# Yellow Sea
# East China Sea

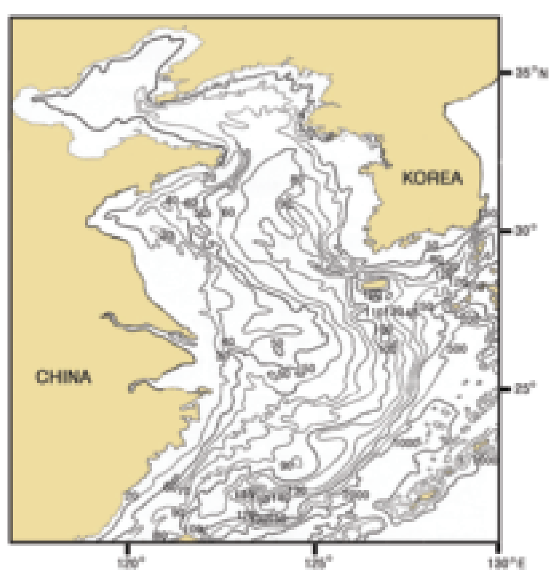
# highlights

- The Yellow Sea / East China Sea show strong influence of various human activities such as fishing, mariculture, waste discharge, dumping, and habitat destruction.
- There is strong evidence of a gradual long-term increase in the sea surface temperature since the early 1900s.
- Given the variety of forcing factors, complicated changes in the ecosystem are anticipated.
- Rapid change and large fluctuations in species composition and abundance in the major fishery have occurred.

# background

## The Yellow Sea and East China Sea are epi-continental seas bounded by the Korean Peninsula, mainland China, Taiwan, and the Japanese islands of Ryukyu and Kyushu.

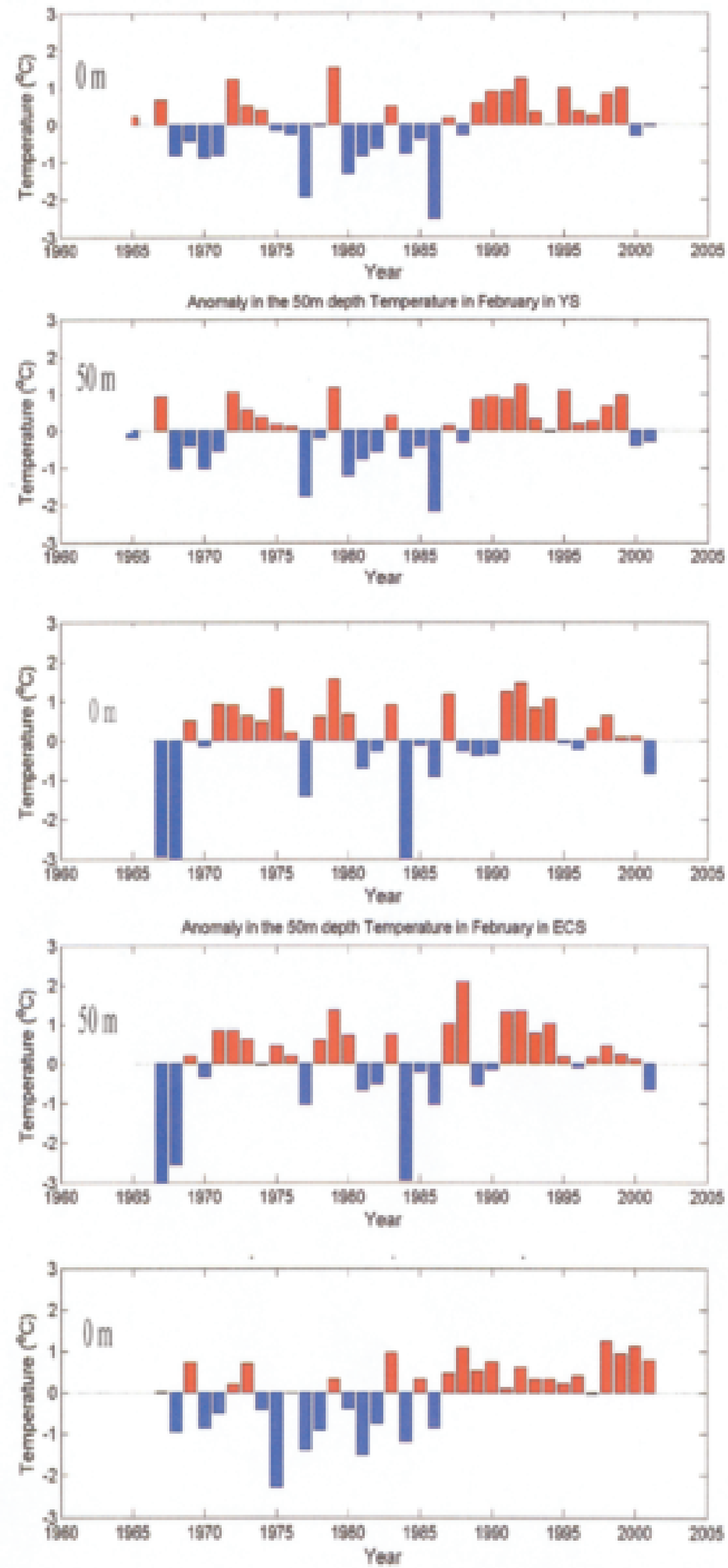
The shelf region shallower than 200m occupies more than 70% of the entire Yellow Sea and the East China Sea. The Yellow Sea is a shallow basin with a mean depth of 44 m. Its area is about 404,000 $km^2$ if the Bohai Sea in the north is excluded. A trough with a maximum depth of 103 m lies in the center. Water exchange is slow and residence time is estimated to be 5-6 years.[37] A large part of the East China Sea is shelf area in the west near the continent. In the southeastern East China Sea, however, there is the deep Okinawa Trough, where maximum water depth varies from greater than 2000 m in its southern section to less than 1000 m in its northeastern section. The main current driving the regional circulation is the Kuroshio and short- and long-term changes in the circulation are anticipated.




