Meteorology & Earth Research Lab. METRI/KMA

Fig. 12. KMA network of oceanic data buoys

Table 5. KMA network of oceanic data buyos

Buoy	Installation	Location	Local depth (m)	Parameters
Dukjokdo	**`96. 7 (05.12 replacement)**	**15 km west of Dukjok island 37°14' N, 126 °01' E**	**30**	**Wind direction Wind speed Gust Pressure Moisture Temperature Max. Wave height Sig. Wave height Ave. Wave height Wave period Wave direction**
Chilbaldo	**`96. 7 (05.12 replacement)**	**2 km northwest of Chilbal island 34°48' N, 125 °47' E**	**33**	
Geomundo	**`97. 5 (06.09 replacement)**	**14 km east of Geomun island 34°00' N, 127 °30' E**	**79**	
Geojedo	**`98. 5(06.10 replacement**	**16 km east of Geoje island 34°46' N, 128 °54' E**	**84**	
Donghae	**`01. 5**	**70 km east of Donghae city 37°32' N, 130 °00' E**	**1520**	
Pohang	**'08. 11**	**35 km east of Pohang Walpo 36°35' N, 129 °78' E**	**310**	
Marado	**'08. 11**	**27 km south of Mosulpo 33°00' N, 126 °33' E**	**105**	

4.4. KORDI (Korea Ocean Research & Development Institute)

KORDI has launched 15 to 30 ARGO floats every year in the East Sea and in the Drake Passage since 2000, and supplied real-time and delayed-mode data. Wave forecasting as well as oceanic wave data along the coastal regions of Korea are also supplied as an internet basis.

Data buoys have been launched in the middle and in the southern areas of the Yellow Sea, which is based upon YOOS (Yellow Sea Ocean Observing System) plan, in association with SOA (State Oceanic Administration), China.

4.5. Universities and Ocean-related industries

- SNU (Seoul National University): HF radar and data buoys have been operated at the marine observatory at Donghae City, and real-time data are supplied (Fig. 13 and 14).

시계열 관측망 : HF 레이다

	Standard Range			Long Range
	SITE A (동해시)	SITE B (삼척시)	SITE C (울진군)	–
행정 구역	동해시 망상동	삼척시 근덕면 덕산리	울진군 죽변면 후정리	
Frequency	13.381 MHz	13.462 MHz	13.381 MHz	4.3 ~ 6.4 MHz
Range	60 ~ 70 km			160 ~ 220 km
Radial Resolution	3 km			3 ~ 12 km
Angle Resolution	6 deg			6 deg
Interval	Hourly			Hourly

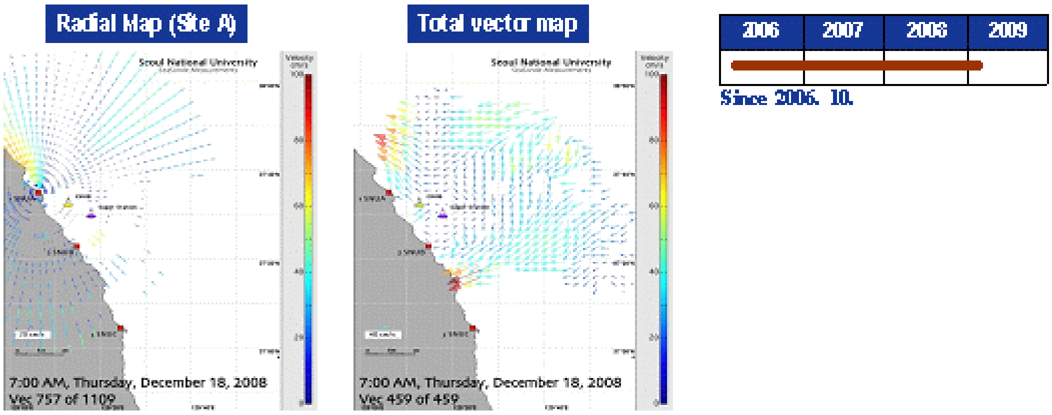


Fig. 13. Time series observation network

시계열 관측망 : 서울대 실시간 해양모니터링 부이

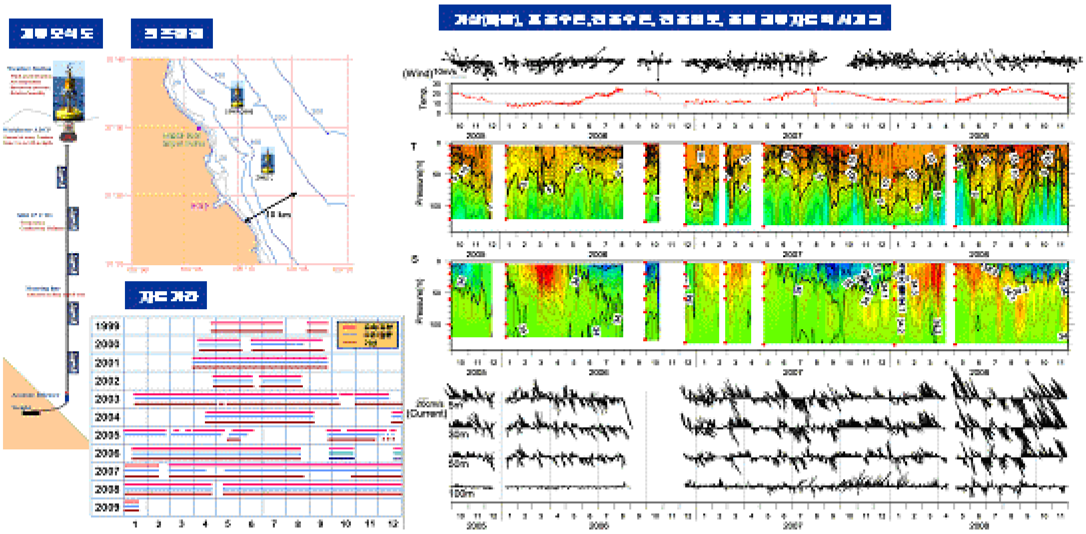


Fig. 14. Time series observation network

- Bukyung National University: Sea surface currents are mapped from HF radar around the southeastern coasts of Korea near Busan and Gampo.

- Busan National University: Sea surface currents by drifters has been measured in the East China Sea and the Luzon Straits for several years, in association with NORI.

- Kunsan National University: Sea surface currents are measured and supplied with HF radar around the Saemangeum reclamation area.

- GeoSR, Co. has monitored major beaches along the coasts of Korea with respect to erosion and shoreline changes, based upon the projects by the Minstry of Land, Transportation, and Maritime Affairs.

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Ⅲ. Fisheries and Aquacultur

1. The capture fishery

In Korean waters around 300 to 400 fish species are found, of which the people of Korea commercially utilize more than 100. Korean fisheries yield over 1 million t of marine fish from Korean waters annually. In general, the increase in fishing activities since the 1970s has reduced fish populations. Ministry for Food, Agriculture, Forestry and Fisheries (MIFAFF) records indicate that total catches of fish and invertebrates from 1980 to 2008 averaged 1,355,480 t. The largest catches of 1,725,820 t occurred in 1986 (Fig. 15). Catches were relatively stable from 1987 to about 1996, and have decreased slightly in recent years.

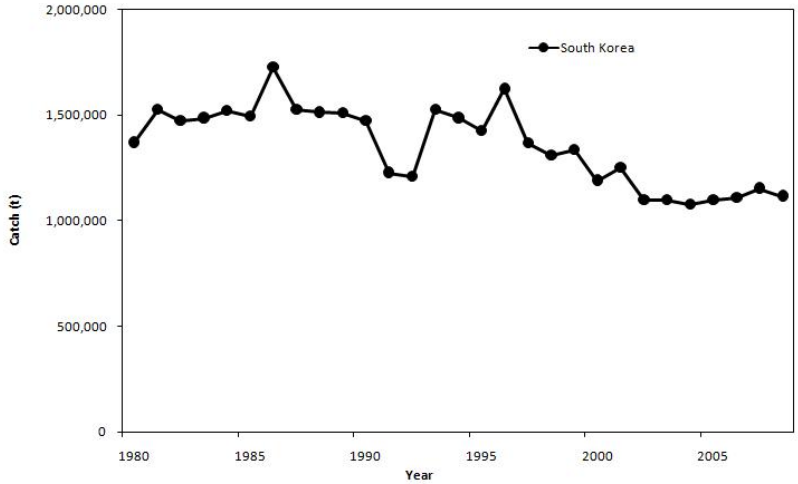


Fig. 15. Catch of fish and invertebrates since 1980.

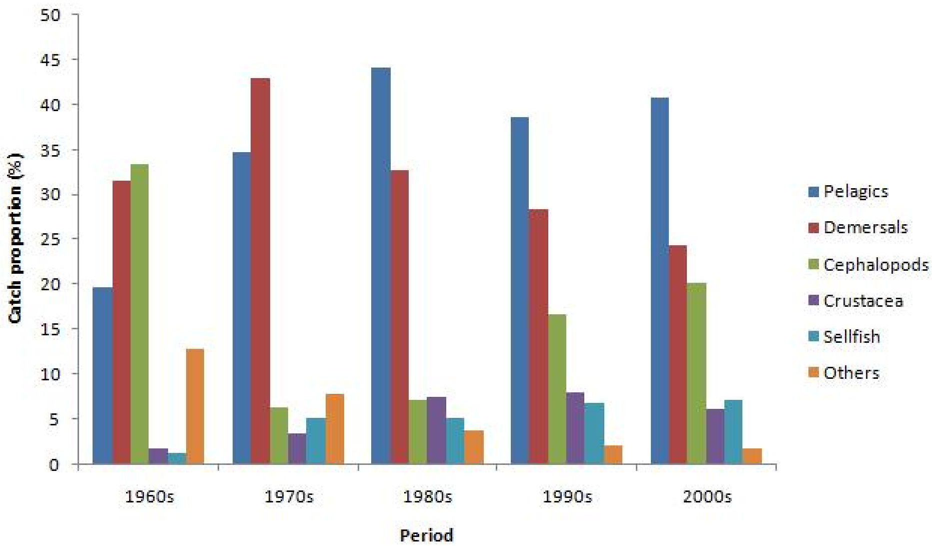
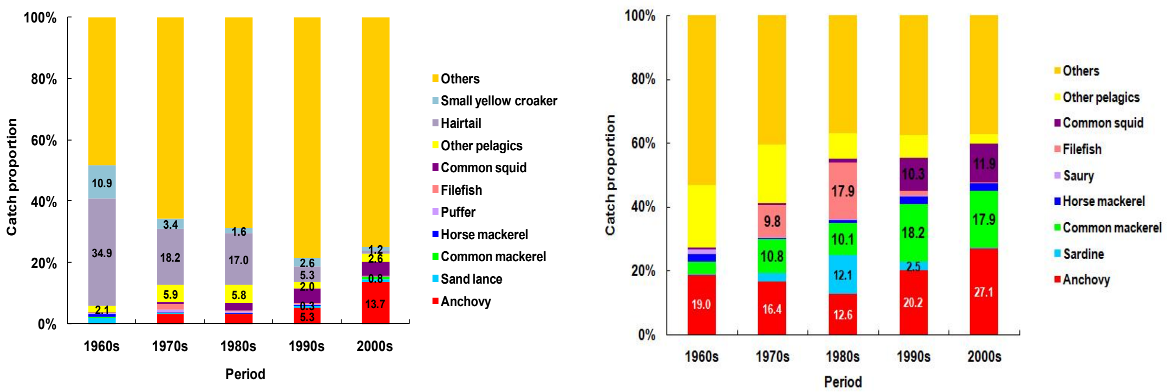


Fig. 16. Catch composition, by group, of Korean fisheries from Korean waters.

From 1980 to 2008, catches in demersal fishes decreased, and increased in pelagic fishes and invertebrates (Fig. 16). Demersal fish used to be abundant in Korean waters and were especially predominant on the Korean side of the Yellow Sea and the East China Sea in the 1960s (Zhang and Kim, 1999). The abundance of small pelagic fish has increased in the Tsushima Warm Current system. For example, Japanese anchovy (anchovy hereafter) is widely distributed in the northwestern Pacific Ocean as demersal fish abundance decreased, and is one of the most abundant pelagic species in the Yellow Sea and the East China Sea. Chinese research surveys in the winters between 1986 and 1995 indicated that anchovy biomass fluctuated between 2.5 to 4.3 million t in the Yellow Sea and the East China Sea. However, recent overexploitation and natural decreases appear to have caused the depletion of anchovy stocks on the Chinese side of the Yellow Sea. Other small pelagic fish, including the common squid, have tended to increase, occupying about 70% of the total catch of Korean marine fisheries.

The seven major target species in the Yellow Sea during the last 40 years were: (1) largehead hairtail (hairtail hereafter), (2) corvenia, (3) anchovy, (4) small yellow croaker, (5) blenny, (6) pomfret, and (7) flounder. The species composition in the catch has changed remarkably during the 1960s to 1990s. Hairtail were most dominant, followed by small yellow croaker in the 1960s and 1970s. Thereafter, the catch of small yellow croaker decreased while corvenia, flounder, and anchovy increased in the 1980s and 1990s (Fig. 17).

The seven major target species in the East China Sea during the last 40 years were: (1) anchovy, (2) chub mackerel, (3) threadsail filefish (filefish hereafter), (4) hairtail, (5) Japanese sardine, (6) corvenia, and (7) common squid. Anchovy, hairtail, and small yellow croaker dominated in the 1960s, but the catch of small yellow croaker almost disappeared from the composition after the 1960s. The relative compositions of chub mackerel, filefish, and sardine increased in the 1970s and the 1980s. In the 1990s, filefish and sardine disappeared and anchovy, chub mackerel, and common squid dominated the composition (Fig. 17).



(a) Yellow Sea (b) East China Sea

Fig. 17. Catch proportions by species (1961–2008).

Around 350 to 400 fish species reside in the East/Japan Sea (which also is called the Japan/East Sea, the East Sea, the Sea of Japan, or the Japan Sea). In the waters of the northern Korean Peninsula, demersal species represent 75% of all species and the ratio of demersal species decrease to 45% in the waters of the southern Korean Peninsula. Pelagic fish are greater in the south than in the north. Total commercial catch by neighboring nations in the East/Japan Sea peaked in 1983, reaching 3.3 million t. Korean catches, however, ranged from 132,000 t in 1967 to 275,000 t in 1982. The major species were common squid, walleye pollock (also called Alaska pollock, pollock hereafter), and saury, though large fluctuations on the decadal scale have appeared during the last four decades.

Commercial catches in the East/Japan Sea indicate the changes in species composition (Fig. 18). The ecological regime shift between small pelagic fish and demersal fish is especially evident in accordance with the climate regime shift. In the 1960s, common squid catch occupied 43% of the catch in the East/Japan Sea, followed by Pacific saury (15%) and pollock (12%). Pollock increased, occupying about 33% from the 1970s to the 1980s. Concurrently, the proportions of common squid and saury greatly decreased in the 1970s and the 1980s. The dominant fisheries catch also shifted from saury, cod, and pollock in the 1980s, to squid in the 1990s (Park *et al.*, 1998). Common squid became the dominant species (45%), and pollock and saury occupied less than 5%. However, knowledge concerning the East/Japan Sea and its relationship to the regime shift has been very limited. There is thus a strong possibility that an increase in the squid catch is closely associated with changes in the lower trophic levels, such as zooplankton biomass and community structure.

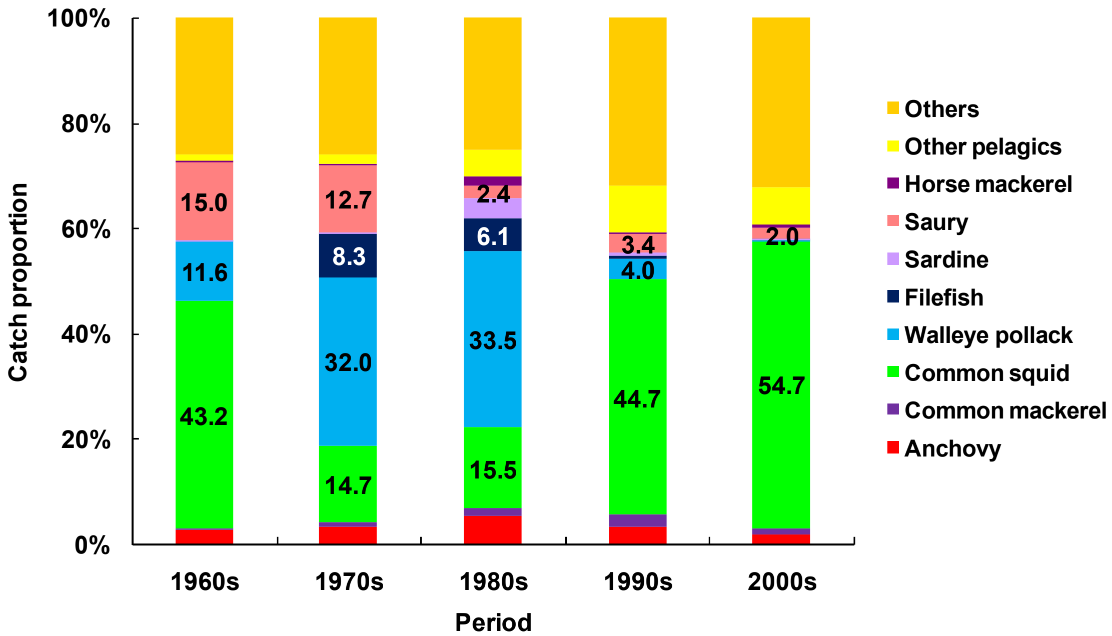


Fig. 18. Catch proportions of major species in the East/Japan Sea (1961–2008).

The trophic levels of resource organisms in the catches from Korean waters showed a significant decreasing trend from 1967 to 2000 (Fig. 19). Mean trophic levels were 3.43 and 3.46 in the Yellow Sea and the East China Sea, respectively, during the 1967–2000 period. Figure comparison shows that the slope of the declining line was steeper in the Yellow Sea than in the East China Sea. Because of the decrease of demersal fish such as small yellow croaker, which are at higher trophic levels, small pelagic fish such as anchovy, common squid, and blenny, which were at relatively lower trophic levels, increased during the four decades.

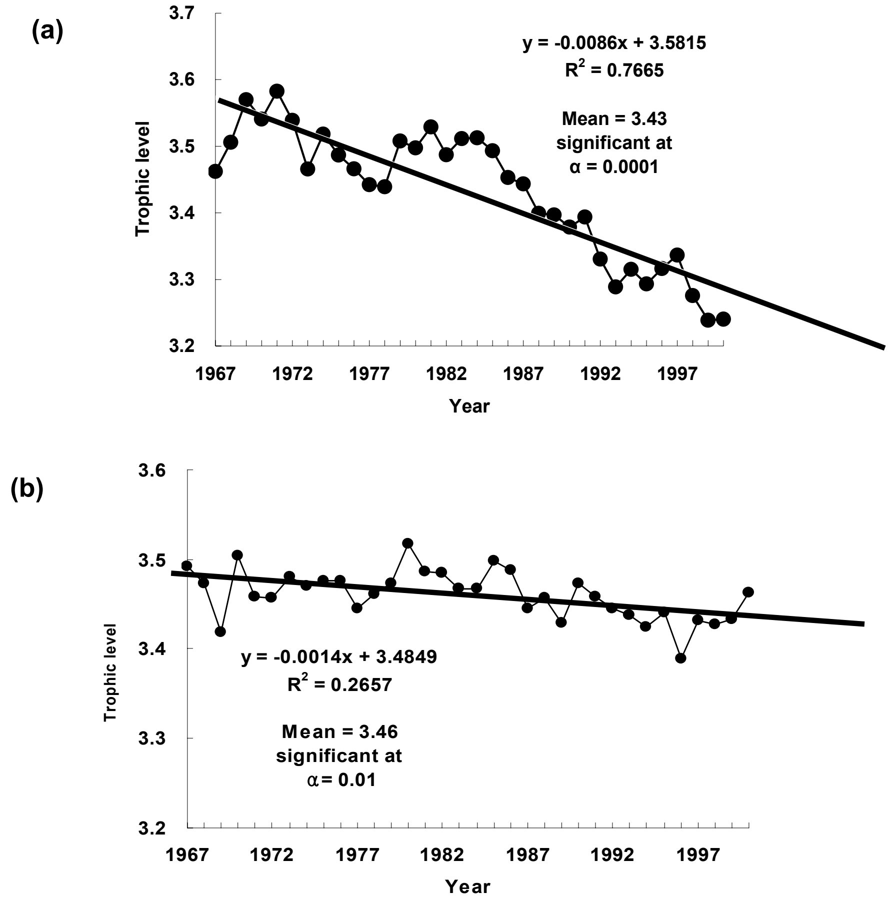


Fig. 19. Catch for trophic levels of resource organisms in (a) the Yellow Sea and (b) the East China Sea.

Regime shifts particularly affect the production of major small pelagic fish. Different fishing grounds of common mackerel, horse mackerel, and sardine were found between pre- and post-climatic regime shifts. There were many changes in the East/Japan Sea ecosystem after the 1976/77 regime shift, as seen through changes in the marine environment. In the East/Japan Sea, the mean trophic level increased from 3.09 to 3.28 during the 1976 regime shift period (Zhang et al., 2004).

1.1 Climate and ocean influences

The Korean Peninsula is surrounded by the Yellow Sea to the west, the East China Sea to the south, and the East / Japan Sea to the east. Large-scale air–sea interaction in the Pacific Ocean is the main driving force controlling the climate over the Korean Peninsula. Some effects of climatic events, such as global warming, atmospheric circulation patterns, climate regime shifts in the North Pacific, and El Niños in the tropical Pacific waters occasionally appear in this region (Kang *et al.*, 2000; Kim and Kang, 2000; Zhang *et al.*, 2000; Zhang and Lee, 2001).

The Korean Peninsula is located where the Siberian High and the subtropical Pacific Low collide producing cold, dry winters and warm, wet summers. North and northwest winds in the autumn and winter are strong, and wind speeds easily reach 10 m s^{-1}. Winds reverse direction and become weaker in the spring and summer. Typhoons developed in the western subtropical Pacific bring heavy rains in the summer and autumn. On the average, about nine typhoons pass through the region every year (Kim and Khang, 2000).

The coastal zone serves as spawning and nursery grounds for fish species, and the survival of some migratory species are threatened by coastal development. The main threat to the coastal habitats is land reclamation, especially in estuaries and shallow bays. During the 1987–1997 period, approximately 25% of the total tidal flats were lost to reclamation in Korea (Cho, 2001). The loss of spawning grounds and habitat degradation due to pollutants is also reducing the productivity of the coastal area.

Ocean changes in the surface layer in the spring have a profound effect on productivity. There has been an increase of 1.8°C in sea surface temperature (SST) in February in the Korean seas during the past one hundred years (Hahn, 1994). The rate of change became greater during the past decade. Hahn (1994) has also shown that there was a northward movement of isothermals during the same period (Fig. 20). Aside from the long-term view of global warming, SST is closely related to the variation of the Asian monsoon. The SST change over Korean waters is also connected to the El Niño/Southern Oscillation with phase lags of 5 to 9 months (Park and Oh, 2000), which results in a cold summer in the East/Japan Sea after an El Niño winter.