[Figure 33] Geography and bathymetry of the Yellow Sea and East China Sea

The coasts of the Yellow Sea have diverse habitats due to jagged coastlines and the many islands scattered around the shallow sea. Intertidal flat is the most significant coastal habitat. The tidal flat in the Yellow Sea consists of several different types such as mudflat with salt marsh, sand flat with gravel beach, sand dune or eelgrass bed, and mixed flat. These flats support important food resources and an ecological niche for diverse organisms, and provide feeding and wintering and summering grounds for migratory birds. The shallow coastal areas, encompassing more than 1,000 islands, also show high productivity and provide good nursery and fishing grounds.

These seas are known to be very productive, supplying a large portion of the protein to the populations in the surrounding nations. The primary productivity of the Yellow Sea and East China Sea has been estimated to be in the range of 150-200 mgC $m^{-2}$ $yr^{-1}$. Approximately 1,600 species were reported from marine and coastal habitats in the Korean Yellow Sea, including 400 phytoplankton, 300 marine macroalgae, 50 halophytes, 500 marine invertebrates, and some 389 vertebrate species.[38] Among them, 166 zooplankton and 276 fish have been reported as resident species from the Yellow Sea. Approximately 100 commercial species have been identified in the region, comprising demersal fish (66%), pelagic fish (18%), cephalopods (7%), and crustaceans (7%).




[Figure 34] SST anomalies at surface and 50m in February from 1967-2001 from the central Yellow Sea (top), East China Sea shelf west of Jeju Island (middle), and Tsushima Current (bottom).

# Status and Trends

## Hydrography

The Yellow Sea/East China Sea region is 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, with speeds reaching 10 m $s^{-1}$. In the spring and summer, monsoon winds reverse the direction and become weaker. Typhoons develop in the west subtropical Pacific bringing heavy rains in the summer and autumn. On average, about nine typhoons pass the region every year.