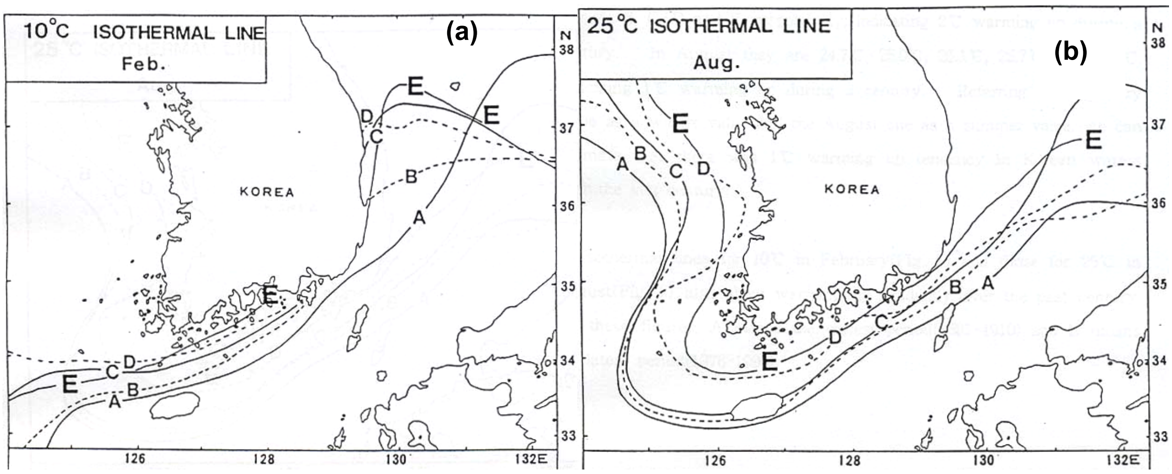
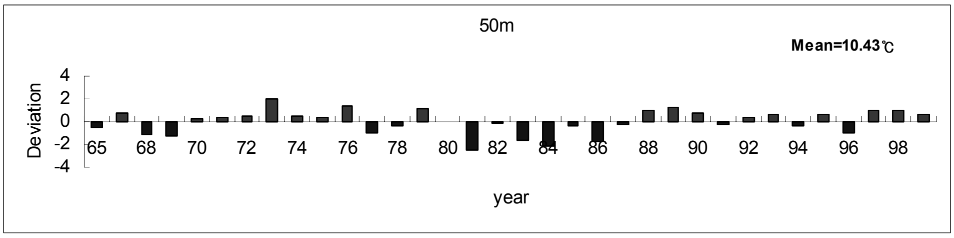


Fig. 20. Northward movement of the isothermals during 1891–1990. (a) refers to February and (b) refers to August. A: 1891–1910; B:1911–1925; C:1926–1940; D:1961–1975; E:1976–1990. (source: Hahn, 1994)

In the surface layer of the East/Japan Sea, warm water masses were prevalent during the 1960s to 1975, cold ones from 1976 to 1986, and warm ones again since 1987 (Fig. 21). This phenomenon was typical in the spring and the autumn and showed a similar trend, with an exception from 100 to 200 m depth during the late 1970s. It is also anticipated that changes of SST due to climate variability could change the pattern of front and current systems in the East/Japan Sea.

Since the early 1990s, high SSTs have prevailed in the East/Japan Sea. Concurrently, zooplankton biomass and catch of warm-water pelagic species (*e.g.*, squids, jellyfish, mackerels, *etc.*) have increased. Recently, the occurrence of warm-water species has been frequently reported, while cold-water species (*e.g.*, pollock) have decreased. The returning rate of chum salmon, which were released from the east coast of the Korean Peninsula, has been depressed. As long as the warming trend of SST continues, more warm-water species (also less cold-water species) are expected to be found in Korean waters.

The spatial distribution of seawater temperature indicated that the isotherms were perpendicular to the coastline at the surface. Those lines, however, became parallel at 50–100 m depth. Especially, during the spring from 1976 to 1986, cold temperatures were prevalent near coastal areas. Warming of seawater was frequently observed from the late 1980s. The vertical structure of temperature represented the cold regime lower than 11°C in the 0 to 100 m layer during the 1977–1983 period. Temperatures warmer than 11°C were common after 1989.



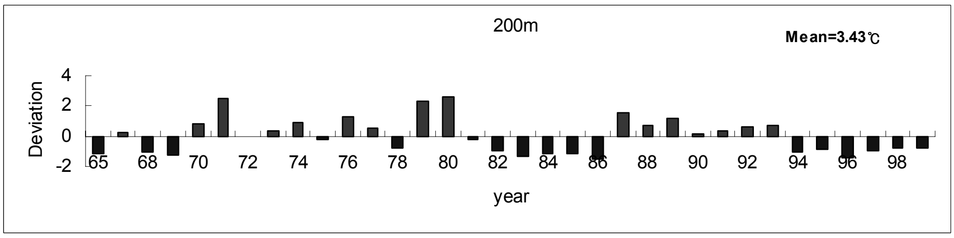


Fig. 21. Change in seawater temperature in April at 50 and 200 m depth in the East/Japan Sea.

1.2 General Description of Ecosystem Status and Fisheries Trends

1.2.1 Changes in ecosystem components

In the East/Japan Sea, there has been a major change in the ecosystem structure and productivity from 1960 to 1990. The mixed layer depth increased from 1977 and fluctuated around depths about 40% deeper than prior to 1976 (Zhang *et al.*, 2000). The mean transparency depth from Secchi disk observations showed 11.9 m during the 1960–1975 period, but increased to 14.2 m during the 1976–1990 period. This resulted in higher primary productivity (and consequently the zooplankton biomass) appearing in the earlier period (Kang *et al.*, 2000). Correlation studies indicate that some fish populations (saury and sandfish) catches occurred when the Southern Oscillation Index (SOI) was positive (*i.e.*, La Niña period), when spring chlorophyll was high, when air temperatures were cooler in coastal cities, and when other fish species (sardine and pollock) were low in catch (Kang *et al.*, 2000).

Some resident fish species are found near the coast, while others show a long-range migration behavior during the course of spawning. Kim (2003) identified three important ecosystems in Korean waters based on marine commercial fish catches: the demersal ecosystem in the Yellow Sea and the East China Sea, the pelagic ecosystem in the Tsushima Warm Current *(i.e.*, a branch of the Kuroshio) from the East China Sea to the East/Japan Sea, and the demersal ecosystem in the northern part of the East/Japan Sea. Most species in these categories generally showed a typical migration pattern: spawning in the coastal areas during the spring, feeding to the north during the summer, and overwintering after southward movement to the East China Sea.

1.2.2 Speculations on the Impact of Greenhouse Gas-induced Climate Change

This chapter speculates on the relationship between environmental changes and fish species in Korean waters. Environments are variable over time, and fish have a relatively routine life history schedule. Fish spawning is influenced by some abiotic environmental factors such as temperature, and their growth and survival are controlled by abundance of prey and predators surrounding them. In order to figure out the ecological phenomena, however, it requires extensive survey efforts, and a multi-disciplinary approach is essential to explain the relationship. In general, the marine ecosystems in Korean waters are varied and complex, because large-scale climate events such as ENSO, monsoons and PDO have an impact on water properties indirectly or directly. The fish species also exhibit numerous patterns of behavior. Oceanography and the biology of fish have not been extensively studied. Therefore, due to limited scientific knowledge, we are limited to explain the relationship between climate change and marine ecosystems, including fish populations in Korean waters. Below is a brief speculation of the environmental impact on major fish species around the Korean Peninsula.

1.2.3 Small yellow croaker, hairtail

In the Yellow Sea, environmental conditions are influenced by many factors such as the Kuroshio, seasonal monsoons and winds, and river runoff. Because of its shallow topography, the Yellow Sea does not have truly demersal fish populations. However, in contrast to pelagic fish species such as anchovy, some species (*e.g.*, small yellow croaker, hairtail, and filefish, *etc.*) locate in the relatively deep waters in the center of the southern Yellow Sea and the East China Sea.

The recruitment success of small yellow croaker is dependent upon seawater temperature, and consequently, catch would be improved 8 to 10 months later if warm and stable conditions formed at 75 m depth during the early life stages. However, the relationship between surface and bottom layers, and the cause–effect mechanism between environment and organisms have not been identified. There are too many unknown factors in the Yellow Sea ecosystems to determine the impact of warming on demersal fish species.

As we showed for small yellow croaker, it is not possible to speculate on the impact of global warming on demersal species such as hairtail because the biology, as well as the ecology, of these species is mostly unknown. However, different fish species have different life cycles and habitat areas, and large-scale climate change might not show the same common effects for all fish species.

1.2.4 Anchovy, mackerels and common squid

In Korean waters, the portion of small pelagic fish species (anchovy, mackerels and common squid) has been increasing. In recent years, ten major small pelagic species have occupied 60 to 70% of the total catch, and common squid alone accounted for 20 to 25%. In many ecosystems around the world, abundance of anchovy follows trends that are opposite to the sardine. In Korean waters, however, the species alternation between anchovy and sardine was not evident. There is improved larval survival and growth when the Tsushima Warm Current is strong near the coast of Korea, but it is not yet known what the relationship is between warming and Kuroshio strength.

Chub mackerel and anchovy abundances increased in the mid 1990s, a period of high SST in December. ENSO might have an influence on seawater temperature in December. An elevated seawater temperature due to ENSO seemed to cause a high rate of growth and a good year class of those populations in Korean waters (Kim and Kang, 2000). In addition, there is clear evidence that climate, and climate shifts, affect the production of chub mackerel.

More intense Aleutian Lows and a positive PDO may have a negative impact. Jack mackerel production follows a cyclic pattern of about 30 years.

There were large increases in the abundance of common squid in the 1990s when SST increased. If there are more frequent periods of intense Aleutian Lows, then abundance would decrease. However, if wind intensity is reduced and SST increased, then common squid will become more abundant.

2. Aquaculture

The western coast in the Yellow Sea has well-developed tidal flats characterized with turbid water and high tidal range (5-10 m). The sandy-mud tidal flats have been used as culture grounds for Manila clam, Ruditapes philippinarum and other marine bivalves such as oysters and hard clams. A small scale shrimp farming also has been practiced using land-based tanks and ponds mostly to raise Peneaus chinensis.

The southern coast is characterized as an archipelago consisting of many small islands and bays, where the tide ranges 3-5 m and the surface water temperature varies 7-25 ºC annually. Relatively shallow (10-30 m deep) bay areas have been used extensively for long-line cultures of seaweeds and shellfishes as well as net cage culture of finfish since 1960. Currently 90% of total landings of seaweeds and shellfishes in Korea come from this area.

Rocky coastline of the East Sea is characterized with small tidal range (<40 cm). Relative to the western and southern coast, aquaculture in the eastern coast is poorly developed because of hard accessibility for inland-farming and high waves in coastal areas. Since mid 1990s, a small scale of scallop (Patinopecten yessoensis) farming has been developed using a long-line suspension culture system.

In Korea, one third of marine products are currently from marine aquaculture, and the Korean aquaculture industry produced over 1.4 million tons of seafood in 2007 (FAO FISH STAT Database). It is noticeable that seaweeds and shellfishes account for up to 90 % of the total aquaculture production in volume. In contrast, production of finfish culture (flounder, rockfish, sea bream and sea bass) was relatively small, contributing only 7 % of the total production, while the economic value of the finfish culture production accounted for more than 50% of the total value. Flounder and rockfish farming using land-based tank or net cage become popular along the south coast and Jeju Island.

2.1 Seaweed culture

The annual seaweed landing in 2007 was 657,995 tons which was more than twice of the seaweed landings in 2003 (Fig. 22 and Table 6). Seaweed culture area is mainly concentrated on small bays in Wando Island off the south western coast where more than 90% of the seaweed farms are located. In this area, long-line suspended culture system is used to raise kelps and laver. *Undaria pinnatifida* (Wakame) is cold temperate brown algae most commonly cultured seaweed in Korea. *U. pinnatifida* landings for the past 5 years accounted for over 50% of the total algae production in volume (Fig. 22). Annual production of the kelp *Laminaria japonica* also has been increased rapidly for the past 5 years due to the recent development of abalone farming in this area. Currently the abalone farmers feed the abalone, *Haliotis discus hannai* with *L. japonica* cultured in this area. Wando Island is also famous for the laver culture, *Porphyra tenera*. Laver is cultured using floating raft system since this red algae needs to be exposed to the air from time to time to produce good quality of Nori.

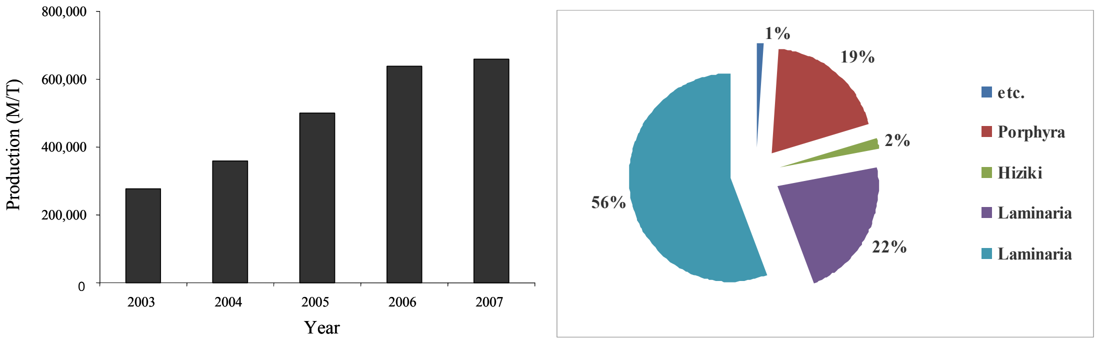


Fig. 22. Total annual aquaculture production and proportion of major algal species in Korea, 2003~2007.

Table 6. Annual aquaculture production of major algal species in Korea, 2003~2007.

	Production (M/T)				
	2003	2004	2005	2006	2007
Undaria pinnatifida	181,350	260,307	285,188	325,228	311,670
Laminaria japonica	10,969	7,571	91,954	185,916	233,427
Porphyra tenera	83,118	90,961	93,136	106,846	100,265
Hizikia fusiformis	386	70	23,516	15,794	5,037
Codium fragile	27	654	4,608	2,969	3,998
etc.	521	446	2,648	2,958	3,598
Total production	276,374	360,009	501,050	639,711	657,995

2.2 Shellfish culture

The mean oyster production from 2003 to 2007 was 154,606 MT, accounting for 56% of the total shellfish landings (Fig. 23 and Table 7). The Pacific cupped oyster *Crassostrea gigas* is exclusively used in the Korea oyster farming with the suspended long-line culture system. The oyster farms are concentrated in small bays on the south east coast where the primary production is high enough to support oyster growth. Oyster seeds for the culture are naturally collected during mid summer from the bays. Mussel farming (*Mytilus edulis galloprovancialis*) is also common on the south west coast where they are raised by the suspended long-line system. Manila clam farming is the most important shellfish species on the west coast since clam seeds are sowed on the tidal flats and harvest 2-3 years after. Clam seeds for the culture are collected from sandy-mud intertidal areas in the small bays on the west. It is remarkable that annual abalone landings have been increased dramatically since 2000; the annual landing of abalone was only100-200 tons until 2002, while total production of abalone in 2007 was over 4,000 tons. Abalones are raised using closed-cages suspended underwater mostly in Wando Island off the south coast. Locally grown kelps (*Laminaria* and *Undaria*) are used as feeds for the abalone culture.

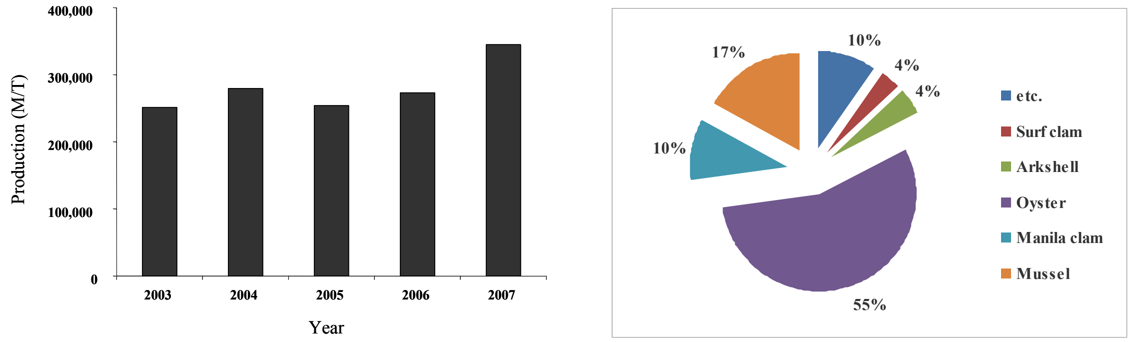


Fig. 23. Total annual aquaculture production and proportion of major shellfish species in Korea, 2003~2007.

Table7. Annual aquaculture production of major shellfish species in Korea, 2003~2007.

	Production (M/T)				
	2003	2004	2005	2006	2007
Crassostrea spp.	133,466	168,811	154,749	142,721	173,281
Mytilus spp.	14,824	16,442	37,931	76,877	91,856
Ruditapes philippinarum	36,809	38,298	28,376	18,645	22,956
Scapharca spp.	7,365	13,314	4,871	8,980	27,927
Mactra veneriformis	21,169	13,426	5,201	7,592	2,598
Turbo cornutus	7,992	4,184	4,372	3,343	3,265
Haliotis spp.	1,093	1,301	2,127	3,019	4,412
etc.	28,538	23,855	16,434	12,359	18,428
Total production	251,256	279,631	254,061	273,536	344,723

2.3 Finfish farming

Owing to the increase in rockfish (Sebastes schlegeli) and flounder (Paralichthys olivaceus) production, the Korean finfish landings from aquaculture sector have been increased gradually for the past 5 years (Fig. 24 and Table 8). In 2007, 41,016 tons of olive flounder Paralichthys olivaceus were produced from land based tanks on the south coast and from Jeju Island (Bae, 1998 and 1999). It is remarkable that more than half of the total flounder landings are originated from Jeju Island where olive flounders are raised in land based tanks using flow-through water system. Good water quality and mild winter water temperature (13-16 ºC) favors the flounder farming in Jeju. In small bays on the west coast, rockfish (Sebastes schlegeli), red sea bream (Pagurus major), striped perch (Oplegnathus fasciatus), black porgy (Acanthopagrus schlegeli) and sea bass (Lateolabrax japonicus) are commonly cultured in suspended net cages (Bae and Kim, 1999). Recently offshore cage culture technology has been introduced from USA and a small scale of offshore cages has been installed off the southern coast of Jeju Island to grow striped perch.

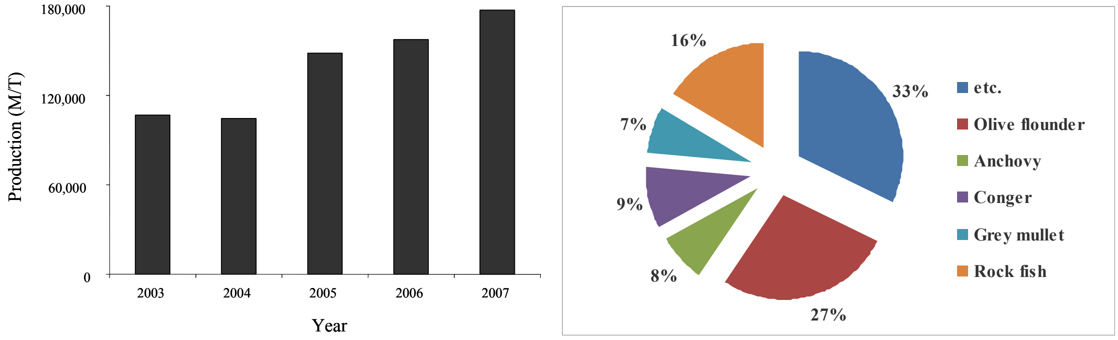


Fig. 24. Total annual aquaculture production and proportion of major finfish species in Korea, 2003~2007.

Table 8. Annual aquaculture production of major finfish species in Korea, 2003~2007 (FAO, 2006-2008).

	Production (M/T)				
	2003	2004	2005	2006	2007
Paralichthys olivaceus	33,948	32,161	40,063	43,761	41,016
Sebastes schlegeli	18,840	16,725	19,808	25,781	33,790
Astroconger myriaster	13,885	12,984	11,798	11,955	15,775
Engraulis japonicus	4,791	8,580	14,809	13,870	10,846
Mugil cephalus	8,165	7,705	11,394	10,640	11,957
etc.	27,168	26,149	50,125	51,699	63,885
Total production	106,797	104,304	147,997	157,706	177,269

2.4 Climatic changes and its impacts on aquaculture

According to the Fourth Report of the Intergovernmental Panel on Climatic Changes, the global warming could cause changes in coastal marine environment including sea level rise and subsequent shoreline erosion, sea surface water temperature increase, increase in ocean acidity and changes in rainfall pattern. It is likely in Korea that impacts of the climate changes are more intense in shellfish and seaweed aquacultures than land-based fish farming. The dry and warmer winter could increase incidence of pathogenic disease outbreak and subsequent mass mortalities of the host animals. Clam culture on the west is currently experiencing pathogenic disease associated mass mortalities and the incidence of mass mortalities is expected to increase. Run-off changes in estuaries and shallow coastal areas along the south coast may change the supplies of freshwater land-driven nutrients crucial to the primary production in the bays. Oyster farming is likely to be affected by the long-term changes in the run-off since oyster is an estuarine filter feeding organism. Increase in SST may directly affect seaweed culture on the south western coast. Increase in SST may retard growth and reproduction of *Undaria* and *Laminaria* spp, which are known to be cold temperate species. No clear impacts of acidification of seawater on survival and growth of aquaculture species have been reported yet in Korean water, although the acidification may affect survival and growth of any calcitic organisms such as shellfish larvae and juveniles in a long run.

Ⅳ. Marine ecosystem

1. Phytoplankton

1.1 Introduction

Through photosynthetic activity, marine phytoplankton significantly contribute to the regulation of global climate change by playing a central role in both the global oxygen and carbon cycles. These autotrophs produce half of the planet's oxygen and function as an important base for carbon (biological) pump, thus modulating atmospheric and oceanic carbon dioxide (CO_2) concentrations. Phytoplankton are also vital to both nutrient cycles through the production of organic material and the maintenance of marine biological food webs as the key primary producers within ocean ecosystems (Arrigo, 2005; Ducklow et al., 2001; Pomeroy, 1992).

Global climate change is being accelerated by increasing atmospheric CO_2 emissions, which is due at least in part to anthropogenic activities. Several abiotic factors, such as seawater temperature, currents, pH, and nutrient shifts are strongly affected by climate change. Consequently, climate-induced changes in these factors alter the marine environment, thus affecting phytoplankton production, diversity, and community structure.

Studies of the phytoplankton in Korean coastal waters began in the 1930s and has focused on community composition and biomass in the East, Yellow, and South Seas. Although such studies have continued, they have been sporadic, often one-time events with no systematic implementation of long-term monitoring. Thus, it has been historically difficult to clearly determine long-term trends within the phytoplankton communities of Korean waters.

The long-term monitoring programs of the National Fisheries Research and Development Institute (NFRDI) operate 330 sampling stations in the East, Yellow, and South Seas (including the East China Sea) to collect data on water temperature, salinity, and other environmental parameters. NFRDI also runs 77 sampling stations to monitor red tides (Fig. 25). However, the survey parameters included in the NFRDI long-term monitoring program do not include those related to phytoplankton. Hence, data regarding long-term variability of phytoplankton in and around Korean and neighboring waters have been very limited, although trends in the frequency of red tides, red tide blooming regions, and component species of red tides are well documented.

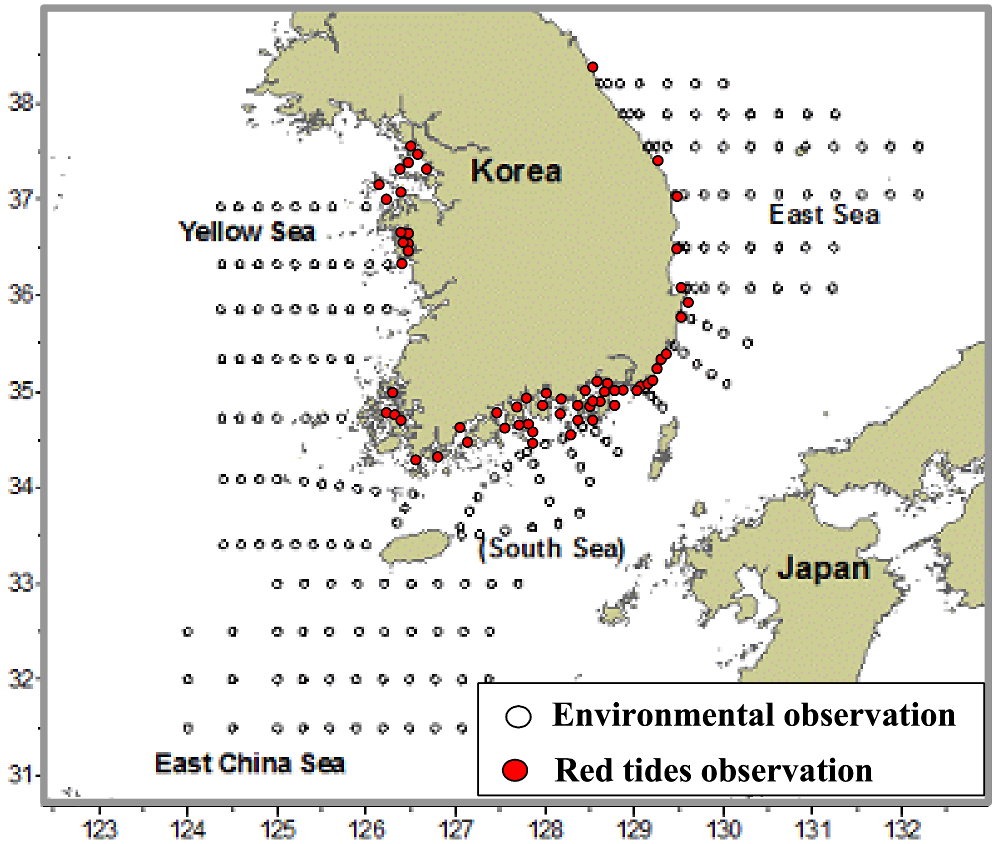


Fig. 25. Sampling stations for the NFRDI long-term monitoring programs for marine environmental surveys and red tides within Korean waters.