There are 14 rivers that drain into the Yellow and East China seas, with a total discharge of greater than 1012 $m^3$ $yr^{-1}$.[39] The Changjiang River has the largest discharge, 895 x $10^9$ $m^3$ $yr^{-1}$. During summer monsoon seasons when large precipitation occurs, salinity drops significantly, sometimes by as much as 6 psu. Such abrupt salinity drops have devastating effects on aquaculture and probably on the adjacent ecosystem.

The surface circulation in the Yellow and East China seas consists, basically, of three main currents: the Kuroshio, the Tsushima Current and the Yellow Sea Warm Current (YSWC). The Kuroshio enters the East China Sea through the strait between Taiwan and Yonakunijima Island, (the easternmost island of the Ryukyu Islands), and flows northeastward along the shelf slope and branches into the Tsushima Strait. The YSWC flows into the Yellow Sea after separating from the Tsushima Current in the west of Jeju Island. There are varying opinions of the circulation systems in the Yellow Sea/East China Sea, regarding the origin of Tsushima Current and YSWC.[40,41,42,43]

The circulation system in the Yellow Sea is rather simple in that the coastal currents flow southerly along both the Chinese and Korean coasts, while no strong and consistent current exists in the open water. The major input of warm saline water into the basin is the YSWC through the trough region in the center, although no consensus has been reached on its perennial existence.

There has been an increase of 1.8°C in the water temperature in February in the Korean seas during the past one hundred years.[44] The increase in August water temperature was 1.0°C. The rate of change became greater during the past decade and there has been a northward movement of isothermals during the period.[44] SST anomalies in February indicate that a switch from a colder period to a warmer period occurred circa 1983-1985 (Figure 34). The contrast with the previous period was more conspicuous in the Tsushima Current region than in the Yellow Sea or East China Sea shelf region. There seems to be a six or seven-year time lag from the PDO.

## Chemistry

Production of fertilizers in Korea doubled between 1975 and 1995. The annual load of phosphorus and nitrogen from the rivers of China and Korea is estimated to be 0.9 x $10^9$ and 100 x $10^9$ moles respectively, which are twice as high as those reported ten years ago. The total nitrogen concentration off the coast of Incheon has more than doubled since the 1990s compared with that in the 1980s. While a few studies on the nutrient budget and transport have been made, there are still substantial uncertainties due to huge seasonal and spatial variations.

Concentrations of heavy metals in mussels (dry weight basis) from the west coast of Korea were in the same range as those from other coastal waters of the world oceans.[45] But concentrations of copper and cadmium in mussels from the west coast of Korea were higher than on the east and south coasts of Korea. In an extensive survey conducted in the Yellow Sea in 2000, heavy metals in the sediments, seawater, fish tissue and organs were examined. The results indicate that the concentrations of most target metals were still lower than the criteria set by Europe and Korea.[46]

Compared to trace metals, few monitoring data of synthetic organics were documented in Korea. By 1995 pesticide production in Korea had increased by more than four times from that of 1970, while since 1995 the production has begun to decrease. PCBs in biota were surveyed in the Incheon North Harbor recently.[47] The biota included zooplankton, Pacific oysters, Chinese clams, shore crabs and fish (goby). Shore crabs and goby showed very high levels of PCBs (polychlorinated biphenyls) among the biota. It seems there were PCB hot spots in this area.

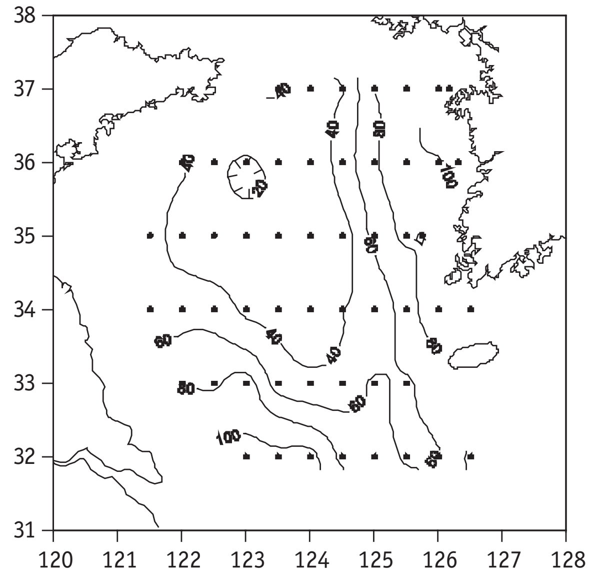
Bivalves collected from Chunsoo Bay, which has no significant pollution source of PCBs and organochlorine pesticides, showed very low levels of PCBs and organochlorine pesticides.