1.2 Changes in Phytoplankton Community Structure

1.2.1 The effects of environmental changes catalyzed by anthropogenic activities

The Yellow Sea is characterized by its high tidal range, gradual slope, and extensive tidal flats. However, the Yellow Sea ecosystem has been greatly altered by national, large-scale reclamation projects, such as the construction of the Shiwha and Saemangeum Dikes (Lie et al., 2008). The construction of such extensive, artificial dikes has reduced overall tidal energy, which has in turn decreased the concentration of suspended particles and resulted in improved light conditions in the area. Higher light conditions have stimulated annual winter blooms of phytoplankton. Moreover, spring and summer red-tide events have occurred more frequently since the 1990s because of the loss of suspended particles and marine eutrophication.

The South Sea was once a pristine environment with well-developed aquaculture. However, severe eutrophication has been caused by human activities on land and in water, and red-tide algal blooms of the toxic dinoflagellate, Cochlodinium polykrikoides, have occurred annually since 1995 (Lee & Lee, 2006).

The East Sea remains relatively free of eutrophication, primarily due to the small coastal population. Despite this, annual red-tide blooms of C. polykrikoides in the South Sea merge with the currents that flow into the East Sea and threaten this once pristine region (Ahn et al., 2006).

The anthropogenic CO2 absorbed by the East Sea is amassed in the formation of deep waters in the northern part of the sea. Consequently, increasing CO2 in the East Sea has reduced the saturation points for aragonite and calcite (Park et al., 2006), which may in turn affect the distribution of plankton that form calcium carbonate ($CaCO_3$) shells, such as coccolithophores and pteropods.

The Chiangjang River watershed of the East China Sea has also recently experienced rapidly increasing frequencies of red-tide events, most likely due to the discharge of high-nutrient waters. In addition, the construction of reservoirs and the Three Gorges Dam has reduced levels of suspended particles flowing into the East China Sea, consequently lowering the Si:N ratios in the Chiangjang River watershed. Reduced Si:N ratios have caused red-tide blooms of diatoms instead of dinoflagellates (Tang et al., 2006). Red tides within the Chiangjang River watershed appear to have expanded in area via wind transport of surface-water mass, however these waters typically do not occur within the Korean Exclusive Economic Zone (EEZ). Yet, in summer 2008, a red-tide event caused by Akashiwo sanguinea in the Chiangjang watershed did extend into the Korean EEZ.

1.2.2 Effects of climate change

The water temperature of the relatively deeper, more pristine East Sea has been increasing on average by 0.06°C annually since 1985. During the past 100 years, East Sea water temperatures rose by 0.8°C during the first 80 years and by 1.2°C during the past 20 years. Due to the lack of long-term monitoring data for phytoplankton in the East Sea, the effects of such rising temperatures on phytoplankton community composition are unknown.

Long-term data collected since 1950 within the Chiangjang River watershed have indicated that rainfall has increased in the region. As a result of the rise in freshwater discharge from the Chiangjang River, the salinity of waters along the continental shelf of the East China Sea has been decreasing (Siswanto et al., 2008). Since 2003, the Korea Ocean Research and Development Institute (KORDI) surveys in the East China Sea have indicated that changes in the strength of Chiangjang diluted discharge water (CDDW) have affected phytoplankton biomass and community structure. However, phytoplankton community shifts in relation to long-term variability in salinity levels cannot be determined because of the absence of long-term data.

In 2007 and 2008, macroalgal blooms of the green alga, Entermorpha prolifera, occurred along the Chinese coast of the Yellow Sea, presenting an additional environmental threat (Sun et al., 2008). This typically benthic species bloomed as a thick, floating mat on the surface of the water. In 2008, huge blooms of E. prolifera were observed near Qingdao, China, some of which were even transported to coastal Jeju Island. These new green-tide events have reportedly resulted from the combined effects of artificial nutrient (pollutant) input as well as natural events, such as precipitation and wind.

1.2.3 Red-tide events

NFRDI has conducted a continuous red-tide monitoring program since 1970. Survey vessels are used to survey 77 sampling stations, and airplanes have recently been used for red-tide surveillance.

According to long-term red-tide survey data since 1980, changes have occurred in the frequency, scale, and species composition of red-tide events. In 1980, three red-tide events occurred, but this number has drastically increased to 122 events in 1998. Since 1988, the frequency of red-tide events has been decreasing, and only 34 events were reported in 2008 (Fig. 26).

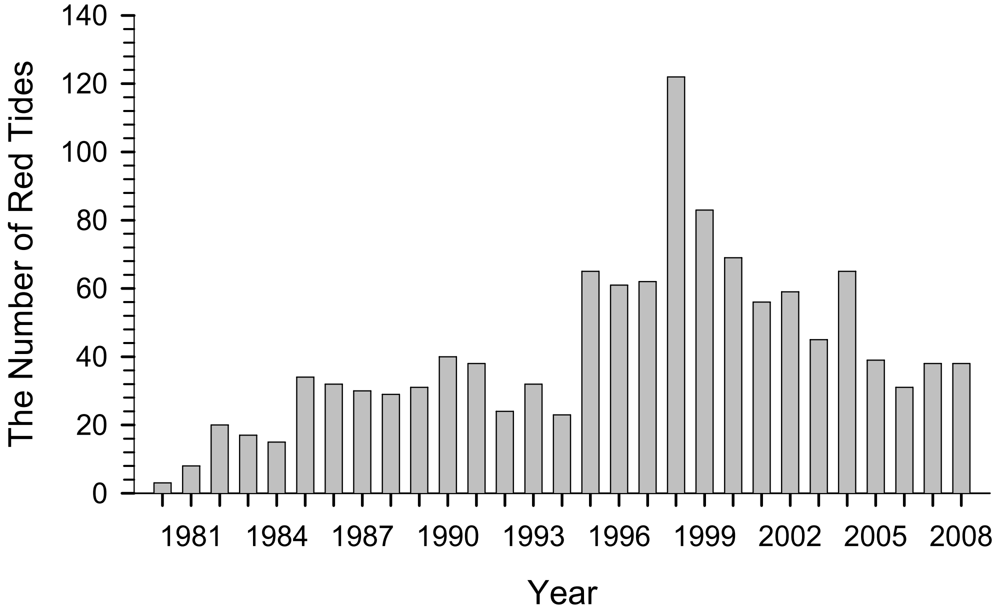


Fig. 26. Frequency of reported annual red-tide events within Korean coastal waters (based on NFRDI data).

In the early 1980s, small-scale red-tide events occurred within the Jinhae Bay. However, as the pollution status of the bay worsened from 1989−1994, red tides have expanded to the South Sea and eastern South Sea areas and have lasted for much longer time periods. In 1995, toxic C. polykrikoides erupted in a large-scale bloom that seriously damaged coastal aquaculture farms. Subsequently, red tides of C. polykrikoides have been observed annually, and more recently, red-tide blooms caused by Chattonella spp. have also been increasing (data from NFRDI)(Table 9).

Table 9. Locations of red-tide blooms and sustained periods of blooms observed along Korean coastal areas (data from NFRDI).

Terms	1982-1988	1989-1994	1995-present
Spatial distribution	Partial area Jinhae Bay	South Sea to southern East Sea	Widespread overall coast
Highest density of *C. polyklikoides* (cell/ml)	No data	No data	5,800-43,000
Persistency	Less than 10 days	Less than 20days	28-62 days

1.2.4 Obstacles and future plans

Determining trends in phytoplankton community structure in relation to environmental changes within Korean marine waters is currently quite difficult due to the lack of continuous, long-term, systematic studies of phytoplankton. To resolve this issue, a long-term research program for phytoplankton has gradually been implemented since 2000.

In addition, since 2006, coastal ecosystem surveys along Korean coastal zones have been conducted based on the "Basic Plan for Marine Ecosystem Surveys." This plan requires studies of the eastern, western, and southern marine ecosystems every 10 years.

The "Marine Ecosystem Preservation and Management Act," which includes articles for invasive organisms and biological diversity, has recently been revised to include basic surveys of phytoplankton as a baseline parameter.

KORDI has developed and continues to develop long-term monitoring strategies using the ocean science research stations at Ieodo, Dokdo, and Gageodo.

To conduct a successful assessment of changes in phytoplankton community structure, data analyses of long-term, in situ monitoring are necessary; however, for surface waters, spatio-temporal changes can be indirectly assessed using satellite data analyses. In addition, it is highly recommended that a comprehensive, long-term monitoring program focus on continuous seasonal and annual surveys of phytoplankton community structure (particularly those influenced by the Kuroshio Current) as well as surveys of harmful algal species.

2. Zooplankton

2.1 Introduction

The Korean marine environment is composed of many different water masses with interesting and complex properties, which arise from the mixing of various combinations of the Tsushima Warm Current as it branches from the Kuroshio Current, the Taiwan Current as it originates in the South China Sea, Chinese and Korean Yellow Sea bottom waters and Yellow Sea coastal waters, and cold currents from North Korea. These various water masses along the Korean peninsula harbor a diverse community of zooplankton species. For example, the Yellow Sea is known for frequent occurrences of native, site-specific (endemic) zooplankton species. Because of its high diversity and high biomass, the zooplankton community within Korean coastal waters supports an abundant fisheries industry.

Dominant zooplankton groups include copepods, euphausiids, amphipods, chaetognaths, tunicates, and larvae (Table 10).

Table 10. Average biomass and abundance of zooplankton within the Korean marine environment over the past decade (1997−2006).

Seas		East Sea	Yellow Sea	South Sea	East China Sea	All seas
Biomass (Wet Weight, mg m^{-3})		252.7	365.8	761.4	364.0	436.0
Abundance (inds m^{-3})	Copepoda	4611	2863	2198	1956	2907
	Amphipoda	152	28	69	42	73
	Chaetognatha	92	136	68	142	110
	Euphausiacea	117	36	57	42	63

2.2 Changes in zooplankton community structure

In marine food webs, zooplankton primarily graze on phytoplankton and function as important energy carriers connecting primary producers to higher trophic levels. Therefore, zooplankton are strongly affected by the species composition and biomass of both phytoplankton and predators.

Zooplankton area lso a very useful indicator group for monitoring changes in the marine abiotic environment and the ecosystem as a whole. Factors such as climate change, marine pollution, overfishing, and the introduction of invasive species may induce changes in zooplankton community structure and affect the role of zooplankton in the ecosystem. In fact, changes in zooplankton species composition and biomass, specialized zooplankton (e.g., jellyfish) blooms, sustained presence and increased dominance of tunicates and larvae, and changes in species composition and dominant species of copepods have also recently been observed.

2.3 Zooplankton survey

The zooplankton community survey of Korean waters was initiated in 1921 by the Fisheries Testing Institute (predecessor of what is now NFRDI). Beginning in 1965, sampling stations in eastern, western, and southern seas have been regularly surveyed every other month (six times per year). In addition, a marine environmental survey of the East China Sea began in 1995, bringing the total number of NFRDI systematic survey stations to 201 in four marine regions (Fig.27).

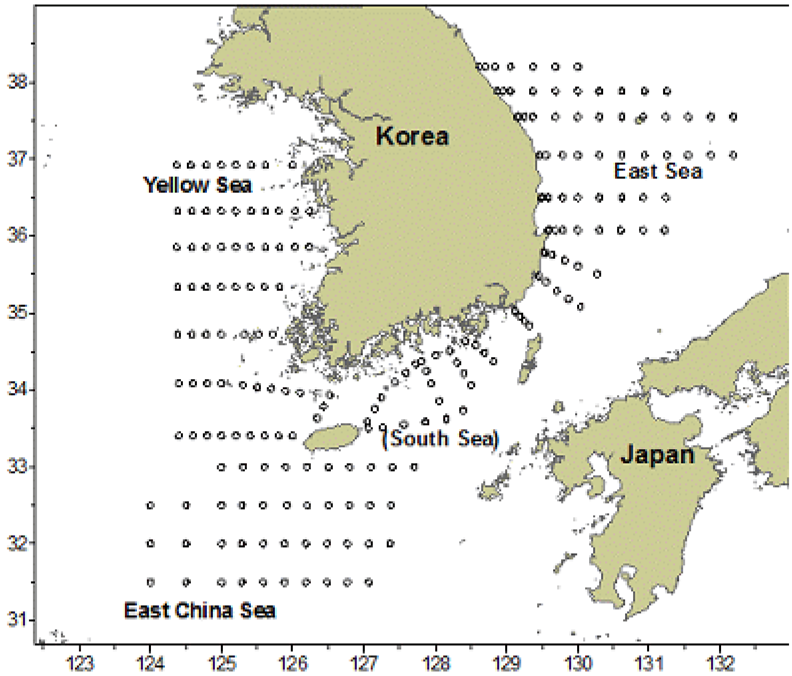
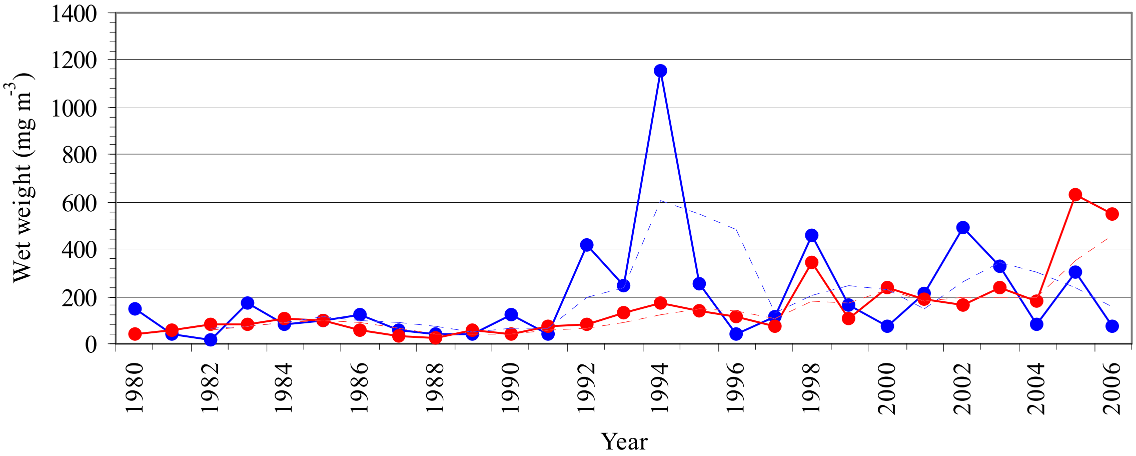


Fig. 27. Locations of sampling stations visited on a regular basis by the NFRDI for marine environmental surveys of Korean waters.

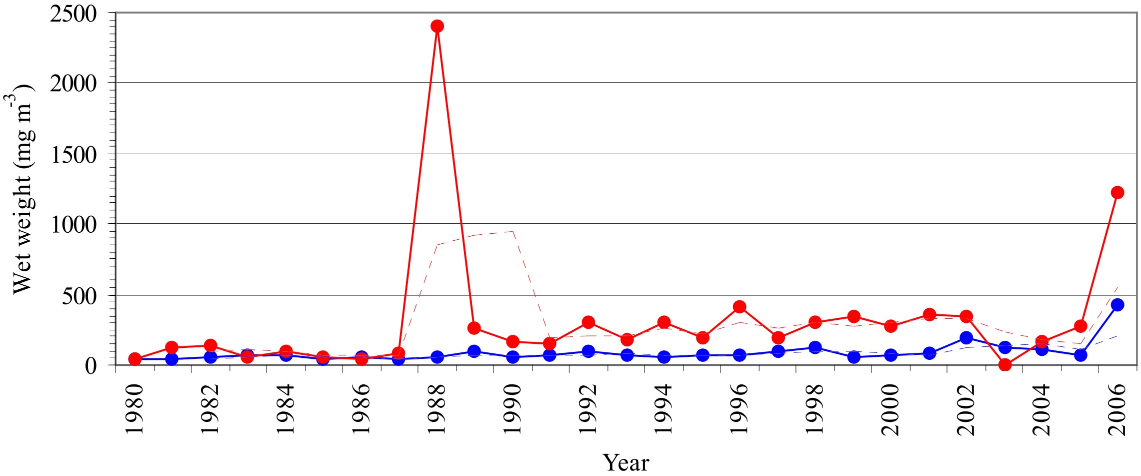
KORDI was established in 1973 as a branch institute of the Korea Institute of Science and Technology and has since conducted a number of studies on the zooplankton community in Korean waters (e.g., the Yellow Sea Large Marine Ecosystem Study).

In general, the biomass of the zooplankton community in eastern, western, and southern Korean seas and the East China Sea has been increasing slightly (Fig. 28; NFRDI). However, copepods, euphausiids, and other selected groups have exhibited either decreasing or increasing trends depending on the specific water mass of the region, making it difficult to determine any clear patterns related to climate change.

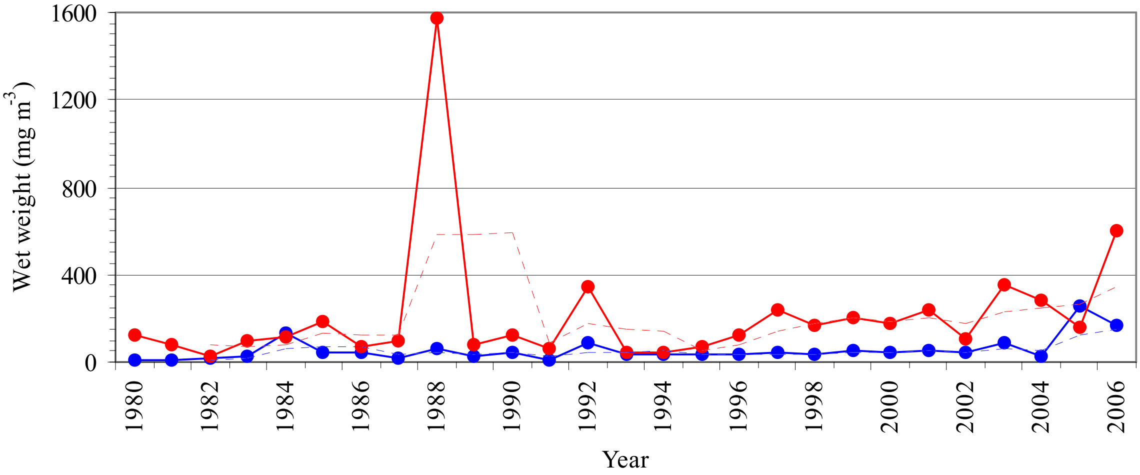
a) East Sea



b) Yellow Sea



c) South Sea



d) East China Sea

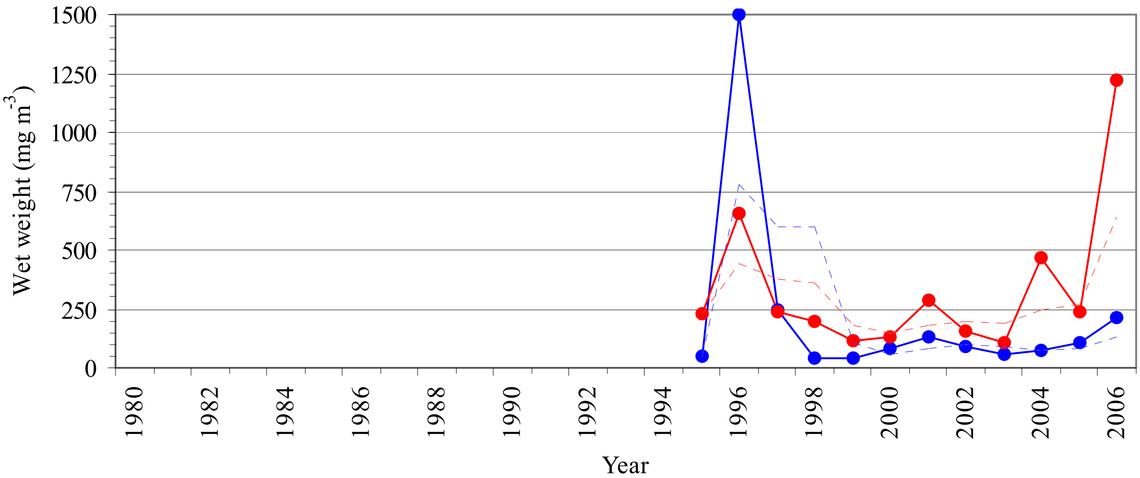


Fig. 28. Changes in zooplankton biomass for (a) the East Sea, (b) the Yellow Sea, (c) the South Sea, and (d) the East China Sea for the months of February (blue dots) and August (red dots), 1980–2006. Dotted lines represent averages for the indicated period. Data are from night samplings only.

As part of a project to determine the response of the zooplankton community to climate change, surveys are in progress to assess the status of invasive species and baseline community dynamics and phenology.

Beginning in the latter half of 1990, western and southern coastal waters of the Korean peninsula experienced several large and dense blooms of the scale moon jellyfish (Aurelia aurita). Since 2003, a number of blooms of Nomura's jellyfish (Nemopilema nomurai) have been observed in even the open ocean of the northern East China Sea and the southern Yellow Sea. These large jellyfish reach up to 2 m in diameter and can weigh 200 kg; blooms of this species have had devastating effects on the regional ecosystem (Fig. 29). Such unusual inundations of these extraterrestrial-like invaders are thought to have resulted from the combination of climate change, increased marine pollution, exhaustion of fisheries resources (particularly predator fisheries), and the construction of marine structures along coastal areas. On the basis of such frequent reoccurrences of extreme and unusual environmental conditions, an ominous scenario is forecasted for the future of the marine ecosystems of Korea. In all likelihood, the structure and function of the Korean marine ecosystem will change and shift to a different regime sooner than expected.

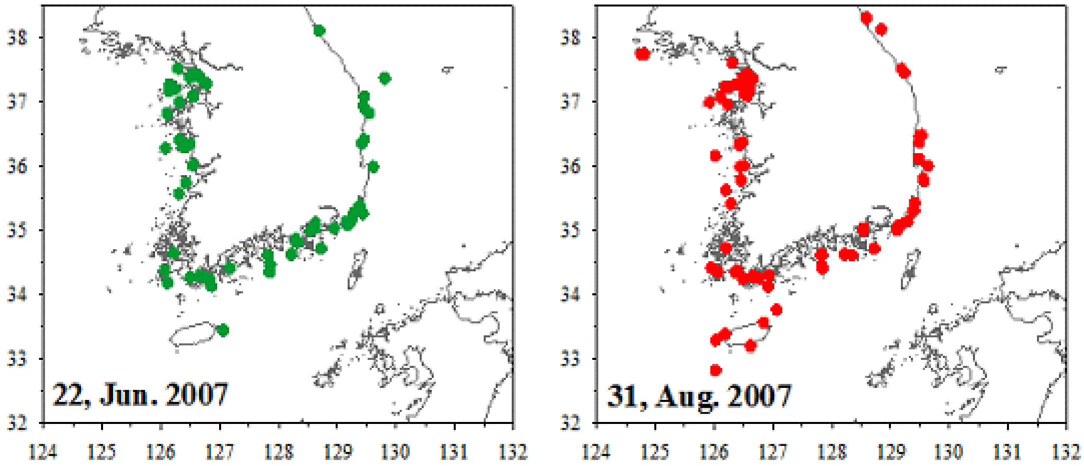


Fig. 29. Inundation of Korean coastal waters by moon jellyfish (Aurelia aurita, right) and Nomura′s jellyfish (*Nemopilema nomurai*, left) in summer 2007.

Moreover, because of the strong dominance of only few species, the zooplankton community within Korean waters (with exception of the East Sea) will be difficult to recover if faced with overburdening external stresses such as climate change and severe marine pollution.

2.4 Indicator species for tracking changes in environmental conditions

Selected individual zooplankton groups and their associated ecology and biological traits can be used as indicators for tracking changes in the marine ecosystem. The copepod Calanus sinicus, the euphausiid Euphausia pacifica, the chaetognath Sagitta elegans, and the tunicate Tethys vagina appear most useful for elucidating changes occurring in the Korean marine ecosystem.