The level of polycyclic aromatic hydrocarbons (PAH) in mussels and oysters collected in Chunsoo Bay were very high. It seems that exhaust from power plants and fishing boats are the main sources of PAHs in this area. From the basin-scale survey in 2000, the picture was not much different. Most organochlorine compounds were not detected in the sediments, while those that were, such as PCBs, were still at a low level. PAHs were detected in most of the sediment and fish tissue samples but the concentrations were lower or comparable to the level found in the other coastal oceans of the world.[46]

## Plankton

**Phytoplankton** Seasonal phytoplankton blooms are known to occur but there are few time-series to show the inter-annual variation in the timing and intensity of the blooms. The current limitation in the ocean color analysis for accurate retrieval of chlorophyll delays such data availability. Compiled in-situ records show that there are great variations in the phytoplankton biomass and primary productivity depending on the area and time. For example, the primary productivity ranged 11.8 to 3175 mg C $m^{-2}$ $d^{-1}$.[46]

In the tidally mixed zone, turbidity is very high and light could be a major limiting factor for phytoplankton growth. Ik was as low as 10-12 μE $m^{-2}$ $s^{-1}$ in a mixed coastal area in the winter.[48] Tyco-pelagic species such as *Paralia sulcata* are dominant. Diatoms are abundant. Species diversity is usually high throughout the year with a less conspicuous seasonal pattern. On the other hand, in stratified water, once bloom conditions subside, species diversity drops quickly.[49] A basin-scale survey made in September 1992 showed this pattern very clearly (Figure 35). In the basin-scale survey, about 400 species were recorded.[50] More than 90% of these are diatoms and dinoflagellates and the proportion of dinoflagellates increases in the stratified water.




[Figure 35] Distribution of phytoplankton species numbers in the Yellow Sea, September 1992.[49]

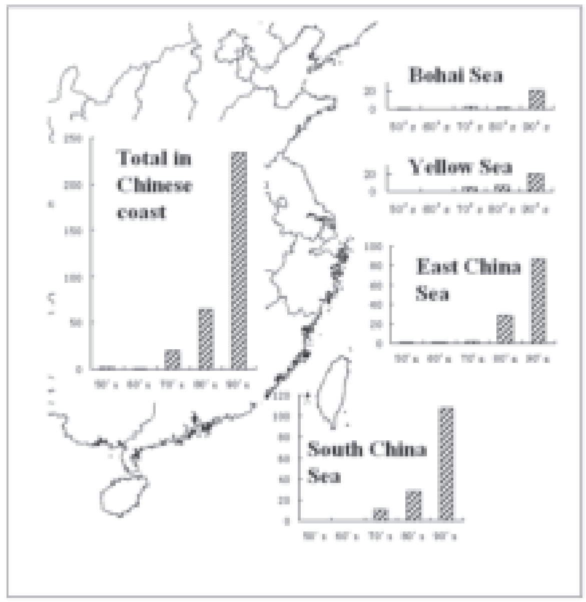
In open waters where the water column is seasonally stratified at shallow depths, bimodal seasonal blooms in spring and autumn occur as expected. Qualitative analysis of CZCS data indicates that seasonal blooms occurred in April and October. A one-year bi-monthly survey indicated that the chlorophyll-a had a mean of 1.5 mg $m^{-3}$ from 12 stations in April (0.4-3.3 mg $m^{-3}$) while in October, the mean was 0.97 mg $m^{-3}$ (range: 0.7-1.2 mg $m^{-3}$).[51] The mean values were 0.70, 0.66, and 0.4 mg $m^{-3}$, in June, August and December, respectively, showing a clear bimodal seasonal pattern. The primary production was highest in June being 1391 mg C $m^{-2}$ $d^{-1}$. The estimate of the annual production was 141 gC $m^{-2}$ $yr^{-1}$. A basin-scale estimate of annual production would be higher than this, since the shallow mixed zone showed higher production. During late spring and summer, a subsurface chlorophyll maximum (SCM) layer is formed near the shallow thermocline (10-30m). The production at SCM was substantial, contributing 17.7-30.1% of the depth-integrated production in June 2000. Continuous measurements by towed profiler show that the SCM depth tends to increase towards the center of the basin.