Opportunistic and resilient zooplankton species can also be used as indicator species to determine the effect and level of coastal marine pollution.

3. Larval Fishes

3.1 Introduction

The species diversity and distribution of larval fishes in Korean waters exhibit distinct seasonal and regional differences due to varying characteristics of the coastal bottom environment and the distribution of different water masses, such as waters of the Tsushima Warm Current, the East Korea Warm Current, Korea Strait Bottom Cold Water, East Sea Proper Water, North Korea Cold Water, and Korea Coastal Water. Dominant species within various waters include the anchovy (East Sea, Yellow Sea, and coastal waters of the South Sea), Pholis fangi (Yellow Sea), the pearlsides Maurolicus muelleri (offshore of the East Sea), and gobiidae fishes (coastal waters of the South and Yellow Seas). Unlike the Yellow Sea, the South and East Seas experience abundant and frequent occurrences of fish larvae of warm-water species. For these reasons, fish species diversity is highest in the South Sea, followed by the East Sea, and lowest in the Yellow Sea.

3.2 Changes in fish larval communities

The marine waters of the Korean peninsula experience large seasonal fluctuations in water temperature; thus, many Korean marine fish species seasonally migrate to find appropriate sites for breeding/spawning, establishment of nurseries, feeding, and overwintering.

Recently, fish larvae of warm-water species as well as adult fish have appeared with increasing frequency in the offshore waters of the East and South Seas. These fish include some warm-water adult and larval species that have not been previously reported in Korean waters. More recently, a tuna fisheries ground was formed in the South Sea for the first time in Korea.

The increasing prevalence of warm-water fish species, the appearance of previously unreported fish species, and the formation of new fisheries grounds all suggest that the structure of fisheries resources is in the process of shifting to an entirely different ecosystem, because of rising water temperatures in the Korean marine ecosystem.

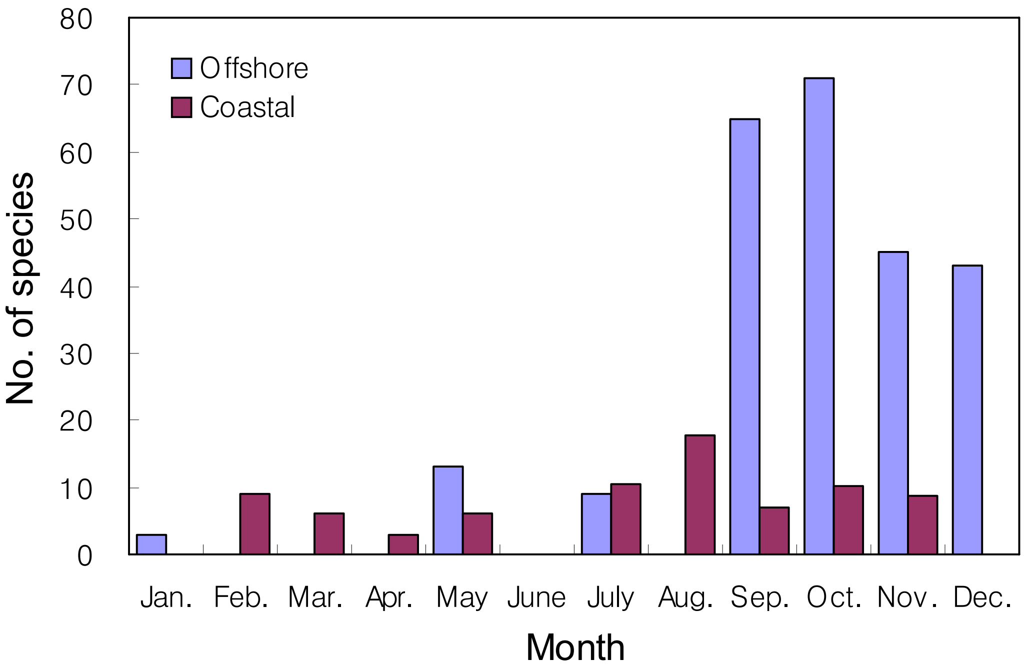
Unlike deep offshore waters, shallow coastal areas and coastal zones of Korea were often indiscriminately developed following the rapid economic development after the 1980s. This coastal development led to reduced opportunities for coastal fish species to find adequate areas for habitation, spawning, and nursery grounds. Furthermore, with improvements in fisheries technology, the efficient catch and use of fisheries resources has also increased. Consequently, coastal fisheries resources have been decreasing more rapidly and experiencing larger shifts in species composition than offshore fisheries.

3.3 Larval fish research

Investigations into the distribution of fish larvae in the East, Yellow, and South Seas were started in 1965 by NFRDI (Lim et al., 1970). Since then, KORDI and other research organizations have also participated in studies of larval fish distribution.

The total observed larval fish diversity in Korean waters was higher in offshore waters than coastal waters. Seasonal species diversity in the Yellow Sea area was higher in the summer, whereas the East and South Seas exhibited higher diversity in late summer and fall (Fig. 30).

Characteristics of the water column and the distribution of various water masses clearly affect the patterns of larval fish distribution. For example, the distribution of the larvae and fish eggs of pearlsides (M. muelleri), a representative dominant fish of the East Sea, was closely correlated with regional factors that affect the water column, such as the inflow of warm-water currents, inflow of Korea Strait bottom cold water, and coastal upwelling of the East Sea (Fig. 31).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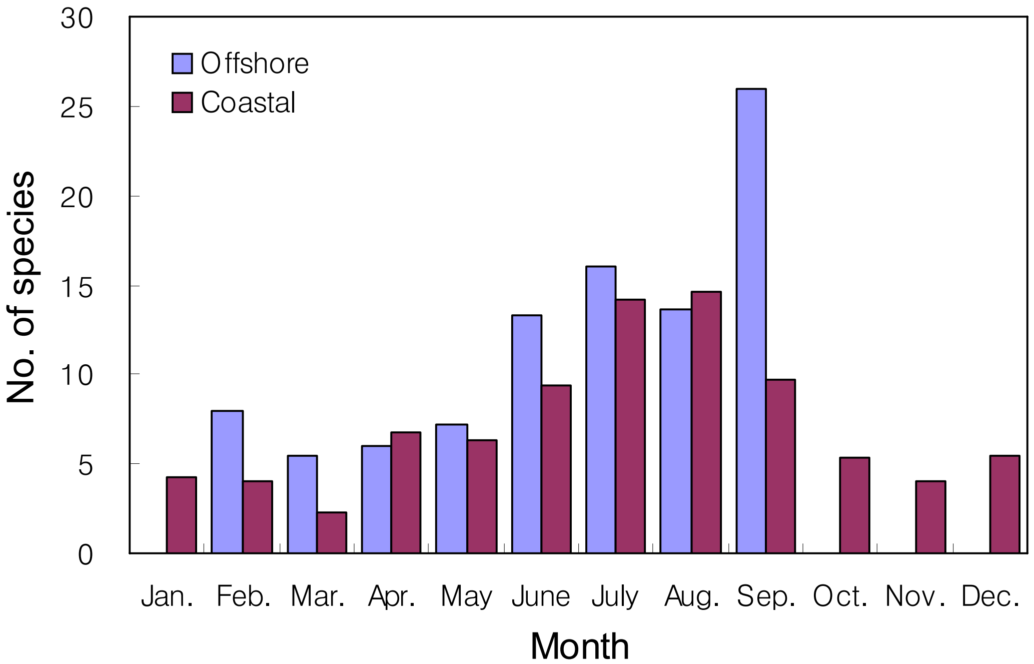
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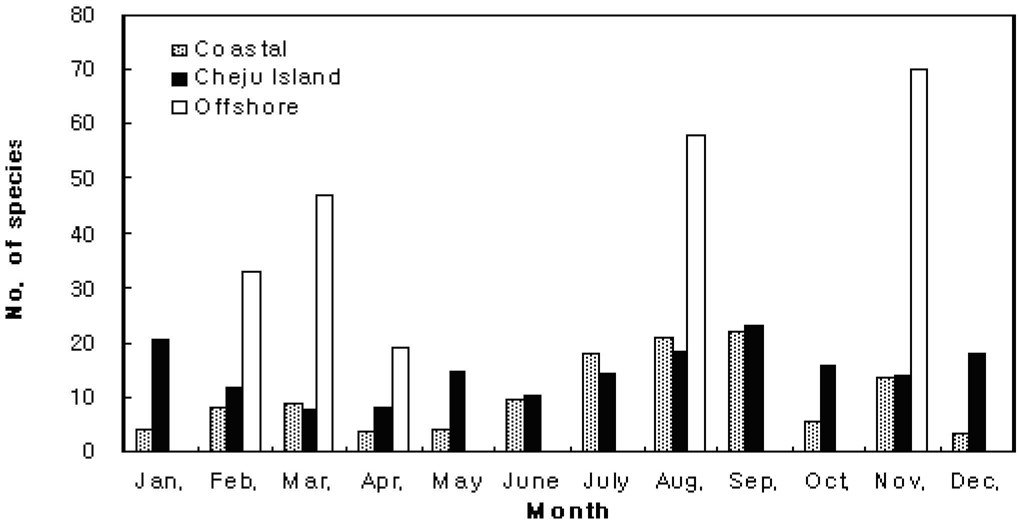

Fig. 30. Numbers of larval fish species for coastal and offshore waters of the East Sea, Yellow Sea, and South Sea (Yoo et al., 2003).

The distribution of fish larvae primarily depends on traits related to the water column and seasonal factors but is also affected by the loss of habitat and spawning grounds due to coastal development.

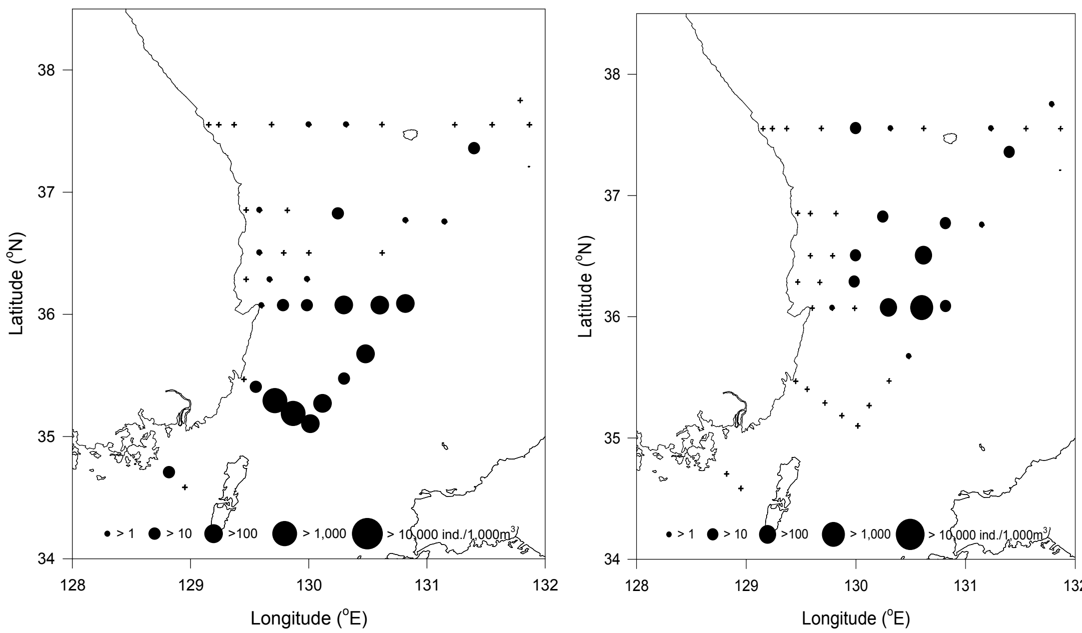

Fig. 31. Distribution of fish eggs (left) and larvae (right) of pearlsides, *Maurolicus muelleri*, in May 2000 (KORDI).

The gunnel, Pholis fangi, a dominant species of the Yellow Sea, is typically caught during its larval stage. This important fisheries resource rapidly increased during the latter half of the 1970s (Yoo et al., 1995). However, the abundance of larval gunnel has been decreasing since 1990. Similarly, dominant coastal fish from the Gobiidae family (Pisces, Perciformes) have also been decreasing in number since reaching a peak at the end of 1980s (Fig. 32). These two groups of fishes are both dominant species in the Yellow Sea; gunnels are dominant in offshore and coastal waters, whereas gobies are dominant in coastal waters. These consistent decreases in catches of goby fish (with the exception of a rapid increase in 2005) appear to be related to coastal development along the Yellow Sea.

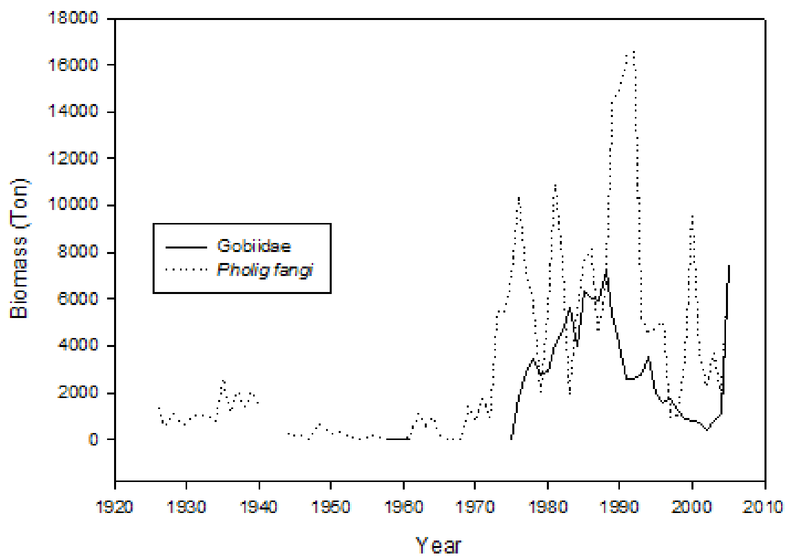

Fig. 32. Annual total catch of Gobiidae and *Pholig fangi* (from 2007 Korea Fisheries Almanac).

3.4 Future studies of fish larvae

Study of the species composition and distribution of fish larvae in different regions are relatively active compared to in other fields. In contrast, studies of fish eggs, which are generally difficult to identify, have been limited to the distinct, easily identifiable eggs of species such as anchovies and pearlsides.

Recently, molecular marker technology has been introduced to overcome difficulties of identifying fish larvae. In addition, attempts have been made at in situ analyses of spawning and nursery grounds.

Variability in the species composition and distribution of fish larvae is strongly affected by climate-induced changes in water column structure as well as the destruction of spawning and nursery grounds due to coastal development. Therefore, larval fish research in the Korean marine environment should separately focus on coastal and offshore waters, establish long-term monitoring stations in different water regions for spatial-temporal observations, and develop basic technology for analyzing fish larvae in real time.

Each marine region differs greatly in water column structure and bottom morphology. Thus, distinct species must be selected for each marine region to best determine changes in the marine ecosystem and assess the effects of climate change and coastal development.

4. Benthos

4.1 Introduction

Benthic species function as important primary consumers in marine food webs, and the species involved often themselves become prey for bottom-feeding fish and other important benthic species. In addition, many species drive material cycles and the degradation of organic material through bioturbation.

Macro-benthic species usually have low mobility and are thus able to reflect changes in the benthic environment. Therefore, such species are often used to assess marine pollution within inner bay waters, which typically have severe pollution problems. The macro-benthos is also a particularly useful survey target for the environmental impact assessment required for various marine public engineering efforts.

Major components of the macro-benthic community in Korean waters include bristleworms (polychaetes), mollusks, and crustaceans. Echinoderms and other benthos are relatively minor components. Although some differences occur across locations, bristleworms and crustaceans are dominant with respect to species composition, whereas bristleworms and mollusks are dominant in abundance.

4.2 Changes in benthic community

Benthic community surveys have often been conducted at a large scale in locations experiencing environmental stresses primarily due to industrial activities and eutrophication caused by organic pollutants (e.g., the Jinhae Bay). Hence, benthic studies of offshore waters or in areas with less developmental pressures are limited.

The benthos includes macro-, meio-, and micro-benthos; however, because of the low availability of systematic taxonomists for the meio- and micro-benthos, most benthic studies have focused on taxonomic and ecosystem research of the macro-benthos. Currently, a few scientists are more actively exploring the meio-benthos of tidal flats.

Benthic community research in soft-bottom ecosystems first started in 1975 in the Yongho Bay of Busan City. The main target was the bristleworm community, and the distribution and environmental effects on these organisms have remained a major focus of benthic studies. Since 1980, many studies have focused on the Jinhae Bay as well as other areas, such as the Gwangyang Bay, watersheds of the Youngsan River, and the Chunsu Bay. Additional, intermittent studies have been conducted for inner bays and coastal areas.

Offshore benthic studies have included polychaete studies in the East Sea and mollusk studies in the Yellow and South Seas. Beginning in the mid-1980s, four comprehensive macro-benthic studies of the Korean marine environment have been conducted by KORDI over 15 years. However, some of the taxonomic analyses for these studies remain unresolved.

The KORDI study was followed by the National Investigation of the Marine Ecosystem in 2006, which has characteristics of screen-survey studies and continues today. The objectives of the national survey are to monitor changes in the marine ecosystem environment and the status of biological diversity, including the benthos. The study area is divided into eight zones along the seas of eastern, western, and southern coastal areas and all EEZ areas. One zone is surveyed each year, and the final results are published as a marine ecosystem map and as a white paper for the marine ecosystem of Korea (Fig. 33).

Macro-benthic species composition and diversity in Korean waters have not yet been determined because of the irregularity and isolated nature of past studies. However, the diverse marine environments and various habitats of Korea, such as the deep waters of the East Sea, the highly productive inner bays of the South Sea, and the extensive tidal flats of the Yellow Sea, indicate high benthic species diversity within Korean waters.

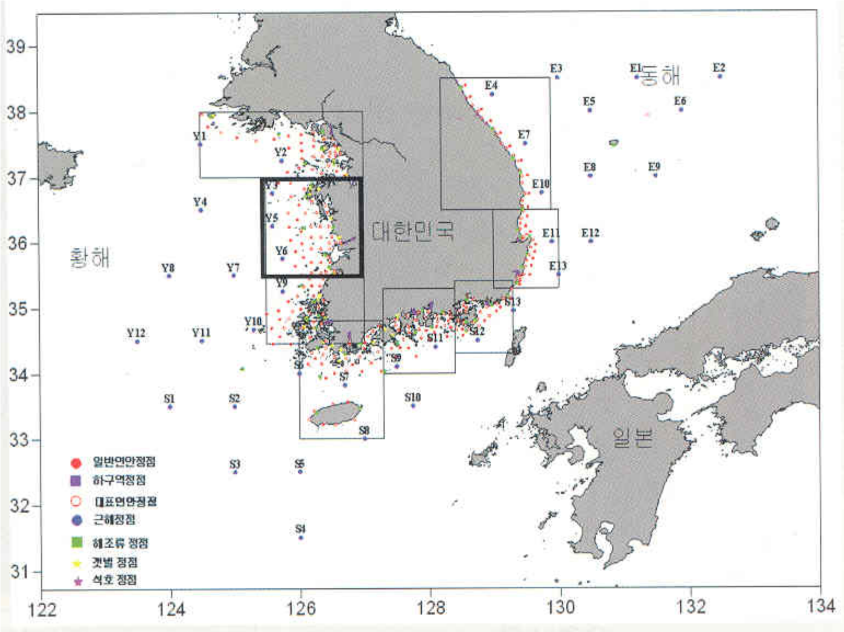

Fig. 33. Survey zones for the National Investigation of the Marine Ecosystem

4.3 Habitation destruction

Over the last 20 years, many coastal reclamation projects have been initiated to secure lands for agriculture, industrial complexes, and urbanization. This coastal artificial land formation has led to changes in coastal lines and coastal current flows, thus severely harming the natural setting of benthic habitats. Moreover, dredging for safe navigation and port construction and sand mining have also greatly affected benthic habitats. Recently, after serious considerations, the environmental impact assessment system was expanded to include these problems.

Two of the most representative oil spill accidents, the Sea Prince accident in 1995 and the Hebei Spirit accident in 2007, have profoundly affected the marine benthic ecosystem. The effects incurred by the Hebei Spirit oil spill accident are currently being monitored by KORDI.

4.4 Hypoxia

In 1970, hypoxic events due to pollution by organic material and during the summer stratification period were reported for the Jinhae Bay. Since then, hypoxia has often been reported in the Gamak Bay, watersheds of the Youngsan River, and the Chunsu Bay. The formation of a hypoxic water column worsened the condition of bay water due to surrounding industrialization and urbanization, which has increased the discharge of organic material, causing eutrophication and expansion of the hypoxic area (Fig. 34).

In the Jinhae Bay, particularly severe eutrophication events have been attributed to the discharge of organic material caused by industrialization and intensive aquaculture of oysters, mussels, and ark shells. Such serious environmental stress annually induces hypoxia in the inner bay waters beginning in May, and by September, half of the Jinhae Bay has become hypoxic, resulting in mass mortality of benthic and aquaculture organisms. Certain areas experience azoic conditions for 4 months, but surface water temperatures rapidly decrease during the fall, and the hypoxia disappears. This appearance and disappearance of hypoxic conditions have become cyclic events in this area.

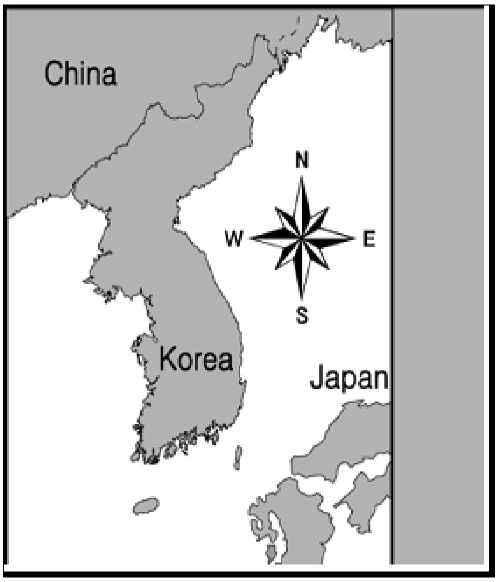

Fig. 34. Hypoxic areas in the summer seasons for Korean coastal waters

4.5 Status of the benthos

Marine waters off of the Korean peninsula are strongly affected by the aforementioned water masses. Diverse sedimentation characteristics occur throughout Korean waters, which are also affected by the discharge of organic materials from terrestrial sources. Thus, the macro-benthos of coastal waters is also strongly affected by sediment characteristics and organic content within the sediments. Bottom hypoxia, formed in the water column during the summer, and salinity and sedimentation characteristics also greatly influence the distribution of macro-benthos.

Some of the opportunistic species observed in the half-enclosed inner bay, which is characterized by high organic content in the sediments and very small grain size, include polychaetes, such as Paraprionospio pinnata, Capitella capitata, Heteromastus filiformis, Sigambra tentaculata, and Tharyx sp., and mollusks, such as Theora fragilis and Raetellops pulchella. There have been no reports of opportunistic crustacean species, although Nebalia bipes has been observed at various locations.

The benthic community includes many commercially important and valuable species, such as Manila clams, oysters, comb pen shells, egg cockles, scallops, surf clams, sand gapers, octopi (whip-arms), and ark shells, which are often produced via aquaculture.

Tidal flats are well developed and very extensive along western coastal areas. These ecosystems are important habitats for benthos, which allow the tidal flats to function as important feeding grounds for water birds. The government has delineated the tidal flats into six zones for preservation purposes. The first coastal wetland survey was successfully completed in 2005 after six years of research. The results from this survey revealed several distributional characteristics of the macro-benthos. A second survey began in 2008 and will last for five years. To date, six tidal flats (the Muan, Jindo, Suncheon Bay, Bosung Beolygyo, Gochangjulpo Bay, and Ongjinjangbongdo) have been designated as wetland protection areas on the basis of results of the first survey. The Suncheon Bay and Muan tidal flats are also registered as Ramsar wetland sites.

4.6 Future plans

Research of the benthic community typically examines the structural aspects of the relationship among environmental parameters and spatial distributional characteristics.

However, the benthos as an energy carrier in the ecosystem, life-cycle studies, and functional aspects of the benthos must also be addressed in future research.

Systematic taxonomic confirmation for species identification should be conducted in parallel with the establishment of a database to determine the exact biological diversity of the macro-benthos. Currently, information related to species identification resides with individual researchers, increasing the difficulty of comprehensively assessing the macro-benthos throughout Korean waters. Such general assessments of the benthic community should be preceded by taxonomic identification. However, only a few systematists work in Korea; thus, additional human resources should be recruited for sustainable research of the benthos.