Seasonal cycles were also observed in some of the shallow tidally-mixed area. The timing of blooms varied depending on local conditions. In Kyungki Bay, the spring bloom occurred in March and the autumn bloom early in September; freshwater discharge probably played an important role in this area.[52] Chlorophyll-a was high throughout the year (1.3-22.6 mg $m^{-3}$). In the Saemangeum area where jetties were built recently, no particular seasonal cycle could be identified. In these areas, chlorophyll-a was also high throughout the year (0.9-6.9 mg $m^{-3}$).

From a limited number of surveys in the Yellow Sea, bacterial abundance was in the range of 0.05-5.8 x $10^9$ cell $l^{-1}$.[53] Bacterial production was estimated at 0.1-46.3 x $10^6$ cell $l^{-1}$ $hr^{-1}$. While the bacterial production was correlated with chlorophyll density in the central waters in the Yellow Sea, that was not the case in the estuaries and strongly-mixed zone. A few studies on the bacteriovory showed that abundance of heterotrophic nanoflagellates was 0.4-4.2 x $10^6$ cell $l^{-1}$ while the grazing rate was 1-30 x$10^6$ cell $l^{-1}$ $hr^{-1}$ accounting for 6-123% of the bacterial production. In comparison, ciliate grazing was 0.1-12.2% of the bacterial production.

HABs were relatively uncommon in the Yellow Sea due to turbulence and turbidity caused by strong tidal currents. Recently, on both the Chinese and Korean coasts, the frequency and extent of the outbreaks have increased. On the Korean coast, construction of dams and barriers inhibiting circulation seems to be the cause. Fifty-six red-tide events have been observed between 1984 and 2002. Based on a chronological review of the red tides in the Yellow Sea, there were 10 outbreaks of red tides in 1998 and 1999, but generally less than 5 events in other years. Up to 1989, most red tides had taken place between July and August in Korea. In the last decade, the red tide season shifted earlier year by year, with the first bloom observed in June in 1993 and 1994, and in May since 1995. On the other hand, the red tides occurred as late as September and October in two consecutive years, 1998 and 1999. In the last two decades red tides were generally observed from late spring to autumn, with a peak in late summer (between July and September). The bloom season has been prolonged from summer only before 1995 to spring through fall since then.

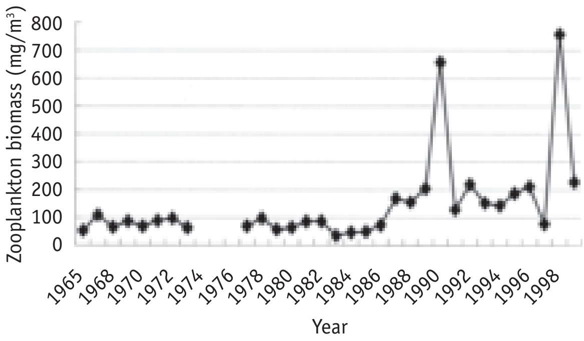
A total of 16 species are responsible for harmful algal blooms in the region; seven are dinoflagellates from six genera *(Noctilluca, Prorocentrum, Gymnodinium, Ceratium, Cochlodinium, Eutreptiella)* and five are diatoms (*Skeletonema, Coscinodiscus, Thalassiosira, Leptocylindrus*). The other species include one ciliate *Mesodinium rubrum,* one Rhapidophrceae, *Heterosigma akashiwo,* one Cryptophyceae *Chroomonas salina* and a blue green algae *Microsystis* sp. The most important dominant species are *Noctilluca scintillance* and *Mesodinium rubrum.* The fish-killing dinoflagellate, *Cochlodinium polykrikoides* occurred in October in 1998 and 1999.




[Figure 36] HAB events reported in the coastal seas of China during the past decades (1958-1998).

HABs have occurred in the coastal embayment, especially Kyunggi Bay and Chonsu Bay, since the 1980s, but have become frequent and widespread since 1995. Most HABs lasted for one week or less even in enclosed or semi-enclosed bays. However, recent HABs, especially since 1995, were more frequent and widespread. Outbreaks of the fish-killing dinoflagellate bloom of *Cochlodinium polykrikoides* since 1998 in Kunsan coastal water have become a serious threat to the development of aquaculture industries and marine animals. On the Chinese coasts, HABs are related to eutrophication due to mariculture activities. HABs caused huge economic damage in the Bohai Gulf and in semi-enclosed bays (Jiazhou Bay and Haizhou Bay). In the vicinity of the Changjiang River estuary, HABs are more frequent. All along the Chinese coast, the incidence of HABs has increased rapidly during the past decades (Figure 36).

**Zooplankton** Bimonthly zooplankton samples have been taken in Korean waters during the past decades, and there is some evidence that a long-term change has occurred. Beginning in the late 1980s, the zooplankton biomass on the Korean side of the Yellow Sea showed an increasing trend with an annual biomass average of 129.2 mg $m^{-3}$ (Figure 37). The causes of the change are not yet understood.




[Figure 37] Long-term change in the zooplankton biomass in the central area of the Yellow Sea.

A detailed analysis of bimonthly samples during the 1997-1999 period showed that copepods were the major group comprising 70.1% of the total zooplankton biomass, on average.[54] The remainder was comprised of dinoflagellates (5.78%, mostly *Noctiluca*), Cladocera (5.42%), Chordata (5.26%) and Chaetognatha (5.19%). The proportion of copepods was highest during late autumn through early spring because the biomass of other groups increased from late spring and remained high till late autumn. Among the copepods, *Calanus sinicus, Paracalanus* sp., *Oithona atlantica, Corycaeus affinis* were dominant through all seasons and occurred in most areas, comprising 75.6% of the total copepod biomass. The total zooplankton biomass was highest in June and October. There was a year-to-year variation in the pattern. For example, in 1997 and 1998, the biomass was highest in June, while in 1999, the biomass was highest in October. Seasonal fluctuation was higher in the northern and neritic environments. A conspicuous feature of the zooplankton in recent years are blooms of the large scyphomedusa, *Nemopilema nomuri,* in the East China Sea.[55] An unusual bloom was first observed in 2000, and the largest bloom occurred in 2003. Ocean currents carried the jellyfish northward into adjacent seas causing serious problems for fishing activities.

## Benthos

In the northern Yellow Sea, the biomass of zoobenthos was higher than in the central and southern regions. The seasonal maximum of 49.68 g $m^{-2}$ occurred in the spring, and seasonal means were 39.14 g $m^{-2}$ in winter, 38.05 g $m^{-2}$ in autumn, and 37.85 g $m^{-2}$ in summer. In the central and southern Yellow Sea, the mean biomass was 19.71 g $m^{-2}$. Here, the maximum, 27.36 g $m^{-2}$, also occurred in the spring. In other seasons, mean biomass did not vary significantly, ranging from 17.29 g $m^{-2}$ in summer, 16.39 g $m^{-2}$ in autumn and 16.38 g $m^{-2}$ in winter.[56] Molluscs account for over 55% of the total biomass, the echinoderms, polychaetes and crustaceans, approximately 20%, 15% and 10% respectively, and the remaining species groups, about 5%.