With recent global warming trends, warm-water benthic species are expected to migrate to Korean waters. In addition, more invasive species are expected to arrive through increased ship movements. However, no systematic investigations of these issues have been conducted and should be strongly considered in the future.

Reclamation efforts of tidal flats continue to secure lands for various industrial complexes. Through this continuous developmental pressure, habitat destruction and coastal pollution are threatening the benthic ecosystem. Therefore, to establish effective and efficient coastal zone management policies based on scientific data and information, a continuous coastal zone monitoring system must be implemented.

5. Sea Birds

5.1 Introduction

A total of 27−29 orders (depending on the source) of birds are present in Korea. These include the true sea birds, penguins, albatross, and fork-tailed petrels, which belong to only two orders. Another eight orders include mixed specialists for land, coastal areas, and the sea. Because of difficulties in focusing strictly on sea birds, the current assessment examined general water birds, including species in coastal wetlands, seashore birds, and birds preferring islands/islets.

In Korea, waters birds of islands/islets, coastal wetlands/tidal flats, and the seas include 167 species in 16 families: the Anatidae, Gruida, Rallida, Scolopacida, Rostratulidae, Jacanidae, Charadriidae, Glareolidae, Laridae, Podicipedidae, Phalacrocoracidae, Ardeidae, Threskiornithidae, Pelecanidae, Ciconiidae, and Gaviidae. In addition, some of the marine birds that inhabit the shorelines include the Procellaridae, Diomedeidae, Hydrobatidae, and Fregatidae. The Order Laridae also includes water birds of the Stercorariini and Alcinae.

North and South Korea combined have recorded a total of 430 species of birds. The number of water birds for the entire Korean peninsula totals approximately 176 species, including those mentioned above (167 species) and several other observed water birds, representing approximately 40.9% of all bird species in Korea. The Korean peninsula is an attractive area for water birds, as reflected by the relatively high percentage of water birds compared to the global percentage of water-bird species (8.6% of total bird species). Despite a high percentage (67%) of mountainous terrain, the Korean peninsula has well-developed coastal wetlands/tidal flats, artificial lakes, and extensive watersheds and estuaries, all of which contribute to this high rate of occurrence of water birds.

5.2 Status of sea birds

The Korean peninsula is an important wintering ground for a variety of bird species, including sea birds. Korea is also well situated within a strategically important migration route for birds flying from Siberia, Manchuria, and Mongolia to different wintering areas. As a wintering and resting ground for migratory birds, Korea receives approximately 1,470,000 birds from October to March. Since 1999, the National Institute of Environment Research (NIER)/ Ministry of the Environment has conducted a simultaneous nationwide census of wintering birds in Korea. In January 2008, a census of 128 inland and coastal wetlands/tidal flats revealed that watersheds of the Gum River housed 303,000 birds, Haenam/Sunchun Bay had 112,000 birds, the Dongjin and Mangyung Rivers harbored 66,000 birds, the Nakdong River estuary had 16,000 birds, and the Han River estuary had 16,000 birds.

The tidal flats/coastal wetlands of Korea are abundant with invertebrate prey for water birds and are well known for having conditions that are excellent for the birds. Water birds using coastal wetlands and tidal flats as resting or wintering grounds function as the top predators of their marine food web. As top predators in these ecosystems, water birds are representative indicator species for long-term monitoring of marine environmental changes, such as marine pollution, habitat alteration, changes in prey resources, and the benthic ecosystem.

5.3 Results from the sea bird census of the Ministry of Environment

Since 1999, NIER and the Ministry of the Environment have annually reported the national winter census of migratory birds from 128 inland and coastal wetlands/tidal flat sites. The reports include the abundance of wintering birds in river watersheds, artificial lakes formed after reclamation, coastal wetlands/tidal flats (excluding inland wetlands), and freshwater lakes.

The results of the 2007 census indicated that 198 species of 1,697,000 birds occurred at these sites, representing the highest number since the census began in 1999. The bird census has reported increasing numbers since 2002. The highest count of wintering birds (748,000) was observed at Gumgang Lake, which is the largest observed gathering place of Baikal teals in Korea. Sapkyo Lake followed with 79,200 wintering birds, the Han River estuary with 56,900 birds, and the Nakdong River estuary with 42,100 birds. Artificial lakes have been formed as the result of various reclamation activities, and watersheds located near coastal wetlands harbor high densities of diverse prey organisms, thus attracting huge numbers of wintering and migrating water birds(Fig. 35).

Bird Life International has also recognized the significance of coastal wetlands in Korea and has selected 40 sites in the Republic of Korea as internationally Important Bird Areas (IBA). Among these 40 sites, 27 are distributed among islands (6 sites), watersheds/estuaries (6 sites), artificial lakes (6sites), coastal wetlands/tidal flats (5 sites), and bays/inner bays (4 sites).

As mentioned above, the highest count of 820,000 Baikal teals, since the census began, was observed in 2007. This value is 1.8 times the number of birds counted in 2004 (450,000), and three times the number in 2006 (270,000). To determine the reason for such rapid increases in Baikal teals, censuses in neighboring China and Japan were examined to determine whether birds from these countries are migrating to Korea. However, Japan and China only counted 2,000 and 300 teals in 2006, respectively, negating the possibility of influxes from these neighboring nations(Fig. 36).

Recent reports have indicated that climate change is strongly affecting the primary habitats for migrating birds in tundra areas, and the breeding grounds for some migrating birds are expanding with increasing availability of prey (UNEP-WCMC, 2007). These findings suggest that rapid increases of Baikal teals in Korea are may be the consequence of environmental changes that increase the success rate of breeding by Baikal teals in the Siberian tundra(Figs. 35~39).

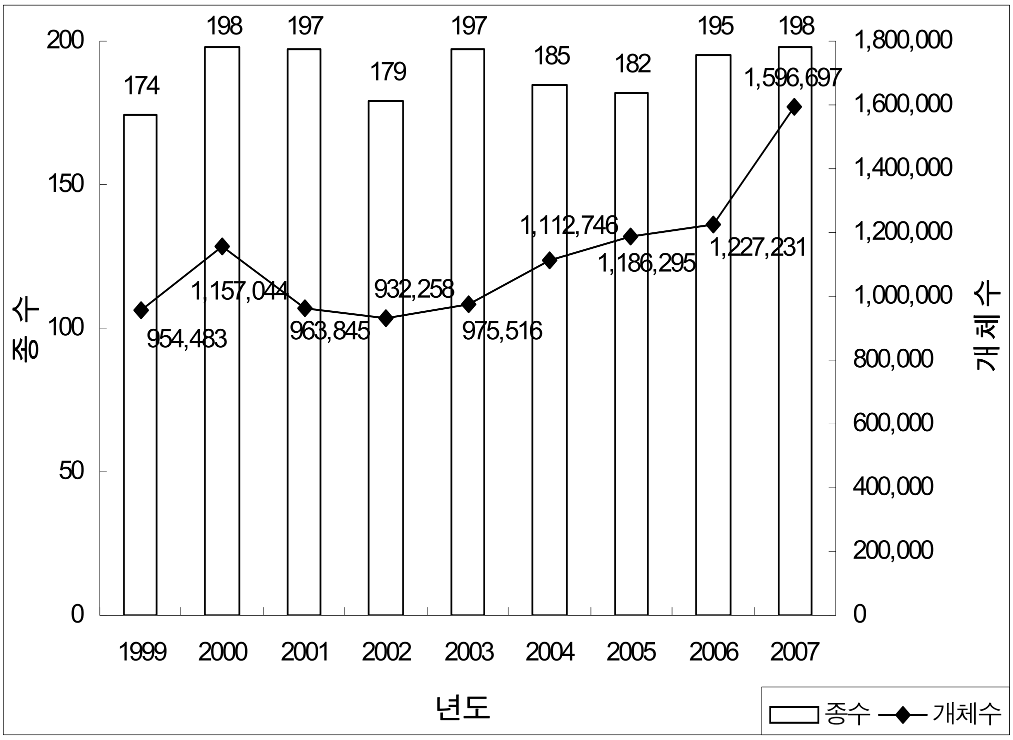

Fig. 35. Annul abundance and species number of water birds

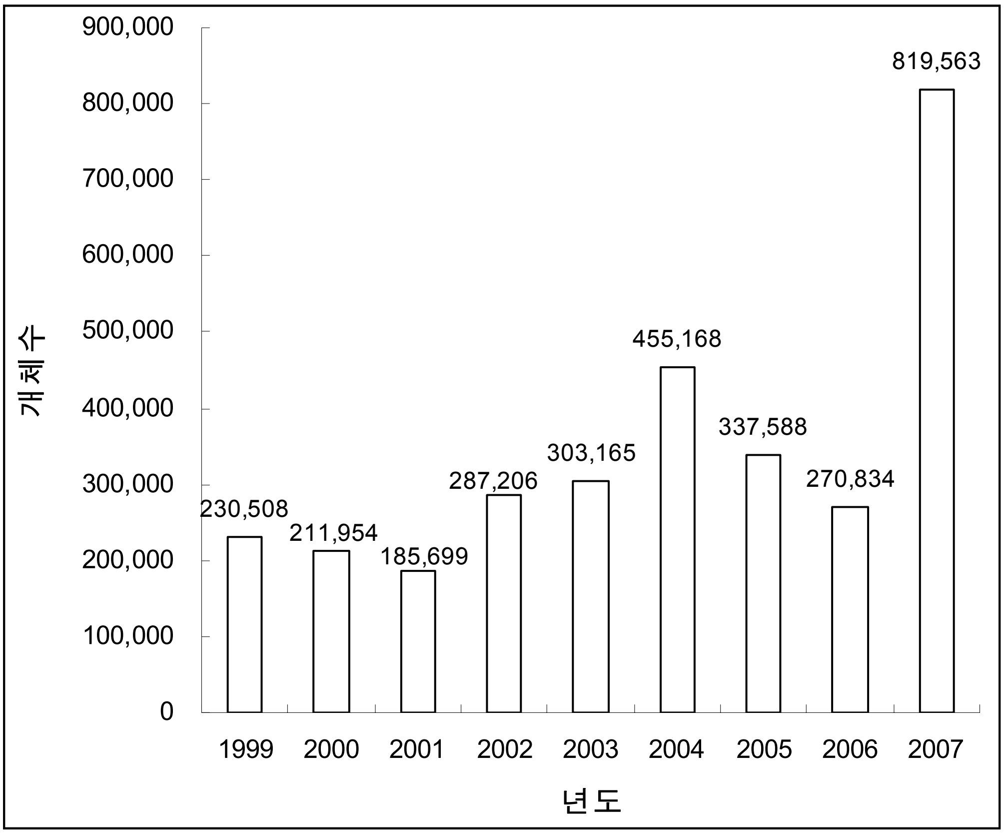

Fig. 36. Annul abundance of the Baikal teal

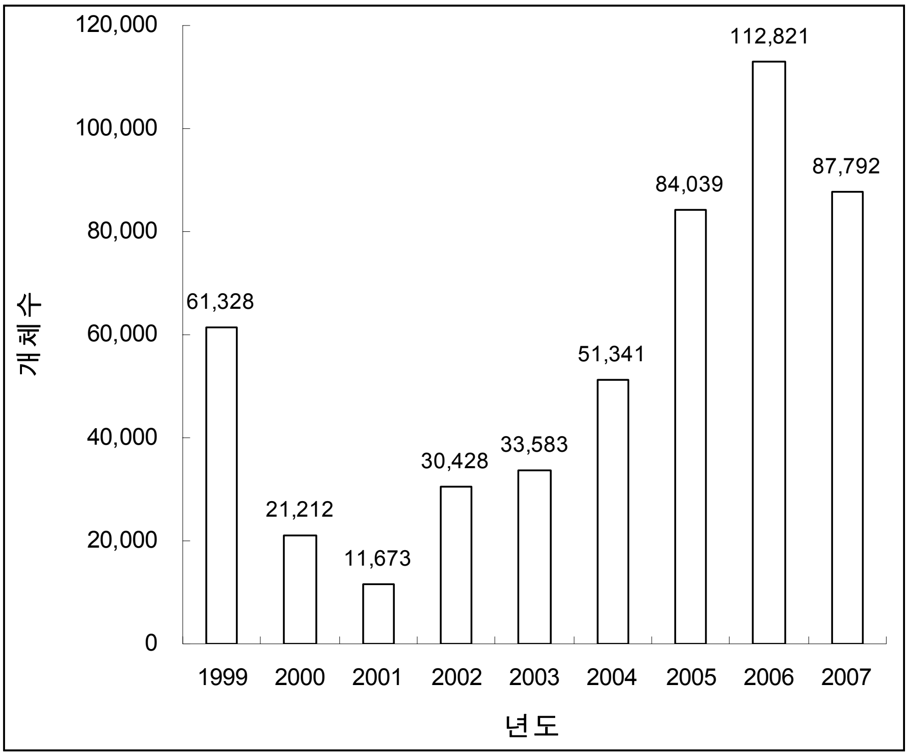

Fig. 37. Annual abundance of the white-fronted goose.

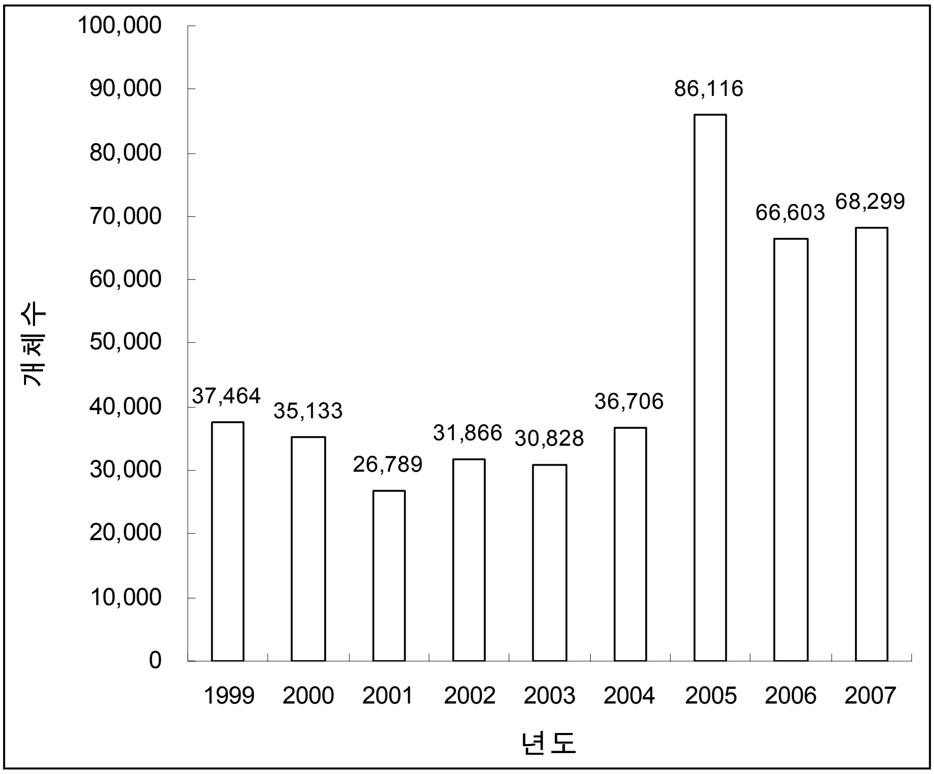

Fig. 38. Annual abundance of the bean goose.

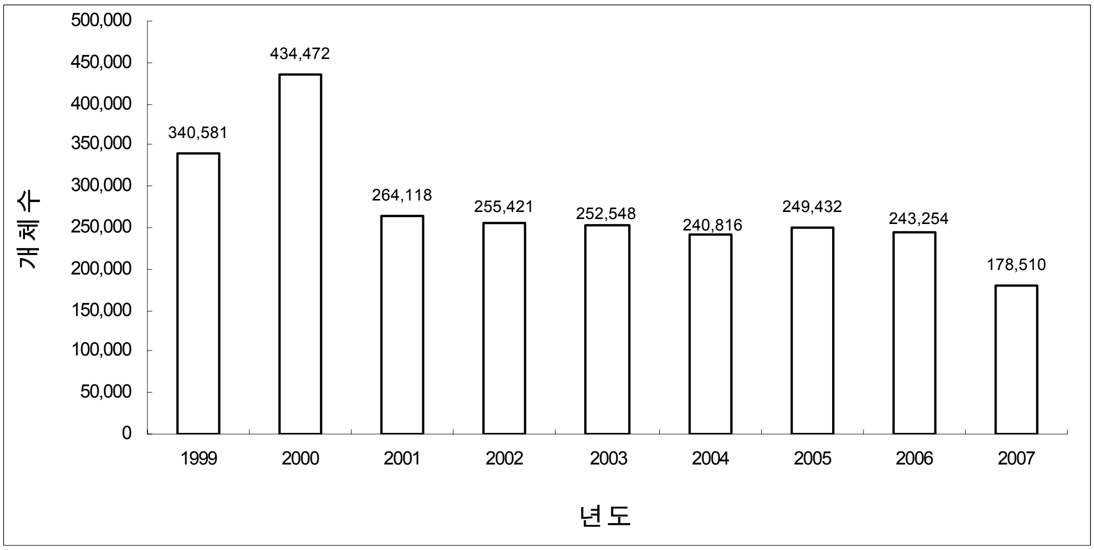

Fig. 39. Annual abundance of mallards

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Ⅴ. Chemical components and pollutants in Korean Ocean

1. Goal and objectives of this report

1.1 General information

The efforts of Korean people and its government to manage marine environment initiated in the creation of the Ministry of Maritime Affairs and Fisheries (MOMAF) in 1996 followed by the establishment of the Ministry of Environment (MOE) in 1994. Especially MOMAF has provided an institutional framework for sustainable development of coastal resources and a firm base for coastal environment management, and it transited to Ministry of Land, Transport and Maritime Affairs(MLTM) in 2008.

The Korean government started to reinforce policies of preservation for healthy and sustainable marine ecosystem and habitats protection on coastal area from 2006; the enactment of Law on the Conservation and Management of Marine Ecosystem, the amendment of Public Waters Reclamation Act & Coastal Management Act, the strict application of environmental impact assessment on coastal utilization & development projects. Those actions are to prevent habitats degradation, loss of marine living resources, and decrease of fishery and ensure sustainable development based on healthy marine environment as ecosystem-based management approach.

1.2 Goals and objectives of this report

The assessment of marine chemical circumstances and pollutants conditions serves protect and reconstruct coastal habitats, secure fishable and swim able environment, and ensure sustainable use of coastal resources, living and non-living. Primary approaches to achieve the goals are to "Anti-degradation of current environment and ecosystem condition" and "Improvement of deteriorated coastal environment. Objectives for attaining the goals are classified into enhancement of ecosystem health, improvement of water and sediment environment qualities, and strengthening of legal and institutional bases.

1.3 Geographical scope of relevant region of ROK area

This report deals with a full range of chemical components and pollutants in coastal and marine of Korea. Setting a geographic boundary is required to effectively assess the components and institutional arrangements. Geographic boundary covers inland where affects to marine environment from air-pollutants and point and non-point sources including sewage treatment plants and sea areas. Sea area for this report extends EEZ from coastlines.

2. Assessment of present social, environmental and economic situation

2.1 Geographic features

Surrounded by seas on three sides, ROK has a relatively long coastline of 11,942 km due to rias coast on the western and southern parts. The coastal area accounts for 31.8% (31,641 km^2) of the total land area (99,514 km^2). The areas of territorial sea and exclusive economic zone (EEZ) are 71,000 km^2 and 447,000 km^2 respectively.

2.2 Serial Oceanography Investigation in Korean Waters

Since 1921, NFRDI (National Fisheries Research and Development Institute) has carried out Serial Oceanography Investigation in Korean Waters. Current scheme of Serial Oceanography Investigation in Korean Waters was started from 1961 with 22 lines and 175 stations. This investigation system has been carried out 6 times a year in February, April, June, August, October and December. Since 1995, Serial Oceanography Investigation in Northern East China Sea, which was carried out 4 times a year, was started with 3 lines and 32 stations. It measured temperature and salinity as physical factors with all stations and all standard depths, dissolved oxygen, Chlorophyll-a and nutrients as chemical factors with half stations and 4 standard depth (0, 20, 50, 100m), Zoo- and Phyto plankton as biological factors with half station and vertical collection from 100m depth or bottom.

The only composite ocean observation network in Korea is being operated in order to promptly and accurately understand the status of fluctuations in sea areas with formation of major fishing grounds and to understand changes in status of the coastal waters of Korea per time period and area. In addition, high-tech remote ocean research techniques by satellite were developed and have been used in identifying fluctuations in the status of wider sea areas since 1990. From 1995, a study is being conducted on fluctuations in the environment of northern coastal areas of East China Sea that serves as a bridge connecting Korea and the Pacific Ocean. It provides heat and biogeochemical properties to the surrounding waters of the Korean peninsula. Data accumulated through these studies are used to understand impact on the surrounding waters of Korea by marine environments of neighboring countries. This serves to help identify and predict fluctuations in the status of surrounding waters of the Korean peninsula and to achieve efficient research on fishing grounds, etc. They also provide scientific politic data to secure upper hand for confirmation of exclusive economic zone (EEZ).

Since 1966, quantitative analysis of nutrients was started in this Serial Oceanography Investigation. Measured factors of nutrients in this investigation are NO_2^--N, NO_3^--N, PO_4^+-P, SiO_2¯Si with about 110 stations in Korean Waters.

2.3 Marine Environment Monitoring Approaches in Korea

Marine Environment Monitoring Approaches in Korea were established to provide protection for a marine environment in the Korea so that emphasis on protecting the health and living environment of human populations and extend to examining the health and diversity of marine ecosystems. These are conducted by National Fisheries Research and Development Institute (NFRDI) as scientific investigations for the prevention of marine pollution and the preservation of marine environment based on the Korean Law with Marine Pollution Prevention Act. Generally, Research Monitoring Systems in Korea involved National Marine Environment Monitoring Network (NMEMN), National Investigation of Marine Ecosystem (NIME), Serial Oceanographic Investigation (SOI), Harmful Algae Blooms (HABs) Monitoring Network (HABMN), Monitoring of Korean waters using satellite remote sensing and Real-time Monitoring System were Real-time Information

System for Aquaculture Farm Environment (RISAFE) and Automatic Monitoring Network of Seawater Quality (AMNSQ). This Marine Environment Monitoring in Korea pursues a preventative marine environment management policy with "Creation of clean and living marine environment" as its goal.

2.4 Variation of water quality

The coastal and estuarine water quality has been of great concern in ROK due to its impacts on biological diversity, seafood safety, and tourism potential.

The overall coastal water quality has remained at seawater quality grade II (1~2 mg/L) in terms of chemical oxygen demand (COD) since 1991, despite the continuous investment in treatment facilities. Rapid urbanization and industrialization of the coastal area are responsible for increased inflow of domestic sewage and industrial wastewater into the Korean seas, reducing the effect of the facilities.

2.5 Variation of Nutrients

Variation of Nutrient is usually influenced the variation of primary productivity of phyto-plankton, zoo-plankton and fish. Nutrient, which is one of non-conservative constituents, provide the important information to understand the environmental related with biological activity. In case of offshore, the cause of concentration change of nutrients is usually depended on biogeochemical circulation process as creation and extinction occurred in water masses. Monitoring of nutrient, therefore, is indispensable to prediction of environmental change and preparation of environmental preservation.

In results of nutrients analysis with 4 constituents (PO_4^+-P, SiO_2^{--}Si, NO_2^--N, NO_3^--N) by Serial Oceanography Investigation of NFRDI during recent 10 years from 1998 to 2007, spatial surface distributions of each constituent are examined in winter and summer in Korean Waters.

Distribution of PO_4^+-P concentration in winter and summer are shown in Fig. 40. In winter, higher concentration of PO_4^+-P appeared in southern Yellow Sea. Spatial change of PO_4^+-P concentration in winter is also larger in Yellow Sea than northern East China Sea and East Sea. Range of PO_4^+-P concentration in winter is about 0.4~0.8 μg-at/L in Yellow Sea, about 0.2~0.3 μg-at/L in East Sea and about 0.3~0.6 μg-at/L in Northern East China Sea. In summer, PO_4^+-P concentration clearly decreased compared to winter. Larger PO_4^+-P concentration in summer appeared in southern Yellow Sea, where are usually formed tidal front. Relatively larger concentration of PO_4^+-P in summer also appeared near coast of southern East Sea larger than 0.3 μg-at/L. It caused by coastal upwelling during summer time in this area. Range of PO_4^+-P concentration in summer is about 0.2~0.7 μg-at/L in Yellow Sea, about 0.2~0.4 μg-at/L in East Sea and about 0.2~0.5 μg-at/L in northern East China Sea.

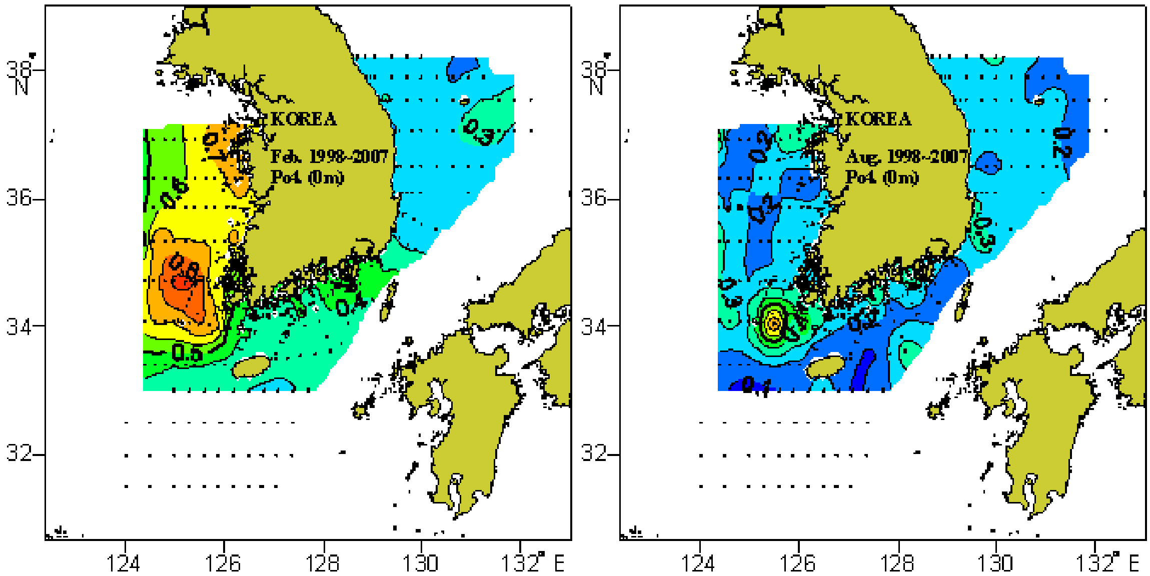

Fig. 40. Spatial surface distribution of 10 years mean (1998~2007) PO_4^+-P concentration in winter (left) and summer (right) in Korean Waters by serial oceanography investigation of NFRDI.

Distribution of SiO_2‾Si concentration in winter and summer are shown in Fig. 41. In winter, higher concentration of SiO_2‾Si appeared near coastal area in Yellow Sea. Spatial change of SiO_2‾Si concentration in winter is larger in southern Yellow Sea and northwestern East China Sea. Range of SiO_2‾Si concentration in winter is about 9.0~12.0 μg-at/L in Yellow Sea, about 4.0~7.0 μg-at/L in East Sea and about 6.0~10.0 μg-at/L in Northern East China Sea. In summer, SiO_2‾Si concentration clearly decreased compared to winter, especially in Yellow Sea. Larger SiO_2‾Si concentration in summer appeared near coast of northern Yellow Sea. Relatively larger concentration of SiO_2‾Si in summer also appeared north off Tshushima in East Sea larger than 6.0 μg-at/L. Range of SiO_2‾Si concentration in summer is about 3.0~7.0 μg-at/L in Yellow Sea, about 4.0~6.0 μg-at/L in East Sea and about 4.0~6.0 μg-at/L in northern East China Sea.

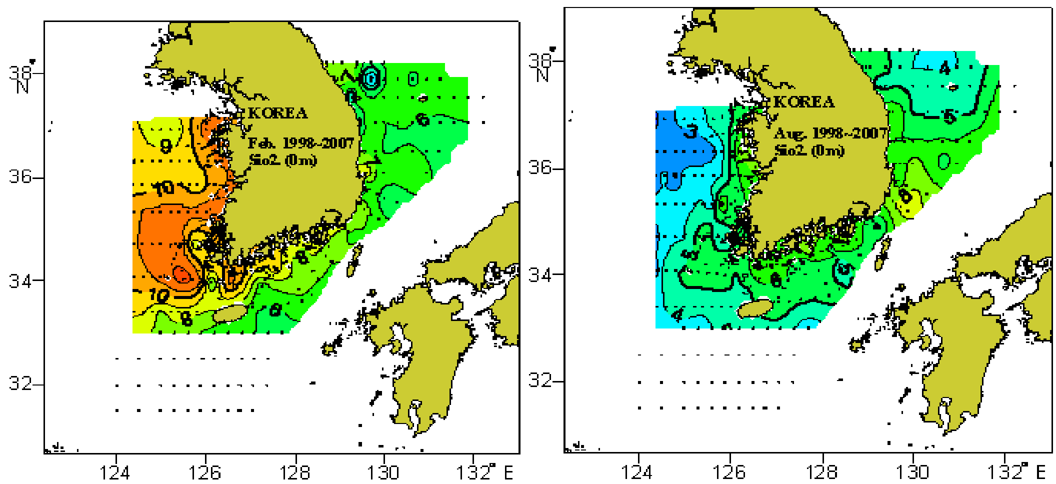

Fig. 41. Spatial surface distribution of 10 years mean (1998~2007) SiO_2‾Si concentration in winter (left) and summer (right) in Korean Waters by serial oceanography investigation of NFRDI.

Distribution of NO_2^--N concentration in winter and summer are shown in Fig. 42. In winter, higher concentration of NO_2^--N appeared in offshore of Yellow Sea. Spatial change of NO_2^--N concentration in winter is also larger in Yellow Sea than northern East China Sea and East Sea. Range of NO_2^--N concentration in winter is about 0.2~0.8 ㎍-at/L in Yellow Sea, about 0.3~0.5 ㎍-at/L in East Sea and about 0.2~0.5 ㎍-at/L in Northern East China Sea. In summer, NO_2^--N concentration clearly decreased compared to winter, except near coast of northern Yellow Sea. Larger NO_2^--N concentration in summer appeared in Northern Yellow Sea and northwestern East China Sea, where are also usually formed tidal front. It could be supplied higher nutrient from bottom layer by vertical mixing. Relatively larger concentration of NO_2^--N in summer also appeared near coast of southern East Sea larger than 0.2 ㎍-at/L. It also caused by coastal upwelling during summer time in this area. Range of NO_2^--N concentration in summer is about 0.1~0.7 ㎍-at/L in Yellow Sea, about 0.1~0.2 ㎍-at/L in East Sea and about 0.1~0.8 ㎍-at/L in northern East China Sea.

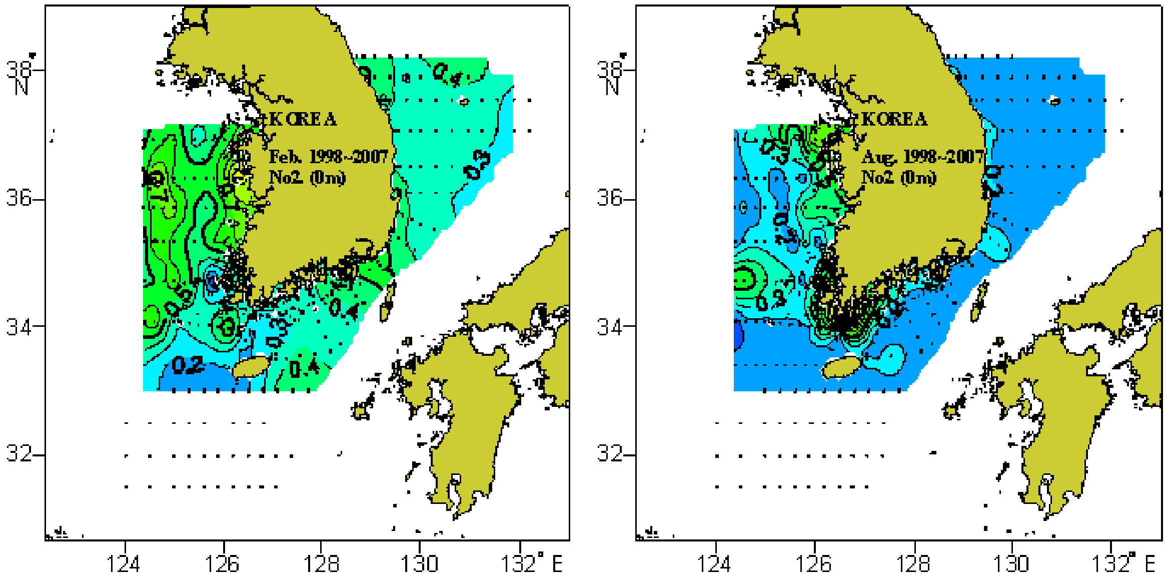

Fig. 42. Spatial surface distribution of 10 years mean (1998~2007) NO_2^--N concentration in winter (left) and summer (right) in Korean Waters by serial oceanography investigation of NFRDI.

Distribution of NO_3^--N concentration in winter and summer are shown in Fig. 43. In winter, higher concentration of NO_3^--N appeared in near-shore of northern Yellow Sea and near-shore of northern East Sea. Spatial change of NO_3^--N concentration in winter, it decreased from onshore to offshore, is also larger in Yellow Sea than northern East China Sea and East Sea. Range of NO_3^--N concentration in winter is about 3.0~13.0 ㎍-at/L in Yellow Sea, about 7.0~12.0 ㎍-at/L in East Sea and about 6.0~9.0 ㎍-at/L in Northern East China Sea.

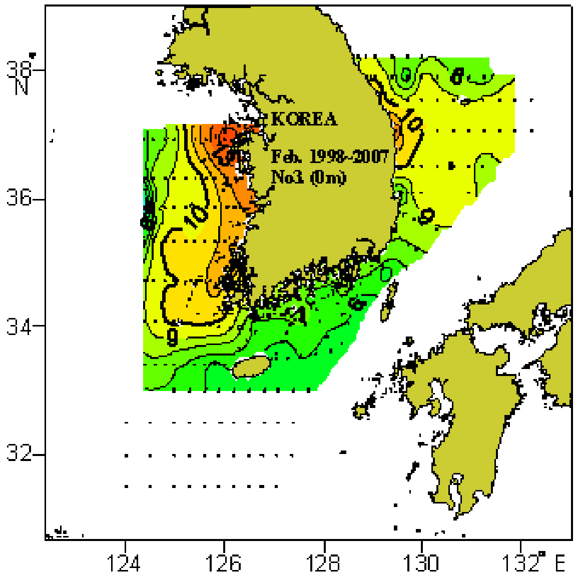

Fig. 43. Spatial surface distribution of 10 years mean (1998~2007) NO_3^--N concentration in winter (left) in Korean Waters by serial oceanography investigation of NFRDI.

Seasonal variations of each constituent were examined using 10 years mean concentration of surface nutrient like Fig. 44. All constituents, which are PO_4^+-P, SiO_2^-Si, NO_2^--N, NO_3^-N, have significant seasonal variation. Maximum concentration of surface nutrients appeared in winter and minimum concentration appeared in summer. It caused by limit of supply from bottom layer according to seasonal strong stratification in summer, except several well mixed areas like near-shore of southern Yellow Sea and near-shore of southern East Sea.

Higher concentration and larger spatial change of nutrients usually appeared in Yellow Sea. The relatively higher concentration of nutrients also locally appeared in tidal front area and coastal upwelling area in summer. Seasonal variations of all nutrient constituents are also clearly appeared. Maximum concentration appeared in winter and minimum concentration appeared in summer.

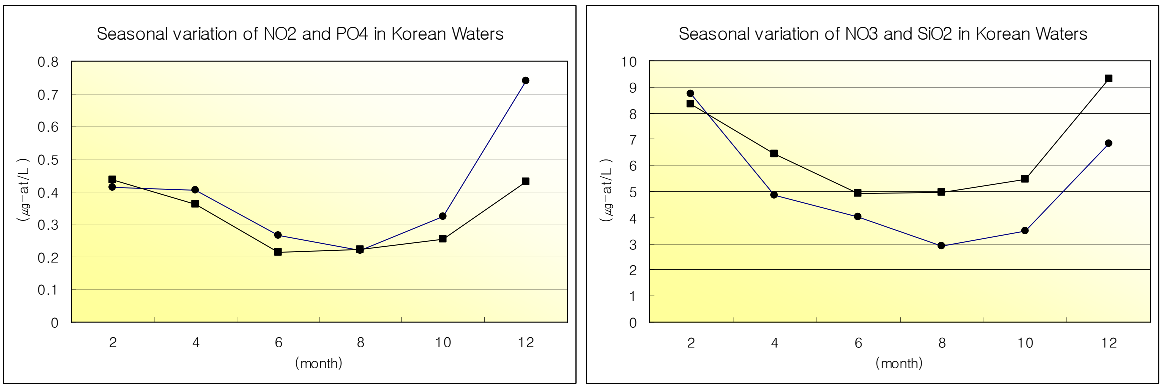

Fig. 44. Temporal variations of bimonthly 10 years (1998~2007) mean concentration of NO_2^-N (circle), PO_4^+-P (square) (left) and NO_3^-N (circle), SiO_2^-Si (square) (right) in Korean Waters by serial oceanography investigation of NFRDI.

2.6 Trace metals, hazardous substances, and sediments

Trace metals and hazardous substances are new environmental issues in the marine environment of ROK. Although only limited data and information are available for these pollutants, most coastal waters of ROK are in good condition with regard to trace metals and hazardous substances, with their concentrations in water column and sediments within domestic legal standards or foreign standards (for materials without domestic standards). However, ROK is progressing a project for legal standard to the provide protection for a marine environment in the Korea so that emphasis on protecting the health and living environment of human populations and extend to examining the health and diversity of marine ecosystems.

Pollution by trace metals and hazardous substances is, however, in progress in semi-enclosed bays (ex, Masan bay) and estuaries next to industrial complexes, harbors, and densely populated urban areas, requiring management measures to be implemented. More surveys and investigations are required to better evaluate pollution of the coastal waters of ROK by trace metals and hazardous substances.

2.7 Toxic organic contaminants in marine environment

Considering the current deficient efforts (expressed as fund and participant numbers) in marine environment monitoring of Korea, more comprehensive monitoring strategies for toxic organic contaminants would be strongly needed. Therefore, the Korean government has to develop a plan for a comprehensive marine environment monitoring network in Korean coastal waters. Issues that need to be addressed in order for a regional monitoring network to be established include determining the types of pollutants monitored, the spatial and temporal scales of monitoring, the ocean areas to be monitored, and the media (water, sediment, and biota) and parameters to be monitored. For instance, the emerging POPs such as polybrominated diphenyl ethers (PBDEs) and perfluorinated compounds (PFCs) should be included as nationwide monitoring component in Korean coastal waters. In addition, the international cooperation has to be considered, as an aspect of a contribution of international monitoring of global scale such as climate change.

Public concern over the POPs re-emerged in the 1990s due to studies describing endocrine disrupting effects of some POPs. While monitoring data suggested that concentrations of POPs were less in Korean coastal waters than in marine environment from more industrialized countries, the public perception was that there were significant risks posed by POPs. This perception may have resulted from inaccurate and insufficient information about the status of POPs in Korean coastal waters. In particular, only occurrence of POPs, especially such as dioxins, in seafood is a great social and scientific concern. The NFRDI started ‘nationwide monitoring of POPs’, which includes dioxins, polychlorinated biphenyls (PCBs), organochlorinated pesticides (OCPs), PAHs and TBT, in water, sediment and bivalves from 25–30 representative stations in Korean coastal waters since 2000s. NFRDI have also surveyed some hot spot areas, which were designated as ‘Special Management Coastal Zones (SMCZs)’ by Korean administrations, to grasp pollution sources and toxic effects to aquatic organisms of these contaminants.

In general, concentrations of toxic organic pollutants in marine environmental matrices such as water, sediment, and biota were found to be relatively small, compared to most other industrialized countries. In fact, concentrations of POPs and related contaminants were less than the environmental quality criteria suggested by international authorities and/or developed countries, except for a few ‘hot spot areas’. For instance, concentrations of dioxins in marine sediments collected from around wastewater treatment plant (WWTP) in Masan Bay showed higher values than those in industrialized bays from other countries. However, due to a lack of sufficient information, the contamination status and trends of POPs in marine environment could not be assessed. Additional information from monitoring studies would be needed for certain locations. The MOMAF has launched 'EDCs Project in Marine Ecosystem', to survey seafood contamination and risk assessment by EDCs to general populations and certain sub-population groups such as infants and high seafood consumer in Korea. In brief, the concentrations of EDCs in seafood were not so high compared to those reported from other countries, except for some species with high content of lipid. There were a little potential risk of EDCs through seafood consumption to general populations and some sub-subgroups in Korea. For instance, the dietary intake of dioxins associated with seafood consumption did not exceed tolerable daily intakes (TDIs) established by the Korean Food and Drug Administration (KFDA), World Health Organization (WHO), and United Kingdom Scientific Committee on Chemicals in Food. In addition, the cancer risks and adverse effects to Korean general populations by PAHs and OCPs in seafood were small, compared to guidelines recommended by United States Environment Protection Agency (US EPA).

Worldwide, the levels of POPs and related contaminants have decreased considerably during the past three decades as a consequence of the ban on production and reduction in emission. However, there are limited data on monitoring of the POPs and related contaminants from Korean coastal waters, as mentioned above. To date, Korea's monitoring efforts have focused primarily on water pollution, not marine ecosystem protection. In addition, there are no guidelines or laws concerning POPs and toxic chemicals in marine environmental matrices in Korea. Some research projects have been carrying out to establish guidelines and environmental standards for trace metals and POPs in water, sediments, and biota a few years ago.

In recent years, with the rapid economic development in Korea, the effects of various toxic organic contaminants on marine ecosystem have caused increasing concerns among scientists and administrators in Korea. Due to the hazardous effects to marine ecosystems including aquatic organisms, a number of monitoring and research projects on toxic organic contaminants in marine environment have been performed by research institutes such as National Fisheries Research and Development (NFRDI) and Korea Ocean Research and Development Institute (KORDI) in Korea. The NFRDI is responsible for the nationwide marine environment monitoring program since 1910s. In fact, such monitoring is more in line with the intent of the 'Marine Pollution Prevention Law', which was passed in March 1991. Recently, the persistent organic pollutants (POPs), polycyclic aromatic hydrocarbons (PAHs), tributyltin (TBT) was included to nationwide environment monitoring program in NFRDI as measured parameters, to investigate contamination status and long-term trends of these contaminants from Korean coastal waters. In addition, the nationwide survey on POPs and related contaminants in seafood commonly consumed has launched to monitor seafood safety through risk assessment by seafood consumption of these contaminants. The KORDI has been carrying out short-term research projects funded by Korean governments such as Ministry of Maritime Affairs and Fisheries (MOMAF), Ministry of Science and Technology (MOST), and Ministry of Environment (MOE) and by local government agencies and private sectors. It has been carrying out monitoring projects to not only survey pollution levels but to also measure the effects of pollutants on marine organisms using biomarkers (histopathology of bivalves) and benthic organisms.

3. Experience of pollutants management

3.1 Assessment of problems

As a valuable socioeconomic and cultural asset as well as environmental resource, the coastal environment of ROK has been one of the essential sources of economic prosperity. However, very intensive development and utilization of the environment over the last four decades has resulted in deterioration and degradation of the environment and the base of the economic potential. The assessment of environmental problems is the first step to formulate practical actions, providing a solution for sustainable development of coastal and marine areas. The assessment will also be used to set priorities.

Sewage is a chronic threat to public health and the coastal environment. Improperly treated sewage from land is the major cause of water quality deterioration, leading to eutrophication and bottom anoxia. As a result of continuous investment for sewage treatment facilities, as of 2005, the average sewage treatment rate of the coastal area. However, this is still low compared to the national average and most investment on sewage treatment facilities in the coastal area has been concentrated in coastal urban areas. As sewage discharge from household accounts for about 53% of organic pollutant input in terms of BOD, the Korean government has expanded investment on the construction of sewage treatment plants, which will increase the sewage treatment rate in the coastal area to 80% in 2011.

Monitoring and surveys done since the mid 1990s in limited areas showed that overall POPs concentrations in the coastal ecosystem of ROK are relatively low compared to those in other countries. Because pollution by POPs is in progress in some coastal areas in-depth monitoring and surveys are necessary for areas near heavily populated urban areas and industrial complexes. Available data are very limited on the levels of POPs in seafood that is one of the staple foods in ROK, in spite of a great public concern on the problem. New research strategies and regulations on POPs management prepared in the late 1990s, and have been implemented.

Heavy metals have significant adverse impacts on food security and marine ecosystem health. Surveys revealed that coastal waters and sediments in trade ports and near industrial complexes are polluted with heavy metals. Except a very few cases, however, heavy metal concentrations are within legal standards for human heath protection. Concentrations of Cu was in the range of 0.90 to 829 μg/g in sediments and 0.04 to 24.6 μg/L in seawater. Concentrations of Hg in sediments varied from 0.003 to 0.316 μg/g, and those of Pb in seawater from 0.004 to 0.693 μg/L. Except Cu in sediments in heavily polluted areas, most heavy metals in seawater or sediments were satisfied the seawater quality standards of ROK or within guidelines of countries with sediment quality standards.

Nutrients are discharged into seas through rivers and treatment plant outfalls and from air. With the construction of sewage treatment plants, point sources are well under control. More attention should be given to the management of non-point sources. Urbanization is directly related to increase in pollution load from non-point sources. Pollution load from non-point sources accounted for 26% of the total pollution load in 2000, increased from 21% in 1995.

Airborne input of nutrients is gaining an interest with regard to reduction of nutrient load into the marine environment. Even though there are very few data and information on airborne inputs of nutrients into the marine environment of ROK, recent researches showed that airborne nitrogen inputs were estimated to be 10~20% of the total nitrogen input. An integrated approach is required to manage nutrients in the marine environment considering various input pathways, river-borne, air-borne, treatment plant outfalls, etc.

3.2 Issues priority setting for solving problems

Pollutions issues cover a very wide spectrum of marine environmental problems. Therefore, it is inevitable to establish priorities for action to effectively implement considering the limitations in financial and personnel resources to manage the issues. The Korean government has assigned management priorities for marine environmental issues in formulating the 3rd National Comprehensive Plan for Marine Environmental Conservation (2006~2010). Ministry of Land and Ocean reevaluated the priorities in the plan based on their relative importance of environmental and socioeconomic impacts, or severity of problems concerning food security and poverty alleviation, public health, coastal and marine resources and ecosystem health, including biodiversity, and social and economic benefits and users, including cultural values (Fig. 45).

The impacts and area affected of pollution issues are divided into three classes of small impact, moderate impact, and severe impact, and the adequacy of the legal and institutional mechanisms were grouped in insufficient, moderate, and sufficient.

	Issues	Rationale
High	• Sewage • POPs • Heavy metals • Physical alteration	• Severe, existing and potential impacts • Moderate or severe areas affected • Insufficient legal framework
Medium	• Oil/Hydrocarbons • Nutrients • Litter	• Moderate or small, existing and potential impacts • Moderate or small areas affected • Sufficient legal framework
Low	• Radioactive substances • Contaminated sediments	• Small, existing and potential impacts • Small areas affected • Sufficient legal framework

Fig. 45. Priority ranking of the pollution issues

3.3 Integrated assessment for status of water quality

The traditional approach to protecting the marine environment has been to focus on the impacts of individual activities. But it is essential to understand how all the various natural and anthropogenic pressures on the seas act together in order to be able to assess how clean, safe, healthy, productive and biologically diverse the marine ecosystem really is. The main purpose of preparing this report has therefore been to get beyond the traditional approach and make a first integrated assessment of the environmental status of water quality in S. Korea seas.

We has applied its expert judgment to the totality of the available evidence to gauge the status of water quality, and selected water quality indexes to assess progress towards cleaning sea circumstances. Table 11 brings together the key findings including a 'traffic light' indication of whether the current status is acceptable, unacceptable or there is room for improvement. Judgments of this kind are inevitably subjective, and it needs more research to make a decision making tools and for the decision makers. Some of the evidence is capable of differing interpretations. The judgments expressed here represent our best estimatation based on the evidence between scientists, policy-makers, community activists, etc. For more understandable and appropriate assessment, we need to steady consult with the experts on indicator of our level of confidence in the assessments.