Korean studies, however, showed somewhat different results. Along the Korean coastline, higher biomass has been reported, ranging from 79.44 - 171.6 g $m^{-2}$. Abundance ranged from 769 - 1,939 ind. $m^{-2}$. A total of about 500 species has been reported comprising 135 mollusks, 148 arthropods, 87 annelids, 24 echinoderms, 34 cnidarians, and 7 poriferan species.[57] Such differences are at least partly related to different sampling methods and strategies.

## Fish and invertebrates

Though the distribution of many fishery resources in the Yellow Sea and the East China Sea is not confined to local areas, and these resources have been utilized commonly by neighboring countries, few joint scientific and management activities occurred. A total of 276 species was identified in the Korean side of the Yellow Sea, and approximately 100 species have been utilized as resources. Over 90 % of these species are warm water or warm-temperate water species. Currently, about 30 species are commercially targeted. Some important commercial fish species (i.e., small yellow croaker, largehead hairtail, chub mackerel, and anchovy) were identified, and these species generally showed the typical migration pattern: spawning in the coastal areas during the spring, and overwintering in the southern Yellow Sea and the northern East China Sea during winter.

Based on scientific bottom surveys in the region, 149 and 177 species were collected from Chinese waters in autumn 2000 and spring 2001, respectively.[58] Biomass in autumn was higher than that in spring. Especially in autumn, biomass of pelagic species was higher than that of demersal fish, while it was reversed in spring. From bottom trawl surveys in Korean waters, 134 demersal species were collected in summer 1967, while only 51 species were sampled in 1980/81 survey, revealing a 62 % reduction in the number of species. In addition, the shift in the major species is obvious. Among the top 15 abundant species in the 1980/81 survey, 8 species were not found in the list of 20 abundant species in the 1967 survey (Table 8).[59]

In the northern Yellow Sea, generally, most pelagic species showed a long-distance migration pattern, but flatfish and rays usually had a short migration between shallow and deep waters. Trawl survey results indicated that the biomass of pelagic fish has increased continuously since the 1950s, while the proportion of demersal fish decreased.[60,61] Species diversity decreased from the early 1980s to late 1990s in the Yellow Sea as well as in the Bohai Sea.

[Table 8] Abundance changes in demersal species in Korean waters between the 1960s and the 1980s based on bottom trawl surveys.