It has been clear from the outset that the evidence available for this report is incomplete. More importantly, however, there are some aspects of the state of the seas on which the evidence on which to base a judgment is either very limited or non-existent.

Table 11. Water quality assessment in coastal areas, S. Korea

Key factors and pressures	Trend	Status	Evidence and Reason for overall status
Point sources(River inputs, discharge, metal, PAHs)	Measurement shows improvement	Room for improvement	Resuction in point sources such as metals, nutrients, PAHs, and other contaminants since late 1990s
Sewage discharges	Measurement shows highly improvement	Room for more improvement in higher facilities	Improvements in sewage treatment plant infrastructure have given greater compliance with water quality standards, but some specialized areas quality still fail the standards
Inputs from diffuse sources	No trend available or implications not understand	Room for improvements and no assessment possible of status	Some persistent chemicals are not routinely monitored and diffuse sources may pose a problem near urban and factorized areas

3.4 Significant pressures affecting on water quality

There are a number of contaminants which influence the chemical status, water quality and cleanliness of the marine environment. These include nutrients, radioactive materials, red-tides, hazardous substances, oil, micro-organisms and litter. For examples, direct inputs of nutrients from point sources discharging directly to the sea and atmospheric emissions of nitrogen have reduced gradually since late 1990s. However, these point sources inputs only account for roughly 50% of all nutrients inputs. Overall inputs from diffuse sources to coastal areas are not quantified yet.

The area of the coastal wetlands has decreased 20% from 3,203 km² in 1987 to 2,550 km² in 2005 through reclamations and other coastal development activities. It is expected that more coastal wetlands will disappear with ongoing and newly proposed reclamation projects in the coastal area mostly aimed at providing lands for commercial districts, agriculture and livestock industries, cities, and harbor facilities. The 1st reclamation plan (1991~2000) in estuary allotted 329 Km^2(34.2% of the national reclamation plan) for agriculture (54.8%), industry (21.7%), city development (9.4%). And 2nd reclamation plan (2001~2011) did 9 Km^2 (23.9% of the national reclamation plan) for city development (48.4%), agriculture (42.6%).

Land-based activities are also accelerating the destruction of coastal forests which have provided a protective buffer zone for coastal communities from natural disasters such as tidal waves and typhoons. Less than 10% of coastal forests are remaining in heavily developed urban areas, while over 20% of coastal forests exist along the coast in less developed rural areas. Reserve areas have dramatically increased to protect sensitive and vulnerable coastal and marine ecosystems since the establishment of MOMAF.

Areas has also contributed to the rapid increase in the reserve areas. As of 2005, a total of 422 areas in the coastal area are designated as reserves for ecosystem protection in the sea and on land, occupying 10.6% (10,603.6km^2) of the national territory.

A total of 78 municipalities (cities and self-governing) border seas and they account for 32% of the total land area. The population of the coastal area was just over 13 million in 2005, 27% of the national population. The coastal area has a population density of 402 persons per square kilometers, slightly lower than that of the national average. Coastal urban and industrial areas are, however, heavily populated with a population density of over 1000 people/km^2.

The coastal area of ROK has been the major center for industrial development due to easy access to marine transportation. A total of 84 out of 189 large-scale national and local industrial complexes and 40 out of 81 power plants are located in the area. Gross regional domestic product by industries in the coastal area occupied 41.9% of the national gross domestic product.

3.5 Implementation of the Total Pollution Load Management System

The Korean government is planning to introduce a total pollution load management system (TPLMS) into the coastal environment management regime of the Masan Bay. A guideline for TPLMS establishment has been adopted in October 2005. A research project has been launched in June 2005 to assess total pollution load to and carrying capacity of the bay, allocate pollution loads, and to evaluate other requirements for the introduction of TPLMS. Even though the introduction of TPLMS is just one of 12 major management measures listed in the “Coastal Environment Management Plan of the Masan Bay,” introduction and implementation of TPLMS is regarded as a very tricky management process. In the process, conflicts between coastal users and authorities, between authorities, and between coastal stakeholders could become a new serious issue to be addressed.

In this regard, the Korean government is now facing a new challenge regarding successful integrated coastal management. To cope with the issue and challenge effectively, Integrated Management Council and Community Advisory Council for the Masan Bay have been formulated and operated based on concreted efforts of relevant ministries and local stakeholders. More emphasis needs to establish a participatory decision-making system for conflict resolution, and increase research investment to reduce scientific uncertainties.

3.6 Action plans for integrated assessments

There are a number of gaps in knowledge. These gaps are evident both in the basic data and in the tools available for assessing the data.

Action 1 would involve the development of water quality indicators including global standards for this purpose. Action 2 would coordinate the current marine monitoring activities, to identify gaps and to develop a more comprehensive approach. Action 3 would involve the pooling of scientific expertise that the relationship of work on water quality issues to the broader marine environment is properly understood. Action 6 would be the development of a better understanding of how climate change affects the marine environment.

Ⅵ. Socio-economy Aspects

1. Utilization and Development of the Coast

1.1 The Coastal Population and Urbanization

An area that has been formed by the interaction between the sea and the land, the coast is not only an ecologically valuable space but also a socially important space where a variety of activities from cities, industrial complexes, tourism, or fisheries, etc. happen. For recent 50 years, Korea's coastal environment was damaged by excessive exploitation and development following rapid industrialization and urbanization, but the government is now pulling out all the policies to improve the coastal environment and make a sustainable preservation and utilization of its coastal resources after Rio Summit in 1992.

As of 2007, 26.6% of Korean population resides in coastal areas and 32.4% of Korean cities are located in those coastal areas. And 88.9% of coastal population inhabits in cities. The population in those coastal cities rises 0.57% per year, which means the urbanization of the coast still in progress (Table 12).

Table 12. Status of The Coastal Population

(unit : a thousand people, person/㎢, a thousand households, ㎢, %)

Details		2002			2007			Area	Population Growth Rate
		Population		Household	Population		Household		
		number	density		number	density			
Total		48,230	482	16,489	49,269	493	18,688	99,990	0.43
Ooast	Sub-total	12,920 (26.8)	403	4,396 (26.7)	13,127 (26.6)	410	4,965 (26.6)	32,036 (32.0)	0.32
	Urban	11,341	649	3,802	11,667	667	4,339	17,485	0.57
	Rural	1,579	109	595	1,460	100	626	14,551	-1.56

Source : Ministry of Land, Transport and Maritime Affairs, Constructive and Traffic Statistics Annual Report(2007), National Statistical Office, Registrated Population,

The growth of a coastal city is closely related to industrialization of it. According to the governmental policies in 1960s, most of industrial complexes were located in coastal areas, considering focusing on logistical tractability and accessibility. As a result, along the coastal line are located 71% of all the complexes in Korea and 14 container harbors for distribution of goods, whose capacity accounts for 761 berths (Table 13 and 14).

Table 13. Coastal Industrial Complexes

(unit : 1000 ㎡, number)

Nation		Coast		Coast/Nation	
Area	Number	Area	Number	Area	Number
481,139	31	372,744	22	77.5%	71.0%

Source : Korea Industrial Complex Corp., Status of Nationwide Industrial Complexes, 2007.

Table 14. Harbor Berthing Capacity

(unit : berth)

Nation	Under 5000 DWT	5000~10,000 DWT	10,000~50,000 DWT	Above 50,000 DWT
761	331	125	258	47

Source : Ministry of Land, Transport and Maritime Affairs, Statistics, 2008.

In and with the economic growth, the urbanization in Korea has been intensively developed from 1960s until currently. Likewise, as the coastal cities started getting crowded in the course of the urbanization, the mega-cities such as Busan, Incheon, or Ulsan grew rapidly, around which harbors and industrial complexes clustered. Therefore, as highly intensive exploitation and development is at work in the coastal areas of Busan, Incheon, and Ulsan in which cities, industrial complexes, or harbors cluster, the sea pollution keeps getting worse. So in order to improve the environment of the waters seriously contaminated around Busan coast, Incheon coast and Ulsan coast, the government is now managing those coastal areas systematically by designating them as Special Management Areas.

Designation and Management of Special Management Areas

Under the Marine Environment Management Act, it is stipulated that the government should designate as Special Management Areas sea areas that are hard to keep the standards of marine environment or that are really damaging or possible to damage marine environment and ecosystem. Now Korea has 5 places that is designated as Special Management Areas (Table 15).

Table 15. Special Management Areas

Location	Area(㎢)	
	Coastal Land	Coastal Water
Busan Coast	505.77	235.73
Ulsan Coast	144.29	56.56
Gwanyang Bay	334.56	131.37
Masan Bay	157.66	142.99
Sihwa Lake．Inchon Coast	576.12	605.76

1.2 Costal Land Utilization Patterns

The marine environment and ecosystem is significantly affected by contaminants flowing from the land and by the socio-economical activities on the coastal land area. The occurrence of land-based pollutants and human behaviors are closely related to utilization patters of the coastal land area.

The area of the coastal land, based on the administrative districts, reaches 32,000 km2 which is 32.15% of the total land in Korea. The agricultural land included in the coastal land area accounts for 24.5% of the coastal land, the forest land occupies 58%, and the area that is used as factories and roads corresponds to 7.1%. Among them, agricultural lands, building sites, and plants or roads that discharge point or non-point source pollutant are located more in the coastal area than inland, which shows that almost all the use and development converges not to inland but to the coast area (Fig. 46).

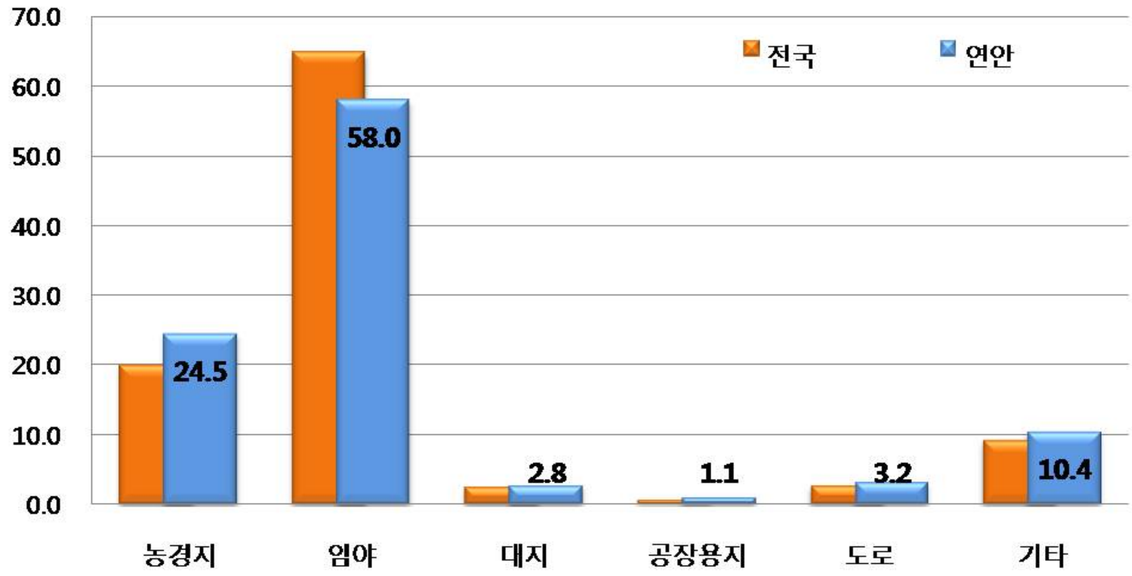

Fig. 46. Land Utilization of Coastal Land Threshold
농경지(Agricultural land), 임야(Forest land), 대지(Building sites), 공장용지(Factory sites), 도로(Roads), 기타(Miscellaneous)

To efficiently manage a territory, Korean government classifies it into four groups of 'urban area', 'agriculture area', 'management area', and 'natural environment preservation area' with an approach using Zoning System. So there is a close relationship between the characteristics of areas designated in the land adjacent to the coastal sea waters and the level of the coastal/oceanic environment. For example, the land designated as urban area or agricultural area and bothering sea waters are easy to undergo ecologically negative influences, while sea waters close to the natural environmental preservation area can be kept clean and sound.

According to Table 16, the urban area designated in the coastal area occupies 18.9 of the total coastal area, the agricultural area 38.2%, the management area 23.0%, and the natural environment preservation area 19.9%. In case of the coastal area, the proportions of the industrial area(63%) and the agricultural(28.7%) is higher than those within inland, but lower the agricultural area(28.7%).) The high occupying rate of the industrial area in the coastal area results from industrial complexes located inside it, whereas the higher rate of the natural environment preservation area is caused by Fisheries Resources Protection Area which is widely designated in the coastal area.

Table 16. Use Zones Designated Along the Coast

(unit : ㎢, %)

Scope Use Zones	Nation		Coast		Coast/Nation
Total	106,247.3	(100.0)	38,287.4	(100.0)	36.0
Urban Area	17,190.1	(16.2)	7,244.2	(18.9)	42.1
Management Area	25,695.5	(24.2)	8,789.0	(23.0)	34.2
Agricultural Area	51,013.2	(48.0)	14,616.2	(38.2)	28.7
Natural Environmental Preservation Area	12,348.4	(11.6)	7,637.9	(19.9)	61.9

Note : Because Use Zones are applicable to both waters and land, the total area of Use Zones is larger than that on land which is applicable just to land except waters.

Source : Ministry of Land, Transport and Maritime Affairs. Korea Land Corporation (2007, City Planning)

Following the Coast Governance Act was enacted for the systematic governance of coastal space in 1999, Ministry of Land, Transport and Maritime Affairs build 'Guideline for a Local Coastal Governance Plan(hereinafter as Planning Guideline) and directed to set up coastal Zoning by Function in accordance with the coastal natural environmental, socio-economical, or institutional characteristics in 2000. Planning Guideline classifies the coastal into five parts of 'Absolute Preservation Coastal Area', 'Semi-Preservation Coastal Area', 'Utilization Coastal Area', 'Development Adjustment Coastal Area' and 'Development Encouragement Coastal Area', providing governance directions for each coastal area. Among these five coastal areas, Preservation Coastal Area(both Absolute and Semi) whose ratio amounts to 63.3% is ranging wider than Utilization and Development Coastal Area 36.5% (Table 17).

Table 17. Coastal Zoning by Function

(unit : ㎢, %)

	Total	Absolute Preservation	Semi-Preservation	Utilization	Development Adjustment	Development Encouragement
Total	56,634	22,208	13,651	19,135	1,065	575
	100.0	39.2	24.1	33.8	1.9	1.0
Coastal Land	2,679	582	751	473	539	334
	100.0	21.7	28.0	17.6	20.1	12.5
Coastal Water	53,955	21,626	12,900	18,662	526	241
	100.0	40.1	23.9	34.6	1.0	0.4

Source : Ministry of Land, Transport and Maritime Affairs, "A Study on Rearrangement Scheme of a Governance Basis Following the Reorganization of Coastal Governance Measures", 2008.

The Coast Governance Act and Coastal Zoning by Function

With the purpose of securing the sustainable coastal development by comprehensibly reformulating all the affairs relative with preservation, utilization, and development of the coastal area and of performing an efficient and systematical management. of it, the Coast Governance Act was established in 1999. The Act stipulates the range of the coastal area, coastal actual conditions investigation, the Integrated Coast Governance Plan, the Local Coast Governance Plan and so on. In other words, this Act prescribes to set up the range of the coastal area for integrated governance of the coastal waters and the coastal lands, adjust activities for coastal development and preservation, and perform the management based on cooperation and consensus among stakeholders.

- coastal sea area : the seashore and the sea ranging from the full tide line of seashore to the outside boundary of the territorial waters
- coastal land area : the land within the range of 500m~1km landward from the landside boundary of the coastal sea area(cadastral map border) and uninhabited islands

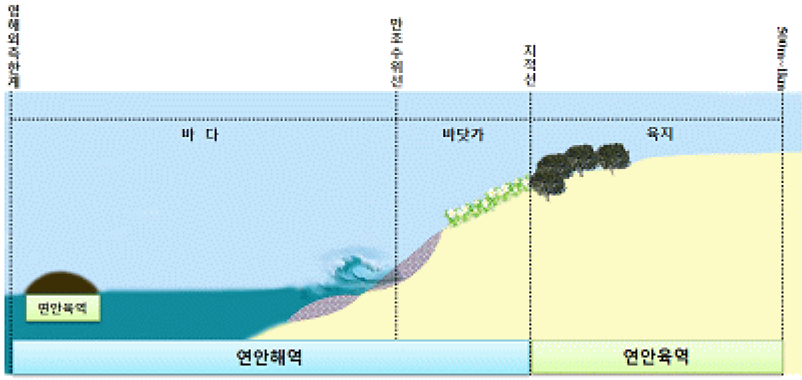

Fig. 47. Spatial Scope Based on the Coastal Governance Law

* 연안해역(Costal sea area, 연안육역(Coastal land area), 영해외측한계(outside boundary of the territorial waters), 만조수위선(full tide line)

Particularly, the Local Coast Governance Plan specifies the coastal zones by function, reflecting the characteristics of the targeted region. Coastal Zoning by Function serves as a means to manage the coastal space reasonably and effectively according to functions and characters of each coastal zone (Table 18).

Table 18. Details of Coastal Zoning by Function

Absolute Preservation Costal Area	the area whose natural scenery and ecosystem needs to be preserved with their original conditions
Semi-Preservation Costal Area	the area that should be preserved in principle, but can be utilized passively, such as ecological education place, access road to the coast, and etc.
Utilization Costal Area	the area whose coastal space and resources can be developed while minimizing the damage to its natural environment
Development Adjustment Costal Area	the area which has already been industrialized or urbanized, but which needs to be reviewed for development in accordance with environment-friendly arrangement, various development plans
Development Encouragement Costal Area	the area which needs to be developed as a foothold or whose function as a city or a coast area be vitalized

1.3 Coastal Reclamation and Inning

Coastal reclamation/inning can be considered as one of factors influence the coastal environment together with urban development, construction of industrial complexes or harbors, and increase in vessel traffic. And it can be thought to do a variety of harms like artificial manipulation on natural coasts, destruction or loss of habitats, decrease in fishery stock, or environmental changes of coastal communities.

In Korea, reclamation/inning projects before 1990 were propelled by government-driven economic development policies designed to expand its territory and secure superior-quality farmland. Consequently, those policies led to too fast artificialization of natural seashore, 20% loss of sea tidal flat compared to that of 1987, weakness of fishery production base following damages of estuaries and bays that is spawning grounds and habitats of fisheries resources.

From 1980 to 2007, the area applied to the public waters reclamation plan amounted to 2,381km2 and the districts 571. The reclamation-applied land area was no more than 506km2 before 1990, but it suddenly jumped up to 1,721km2 during only five years from 1991 to 1995. Yet, as sea tidal flat preservation policies were established, the reclamation-applied land area decreased gradually to 87km2 in the period of 1996~2000, to 41km2 in 2000~2005, and finally to 27km2 in 2005~2007 (Fig. 48).

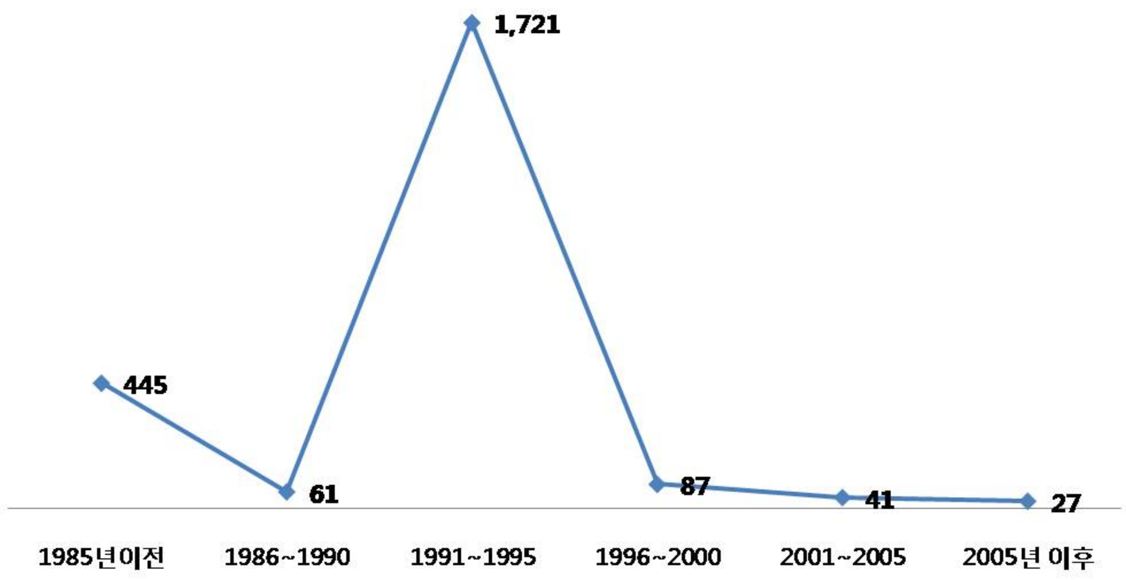

Fig. 48. Trend of Coastal Reclamation/Inning

As the marine ecosystem and environment was severly damaged by coastal reclamation/inning after the mid 1990s, the government has turned its policy direction to controlling coastal reclamation in order to put top priority on protecting the ecological value of the coast. That is, the government applies more strictly the environmental assessment to coastal reclamation on the purpose of restricting it in principle, forbids new large-scale reclamation/inning projects, and implements wetland improvement measures to rehabilitate sea tidal flat destroyed.

1.4 Coastal Tourism

With increase of income level, improvement of transportation, enlargement of desires for leisure and tourism, and pursuit of fresher living standards after 1990s, coastal tourism has become important. Therefore, urbanites request a variety of tourist attractions such as sea tidal flat or sandy beaches so that they could experience the coast and ocean.

Local governments along the coast expect their local economy to be activated by driving forwards coastal tourism development projects that make good use of beautiful scenes like sea tidal flat and migratory birds and marine ecological resources. In other words, they try to improve the quality of life of the inhabitants and promote the image of their regions, transforming the regions devastated by urbanization and industrialization into more pleasant places people can approach easily and safely.

Along the coast, 8 tourist complexes and 66 resorts are distributed while 154 tourism projects are progressing. Of these, 49 projects are for coastal resorts, 22 for coastal history/cultural tourist attractions, and 14 for coastal island resorts. The tourist complex projects in large scale are driven forward across the country, with 8 in Cheju-do, 2 in the Chola province, and 1 in Busan, Inchon, and Gyeongju being in progress respectively.

In general, the large-scale coastal tourism projects are centralized on the coastal cities like Incheon, Gyeonggi, Busan, etc, while simple and plain activities like bathing on the beach, ocean resorting, or tidal-flat eco-tour are main in non-coastal cities. However, as tidal-flat experiential tour activities such as picking and gathering tidal-flat resources is gradually getting attention, those behaviors leads to negative effects of destruction of tidal-flat environment (Table 19).

Table 19. Marine & Coastal Tourism by Type

Tourism Type	Total	Resort	Scenery	Island	Reports	Fishing Village	History	Ecology	Water-front	Complex	Others
No. of Places	154	49	19	14	8	8	22	8	4	13	9

Source : Ministry of Culture and Tourism(East/West/South Coast Wide-rage Tourism Development Plan), Relevant City/Province(the 4th Regional Tourism Development Master Plan)

The government prepares and implements policies to form more user-friendly coastal environment, enlarging various water-front and guaranteing accessibility to the coast. For instance, it not only expand water-front into diverse places such as harbor, industrial complexes and fishing villages including existing tour sites like sea beach, but also build water-front spaces in sea tidal flat and migratory bird sanctuary utilizing natural tourist resources and pure ecological environment

1.5 Ocean Waste

Ocean wastes deteriorate the quality of marine resources, cause ghost fishing, and depreciate the aesthetic value of the coast. That is to say, the ocean waste both directly damages the fishery industry(productivity loss) and marine ecosystem and indirectly threatens the coastal tourism industry and safe navigation, finally aggravates environmental, social, and economic damages.

The source of ocean wastes is divided into two; land-based and sea-based. Land-based waste is what flow through streams and rivers into the sea after occurring in land and sea-based wastes is wastes that were thrown away from vessels or fishing gears that were lost or dumped while fishing (Table 20).

Land-based waste is hard to be controlled because it influxes into the ocean in large quantities when flood or a localized torrential downpour occurs, whereas sea-based waste is caused by fishing activities. While wastes from merchant vessels and cruises is decreasing thanks to crack-downs and regulations on an inflow into the sea, wastes from fisheries activities like fish farming continue to increase.

Table 20. Causes of Ocean Waste

	Cause
Land-based	◦general land-based: inflow to the sea through streams or rivers(especially, when flood or typhoon occurs) ◦coastal land-based: dumping and leaving untreated by tourists or inhabitants along the coast
Sea-based	◦fishery-based - dumping of fishing gear that is thrown or swept away while fishing - dumping of stationary nets or fishing gear swept away by typhoon or replaced ◦ vessel- and ocean facility-based : throwing of wastes while sailing or accidents

Source : Ministry of Land, Transport and Maritime Affairs · Ministry of Environment · Ministry of Food, Agriculture, Forestry and Fisheries · Korea Coast Guard, 2008, the 1st Mater Plan for Ocean Wastes Collection and Disposal(2009~2013)

1.6 Environmental Infrastructure

The sewage is the culprit which hurts the public health and contaminates the river or ocean environment. In other words, the sewage from the land worsens the quality of water, destroys the marine ecosystem, causes eutrophication, exhausts oxygen in water and generates nasty smell or infectious disease. The environmental infrastructure serves as a buffer that filters and purifies house- or factory-based sewage up to the self-purification level and then discharges to streams.

As the result of continuous investment in sewage treatment facilities, the capacity of sewage treatment in coastal regions rose to 70% in 2006 from 66% in 1996, contributing to keeping the quality of the coastal water at the rate of COD II.

Expanding the investment in the sewage treatment facilities, the government aims to raise the treatment rate of the coastal areas up to 87% in 2011. Along with that, the government pays more attention to strengthening the system for Special Management Areas, implementing Total Coastal Pollutant Loads Regulation, or controlling land-based pollutants, which is expected to lessen the land-based pollutants affecting the coastal environment.

2. The Utilization and Development of Fishery Resources

2.1 Total Fish Production

Fish Production is inseparable related to fisheries resources and the marine environment. That is, fluctuation in capture fisheries production can be directly influenced by a change of fisheries stocks, and an increment in production by shallow-sea cultures acts as a variable of changing marine environment since it increases an environmental burden on the adjacent sea waters.

As shown in Table 21, Korea's total fish production as of 2007 is 3,275,000 m/t, with a annual average growth rate of 1.6% in the last decade. As by the type of fishery, while the production has decreased in adjacent waters fisheries, inland waters fisheries, and distant waters fisheries, only that of shallow sea cultures shows a highly increasing rate of 6.6%. Consequently, it might be said that the increase in total fish production of Korea is absolutely because of the rising production by farming.

Production(mainly by shallow-sea cultures and adjacent waters fisheries), except the production by inland-water and deep-sea fisheries that had a little relativeness with the coastal environment, accounts for 2,538,000 tons at the end of 2007.

Table 21. Total Production by Fisheries Type

unit : m/t, billion won, %

	Adjacent Waters Fisheries (a)		Shallow-sea Cultures (b)		Sub-total (a+b)		Inland Waters Fisheries (c)		Distant Waters Fisheries (d)		Total (a+b+c+d)	
	Volume	Amount	Volume	Amount	Volume	Amount	Volume	Amount	Volume	Amount	Volume	Amount
1998	1,308	2,294	777	950	2085	3,244	27	144	723	1,001	2,835	4,388
2000	1,189	2,329	653	684	1,842	3,013	21	123	651	930	2514	4066
2003	1,097	2,406	826	1,166	1,923	3,572	20	127	545	1,073	2,487	4,771
2004	1,077	2,610	918	1,217	1,995	3,827	25	167	499	737	2,519	4,731
2005	1,097	2,706	1,041	1,348	2,138	4,054	24	176	552	819	2,714	5,049
2006	1,109	2,751	1,259	1,443	2,368	4,194	25	200	639	891	3,032	5,286
2007	1,152	2,939	1,386	1,600	2,538	4,539	27	223	710	990	3,275	5,752
Annual Average Growth	-1.4	2.8	6.6	6.0	2.2	3.8	0.0	5.0	-0.2	-0.1	1.6	3.1

Note : The sum of distant waters fisheries(d) refers to the one counted in not the producer price but the consumer price.
Source : KMI 「Fishery . Ocean Environment Statistics」. 2007., Ministry of Food, Agriculture, Forestry and Fisheries . Fishery Production Statistics(www.fips.go.kr).

According to the main species produced by each type of fisheries as shown in Table 22 and 23, production of adjacent waters fisheries centers on the species such as anchovy, squid, chub mackerel, hair-tail, and mackerels, showing a different trend from the past(refer to Table3-2). The key species of it in the past were hair-tail, yellow croaker(West Sea), chub mackerel, squid, anchovy, alaska pollock(or walleys pollock), cod(East Sea). But now alaska pollock(or walleys pollock) and cod, species inhabit in a cold current, are not ranked within top 20 since the catches of them plunged sharply recently. Furthermore, it is scarcely ever to catch alaska pollock(or walleys pollock) off Korea's adjacent waters, those of hair-tail and yellow croaker is decreasing rapidly. Yet, production of squid, anchovy, chub mackerel is slightly up. This change of main species produced doesn't have nothing to do with water temperature increase in Koreas' waters, especially in East Sea.

Table 22. Production of Adjacent Fisheries by Specise

unit : tons

Species	Average Production in 5 years	Rank
Total	1,106,274	
Anchovies	236,442	1
Squid	201,341	2
Chub Mackerel	137,423	3
Hair-tail	63,801	4
Mackerels	32,341	5
Oyster	26,709	6
Trevally	26,178	7
Red Snow Crab	22,716	8
Yellow Croaker	19,118	9
Other Fishes	17,729	10
Croakers	17,259	11
Flounders	16,937	12
Common Conger	16,667	13
Black mouth goosefish	12,092	14
Pacific Herring	11,410	15
Japanese littleneck	11,339	16
Pomfret	10,318	17
Surf Clam	10,014	18
Akiami Passte Shrimp	9,698	19
Other Shrimp	9,684	20

Table 23. Production of Shallow-sea Cultures by Species

unit : tons

Species	Average Production in 5 years	Rank
Total	1,086,022	
Sea Mustard	274,617	1
Oyster	266,775	2
Laver	209,646	3
Kelp	121,613	4
Mussels	51,977	5
Halibut	38,354	6
Sea Weed Fusiforme	25,713	7
Jacoperver	25,545	8
Japanese littleneck	21,122	9
Akr Shells (Baby Clam))	9,990	10
Sea Squirts	7,049	11
Red Seabream	5,164	12
Mullets	4,752	13
Aar Shell	3,091	14

Korean Common Penshell	2,494	15
Abalone	2,357	16
Common Sea Bass	2,232	17
Black Porgey	2,136	18
Warty Sea Squirt	1,975	19
Others	1,802	20

Note : The Average production in 5 consecutive years from 2003 to 2007.
Source : Ministry of Food, Agriculture, Forestry and Fisheries. Fishery Production Statistics(www.fips.go.kr).

In case of fish farming, production ratio of each of sea mustard, oyster, laver, kelp, mussel, halibut, or jacopever are relatively high. Recently production of species high profitable by mixed farming(or cultivation) rises year and year.

As mentioned above, it is thanks to the rise in production by fish farming that Korea keeps its total production of fish products at the level of approximately 3 million tons. In contrast, it is reported that fish stocks in adjacent sea waters has been sharply decreased. Accordingly, Korea is carrying out various institutional measures to enhance fish stock including Total Allowable Catches(TAC), sea-ranching and underwater installation of artificial reefs.

As for TAC, it has been operated since 2004, a year in which 'regulations on management of TAC' was established. TAC is applied to 7 types of fisheries and 10 kinds of fishes as of the end of 2007. In addition, sea-ranching pilot projects, to begin with a sea-ranching project of TongYeong in 2000, have been operated in Yeosu of Cholla province, western/eastern Cheju, respectively and the government recently stated to prepare 9 small-scale ranches in Gangwon-province, etc.1) Besides, the government have installed around 200,000ha of artificial reefs into the sea from 1971 up to now. And also, diverse activities of fish seed release is taken at the level of both central and regional governments.

2.2 Shallow-Sea Cultures Licenses

Even though fish farming does not directly connect with the amount of fish stock of the inshore unlike capture fisheries, it is possible to bring about negative effect on the coastal environmental environment, entailing water pollution from farm sewage, deterioration of the environment caused by raw feeding stuff and dead of cultured species, or an environmental pressure generated with wastes or gas from fish's metabolism. In fact, the mortality of cultured fishes in cage farming soared up from 7.2% in 2000 to 20.0% in 2006. Besides, raw feed that accounts for 80% of total fish feed utilized is regarded as key pollutant to deteriorate the environment of the coastal fishing ground. Also, the chance cannot be excluded that the fish(expecially, fish of imported species) that escape from enclosed cage or farm sites imported can hybridize with other indigenous/natural species and in turn result in disturbance of ecosystem of the coastal fishing ground, even if escaped fishes themselves doesn't impose heavy load on the environment

In Korea, culture licenses includes type of licenses such as set nets fishery, common fishery, and seaweed rake, etc. However, it is the shallow-sea farming that affects the coastal environment more directly than any other (Table 24).

According to the relevant statistics, total number of permitted license for shallow-sea cultures is 9,352 as of 2007, 1.4% tick up in average. Toal area allowed for rise up to 132,416ha with an annual average growth rate of 1.8% at the end of 2007. It means that the area allowed has got widened 1,000ha more than that of 10 years ago. The area per licence continues to grow. Of the total production by shallow-sea cultures, 60% is for seaweed and about 31% for shellfish.

Table 24. Status of Shallow-Sea Culture Licenses

unit : number. ha, %

Year	Shallow-sea Cultures		Seaweeds		Shell Fishes		Fish		Others	
	Number	Area	Number	Area	Number	Area	Number	Area	Number	Area
1998	8,232	112,897	2,352	63,513	4,725	44,511	663	2,303	492	2,570
2000	8,462	121,973	2,331	71,543	4,952	44,819	653	2,216	526	3,395
2003	8,839	121,853	2,209	68,062	5,245	47,381	612	2,136	773	4,274
2004	9,046	123,169	2,277	69,348	5,367	47,087	596	2,002	806	4,732
2005	9,110	124,668	2,194	69,503	5,510	48,193	570	1,822	836	5,150
2006	9,297	130,890	2,381	74,757	5,552	49,550	574	1,987	790	4,596
2007	9,352	132,416	2,525	76,183	5,577	49,261	560	1,962	790	5,010
Annual Average Growth	1.4	1.8	0.8	2.0	1.9	1.1	-1.9	-1.8	5.4	7.7

Source : The Ministry for Food, Agriculture, Forestry and Fishery. 「2008 Food, Agriculture, Forestry and Fishery Major Statistics」, 2008.

Therefore, the government operates purification projects for fish farms and rest year of fishing ground in order to lessen the negative effects on the environment that originate from licensed fisheries like the shallow-sea cultures. And it tries to reinforce the infrastructure for environment-friendly farming industry by financially assisting farms to purchase not raw but formular feed and environment-relative equipments. In particular, 'Direct Payment for Eco-friendly Formular Feed‘ was put into operation from 2004 to minimize use of the raw feed that is still pointed out as the principal offender of environmental deterioration of fish farms.

2.3 Permissions for On-land Farming

As mention above, the chance of disturbance by species-crossing really exist not only in farming in the sea but also in farming on the land. Particularly, because the embank-type farming applied mainly to fish and shrimp is usually done in the bare ground, it's possible that species being cultured there can be swept away or escape from farm sites in case of flood or overflow, flow into the sea, and then hybridize with indigenous species. Also, little doubt that both embank-type and tank-type farming can negatively affect the quality of the river and the ocean.

As of 2007, total number of 1,673 license were issued, whose area permitted correspond to 1,735ha. Both the number and the area of permissions rises every year at the average rate of more than 3.0%. In regard of permission number, the tank-type farming holds the majority, whereas in regard of the area allowed, the embank-type does (Table 25).

Table 25. Status of On-land Farming Licenses

unit : number. ha, %

Year	Total		Tank-Type (Fish . Shellfish etc)		Embank-Type (Fish . Shrimp etc)	
	Number	Area	Number	Area	Number	Area
1998	1.270	1.303	1,038	182	232	1,121
2002	1.882	2.117	1,499	289	383	1.828
2004	1.951	2,162	1,552	379	399	1,783
2006	1,794	2,688	1,417	268	377	2,419
2007	1,673	1,735	1,313	276	360	1,459
Annual Average Growth	3.1	3.2	2.6	4.7	5.0	3.0

Source : The Ministry for Food, Agriculture, Forestry and Fishery. 「2008 Food, Agriculture, Forestry and Fishery Major Statistics」, 2008.

2.4 Fishing Fleet

Fish production by coastal/off-shore fisheries rise or fall according to fluctuation of fishing fleet. In turn, this fish production up/down systematically affects the amount of fish stock of adjacent sea waters. Also, there is a doubt that oil usage for powered vessels will incur negative effect on the marine environment.

At the end of 2007, the fishing vessels amounts to the total number of 85,627(or 663,859 tons) which continues to decrease at the average rate of 0.7% every year. The powered vessels constitute 97% of it. With regards to the fishing vessels of coastal and off-shore fisheries that closely connect with the marine environment, the number of the vessels of off-shore fisheries and their horse-power is descending all together. In contrast with it, that of the vessels for the coast fisheries remains still but the horse-power is ascending.

But the necessity to lessen the number of the fishing vessels has grown due to deterioration of fisheries industry circumstances result from reduction of the fishing ground after EEZ declaration, market-opening pressure in the wake of WTO and FTA, and the high-rocketing oil price. Therefore, total 3,077 fishing vessels of the coastal fisheries were buybacked, starting with the first volume of 639 fishing vessels in 2004. 2,836 vessels have already been under contract for it in 2007. It is certain that the government achieved more than the target, 6,300 vessels(10% of the total vessels of the coastal fisheries at the time of 2003) by clearing off 2,000 vessels in 2008 alone (Table 26).

As for the off-shore fisheries, this buyback project that had been executed for three year from 2001 to 2004 was temporarily brought to a halt. However, it is known that the governmental plans to byuback 1,280 vessels(same with 35% of the total of off-shore fisheries in 2001) to 2012 from 2007 and in fact 84 fishing vessels were reduced in 2008.

Table 26. Status of Total Fishing Fleet

unit : No., G.T, 1,000H.P., %

Year	Total			Powered			Non-Powered		Off-Shore Fisheries (a)			Coastal Fisheries (b)		
	No.	G.T	H.P	No.	G.T	H.P	No.	G.T	No.	G.T	H.P	No.	G.T	H.P
1998	90,997	978,334	13,064	82,803	971,704	13,067	8,194	6,630	6,165	302,324	4,696	58,119	135,881	5,482
2000	95,890	923,099	13,597	89,294	917,963	13,597	6,596	5,136	5,287	247,275	2,301	63,342	150,594	7,804
2003	93,257	754,440	17,094	88,521	750,763	17,094	4,736	3,676	4,166	185,773	2,421	62,532	159,293	11,149
2004	91,608	724,980	16,743	87,203	721,398	16,743	4,405	3,582	3,773	169,724	2,221	62,290	160,479	11,721
2005	90,735	700,810	12,949	87,554	697,956	12,950	3,181	2,854	3,687	164,037	1,763	60,892	158,774	8,326
2006	86,113	673,719	14,388	83,358	671,299	14,388	2,755	2,420	3,629	162,831	1,880	59,889	149,749	9,819
2007	85,627	663,869	14,353	82,796	661,519	14,353	2,831	2,350	3,573	162,264	1,976	59,527	146,248	9,554
Annual Average Growth	-0.7	-4.2	1.1	0.0	-4.2	1.0	-11.1	-10.9	-5.9	-6.7	-9.2	0.3	0.8	6.4

Source : KMI, 「Fishery.Marine Environmental Statistics」, 2007., The Ministry for Food, Agriculture, Forestry and Fishery. 「2008 Annual Report of Food, Agriculture, Forestry and Fishery Statistics」, 2008.

The fishing fleet by construction material shown in Table 27 represents that fishing vessels by wooden and FRP have a big portion based on the number of vessels, whereas steel vessels do when based on tonage. And upon a basis of Horse Power, FRP vessels take a more important place in the fishing vessel force than any kind.

In particular, FRP vessels account for 76.2% of the total vessels. But recently as FRP turns out to be a pollutant, the chance of FRP vessels to pollute the marine environment is surfacing. So the government had underpinned to build fishing vessels by using aluminum, an eco-friendly material, instead of FRP since 2006, but it stopped doing so in 2007 because the governmental support was in contrast with the restructuring project of the fishing fleet then. As a result, the situation that most of the Korean fishing vessels have been made of FRP is raising the probability to pollute the ocean.

Table 27. Status of Fishing Flees by Type of Construction Material

unit : No., G.T, 1,000H.P

	Total			Steel			Wooden			FRP			Others		
	No.	G.T	H.P	No.	G.T	H.P	No.	G.T	H.P	No.	G.T	H.P	No.	G.T	H.P
1998	90,997	978,334	13,064	3,951	716,503	4,961	47,946	143,496	2,915	39,090	118,296	5,190	10	38	1
2000	95,890	923,099	13,597	3,442	656,194	2,571	40,057	112,413	3,345	52,378	154,425	7,681	13	67	1
2003	93,257	754,440	17,094	2,779	494,214	2,172	27,922	67,759	1,578	62,416	192,010	13,328	140	457	15
2004	91,608	724,980	16,743	2,585	469,218	1,835	24,817	56,990	1,343	64,113	198,420	13,552	93	352	12
2005	90,735	700,810	12,949	2,417	444,687	1,721	22,281	49,697	1,169	65,831	205,754	10,044	206	672	16
2006	86,113	673,719	14,388	2,344	432,664	1,952	18,954	40,313	920	64,614	200,111	11,497	201	631	18
2007	85,627	663,869	14,353	2,291	426,096	1,978	17,981	36,606	1,000	65,254	201,015	11,368	101	152	7

Source : KMI, 「Fishery.Marine Environmental Statistics」, 2007., The Ministry for Food, Agriculture, Forestry and Fishery. 「2008 Annual Report of Food, Agriculture, Forestry and Fishery Statistics」, 2008.

2.5 Fishing Ports

Development activities taking place around the coast area can't help affecting the marine environment in whatever ways. Especially, development projects like harbors or fishing ports that have to build large-scale artificial structures eventually have a big and serious impact on the marine environment.

As of 2007, 393 fishing ports in total have been constructed, of which 104 are class 1(state-run/national) fishing ports and 289 are class 2(local-run/regional) fishing ports. In addition, if small-scale fishing ports and fishing village-based fishing ports are included as well, then the total number of fishing ports scattered throughout the nation rises up to around 2,300. As of the end of 2006, there are 1,393 small-scale and 521 fishing village-based fishing ports (Fig. 28).

Table 28. Status of Fishing Ports Designated

unit : ports

Year	Total	State-run/National	Local-run/Regional
2007	393	104	289

Source : KMI, 「Fishery.Oceanic Environmental Statistics」, 2007., The Ministry for Food, Agriculture, Forestry and Fishery. 「2008 Annual Report of Food, Agriculture, Forestry and Fishery Statistics」, 2008.

Recently the government introduces new development models for fishing ports that is aiming to enhancing the function and scenery of those ports, dividing them into three models; Tourism-combined Space(Ⅰ-model), Multi-functional Fighin Port(Ⅱ-model), and Fishing Village Tourist Complex(Ⅲ-model).

2.6 Others

The number of fishery households and population, the party directly concerned to fish production, decreased slightly compared to that of 1998, 10 years ago (Table 29).

Table 29. Fishery Households and Population

unit: households, men. %

	1998	2000	2002	2004	2005	2006	2007	Annual Average Growth
Households	98,972	81,571	73,124	72,513	79,942	77,001	73,934	-3.2
Population	322,229	251,349	215,174	209,855	221,132	211,610	201,512	-5.1

Source : The Ministry for Food, Agriculture, Forestry and Fishery. 「2008 Annual Report of Food, Agriculture, Forestry and Fishery Statistics」, 2008.

Recognizing that this decline of fishery households and population results from the worsening production basis of fishing villages, the government is taking various measures to cope like helping fishermen change their occupation.

3. Governance System of the Coast and Marine Environment

3.1 The history of Governance System

Full-blown environpolitics began with enactment of "Environmental Preservation Law" and "Marine Pollution Prevention Law", but even in early 1990s management of the coastal and marine environment was regarded just as a small part of the land-oriented environmental management.

Following the introduction of the notion "Sustainable Development" adopted in Rio Summit and recommendation of Integrated Coastal Management provided on Article 17th of Agenda 21, Korea's coastal management policies were turned into a development strategy that put all these three components of economy, society, and environment in harmony.

Integrated governance system for the coastal and marine environment was settled down from 1996, the year when the Ministry of Maritime Affairs and Fisheries(now, Ministry of Land, Transport and Maritime Affairs) was established From then, the policies turned into ocean-centered focusing on preservation of ecological value of it from land-centered development, as a result of a series of measures like establishment within the MOMAF of new departments in charge of managing the coast and the oceanic environment, enactment of Coast Governance Act and Wetland Conservation Act, and the amendment of Public Waters Reclamation Act and Public Waters Management Act.

After the year of 2000 when the coastal/marine governance system was set up, the policies broke away from the old post-treatment pattern and turned into a new preliminary pattern so as to prevent the deterioration of marine ecosystem in advance. After then, the government devised "Comprehensive Plan for Marine Environment Preservation", "Integrated Coast Governance Plan", and "Marine Ecosystem Management Plan". And now various MPAs(Marine Protected Areas) have been designated and are being supervised with the purpose of protecting habitats and biological diversity.

Status of Coastal and Marine Protected Area Designated

As of 2007, there are 336 coastal and marine protected areas designated, whose area accounts for 10,187.44 km2, about 10.6% of the total area of the national territory. Since 1996, they have varied in character and shape, such as Wetland Protection Area, Environmental Preservation Sea Waters, Undersea Scenery Zone, with their area growing steadily (Table 30).

Table 30. Status of Coastal and Marine Protected Area Designated

Description	Places	Area(㎢)		
		Sub-total	Land	Water
Marine Protected Area	4	70.4	-	70.4
Wetland Protection Area	8	172.54	-	172.54
Specified Islands	153	10.0	10.0	-
National Parks	4	3,348.4	667.5	2,680.9
Environmental Preservation Sea Waters	4	1,882.1	933.0	949.1
Fisheries Resources Protection Area	10	3,868.1	1,243.0	2,625.1
Scenic Spots and Natural Treasures	153	835.9	742.3	93.6
Total	336	10,187.44	3,595.8	6,591.64

Source : Ministry of Land, Transport and Maritime Affairs, "Study for Establishment of Oceanic Ecosystem Management Mater Plan", 2008,

3.2 Relevant Laws for Coast and Ocean Governance

Now along with the enactment of「Coast Governance Act」,「Wetland Conservation Act」,「Marine Environment Management Act」,「Marine Ecosystem Conservation and Management Law」, and「Uninhabited Islands Conservation and Management Law」and the establishment of "Comprehensive Plan for Oceanic Environment Preservation", "Integrated Coast Governance Plan", and "Oceanic Ecosystem Management Plan", the ocean and coast management system has broken away from the old after-the-fact management and turned into an preventive one (Table 31).

Table 31. Legislation for Coastal and Oceanic Environment Governance

Act/Law	Plans	Contents
Coast Governance Act	* Integrated Coast Governance Plan * Local Coast Governance Plan	- Establishment of the coastal scope(range) - Basic Survey on the coastal actual conditions - Implementation of coastal improvement projects - Organization and operation of the central/local council for coastal management - Operation of honorary coast supervisor
Marine Environment Management Act	Integrated Environmental Management Plan	- Standard of the coastal environment - Operation of the network for surveying the coast - Designation and management of the environment management zones - Organization and operation of the council for the coastal environment management - Levy and collection of the allotment for the coastal environment improvement
Wetland Conservation Act	Mater Plan for Wetland Conservation	- Principles for the wetland preservation - Survey of the wetland - Designation and management of the wetland protection zones - Organization of the national wetland council
Marine Ecosystem Conservation and Management Law	Mater Plan for Marine Ecosystem Conservation and Management	- Principals for the coastal ecosystem preservation and management - Subsidy for the coastal ecosystem protection activities - Installation and operation of the coastal ecosystem information system - Basic survey of the coastal ecosystem - Designation and management of the coastal ecosystem protection zones
Uninhabited Islands Conservation and Management Law	Comprehensive Plan for Uninhabited Islands Management	- Installation of the unmanned island information system - The management council for the unmanned islands - Survey of the conditions of the unmanned islands - Designation of the management patterns of the unmanned islands - Management of the islands on the territorial limits