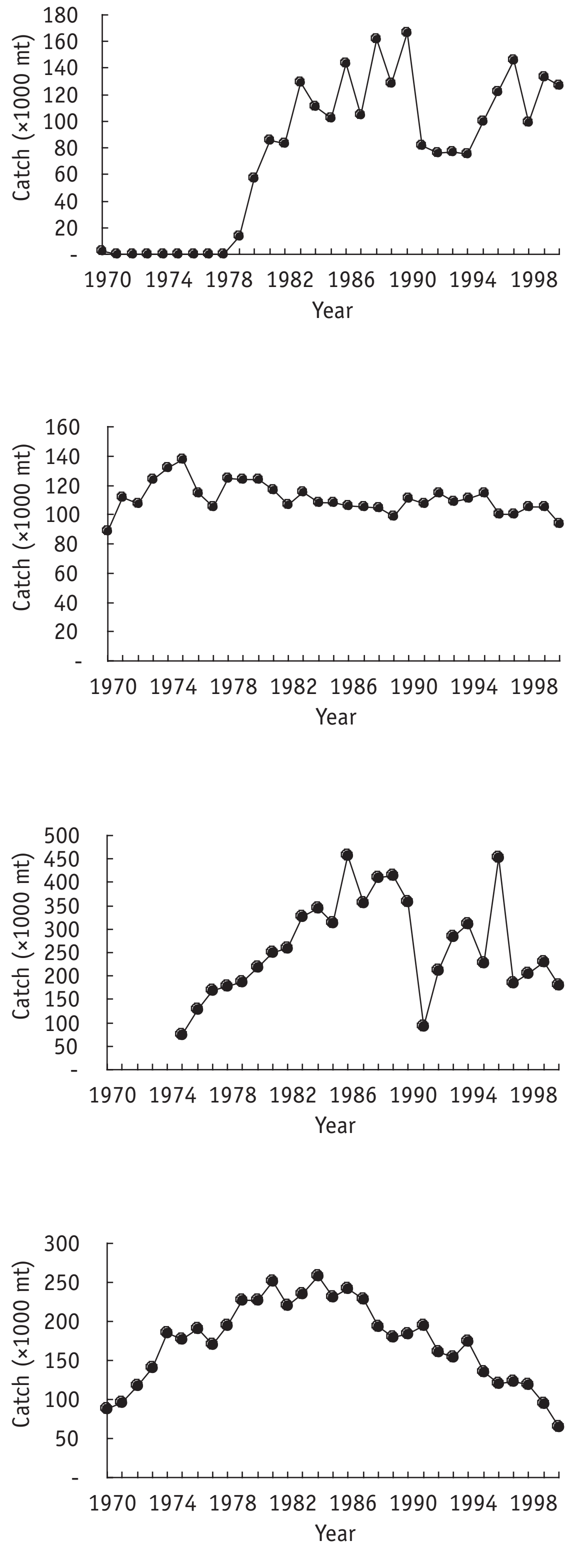
| | 1967 | | 1980/81 | |
|---|---|---|---|---|
| Rank | Fish species | (%) | Fish species | (%) |
| 1 | *Raja kenojei* | 11.8 | *Navodon modestus* | 23.3 |
| 2 | *Areliscus trigrammus* | 9.4 | *Trichiurus leptulus* | 15.7 |
| 3 | *Tanakius kitaharae* | 7.2 | *Raja kenojei* | 14.0 |
| 4 | *Eopsetta grigorjewi* | 5.4 | *Zeus japonicus* | 6.6 |
| 5 | *Lophiomus setigerus* | 5.3 | *Zoarces gillii* | 3.9 |
| 6 | *Helicolenus hilgendorfi* | 5.3 | *Doderleinia berycoides* | 3.8 |
| 7 | *Collichys niveatus* | 5.2 | *Pampus argenteus* | 2.7 |
| 8 | *Liparis tanakai* | 4.3 | *Eopsetta grigorjewi* | 2.1 |
| 9 | *Platyrhina sinensis* | 3.9 | *Heterodontus japonicus* | 1.9 |
| 10 | *Branchiostegus japonicus* | 3.8 | *Lophiomus setigerus* | 1.5 |
| 11 | *Lepidotrigla microptera* | 3.2 | *Liparis tanakai* | 1.4 |
| 12 | *Raja porosa* | 2.7 | *Chrysophrys major* | 1.1 |
| 13 | *Pampus argenteus* | 2.4 | *Branchiostegus japonicus* | 1.0 |
| 14 | *Pseudosciaena polyacits* | 2.2 | *Sebastes inermis* | 1.0 |
| 15 | *Scyliorushinus torazame* | 1.9 | *Collichthys fragilis* | 1.0 |
| 16 | *Taius tumifrons* | 1.9 | | |
| 17 | *Fugu pardalis* | 1.8 | | |
| 18 | *Trichiurus leptulus* | 1.7 | | |
| 19 | *Fugu niphobles* | 1.6 | | |
| 20 | *Pseudohombus cinnamoneus* | 1.5 | | |

Japanese anchovy is widely distributed in the northwestern Pacific Ocean, and is the most abundant pelagic species in the Yellow and East China seas. The annual average (1997-2000) Chinese catch of small pelagic fish was about 6 million t, of which Japanese anchovy constituted 20% (1.2 million t).[62] Research surveys during the winters of 1986-1995 indicated that anchovy biomass fluctuated from 2.5 to 4.3 million t in the Yellow and East China seas.[62] However, recent overexploitation seems to have depleted anchovy stocks in the Yellow Sea. Changes in the pelagic community are also obvious. In 1959, demersal fish species were dominant in Chinese waters. However, they were mostly replaced by small pelagic fish and invertebrates within two to three decades.[61]

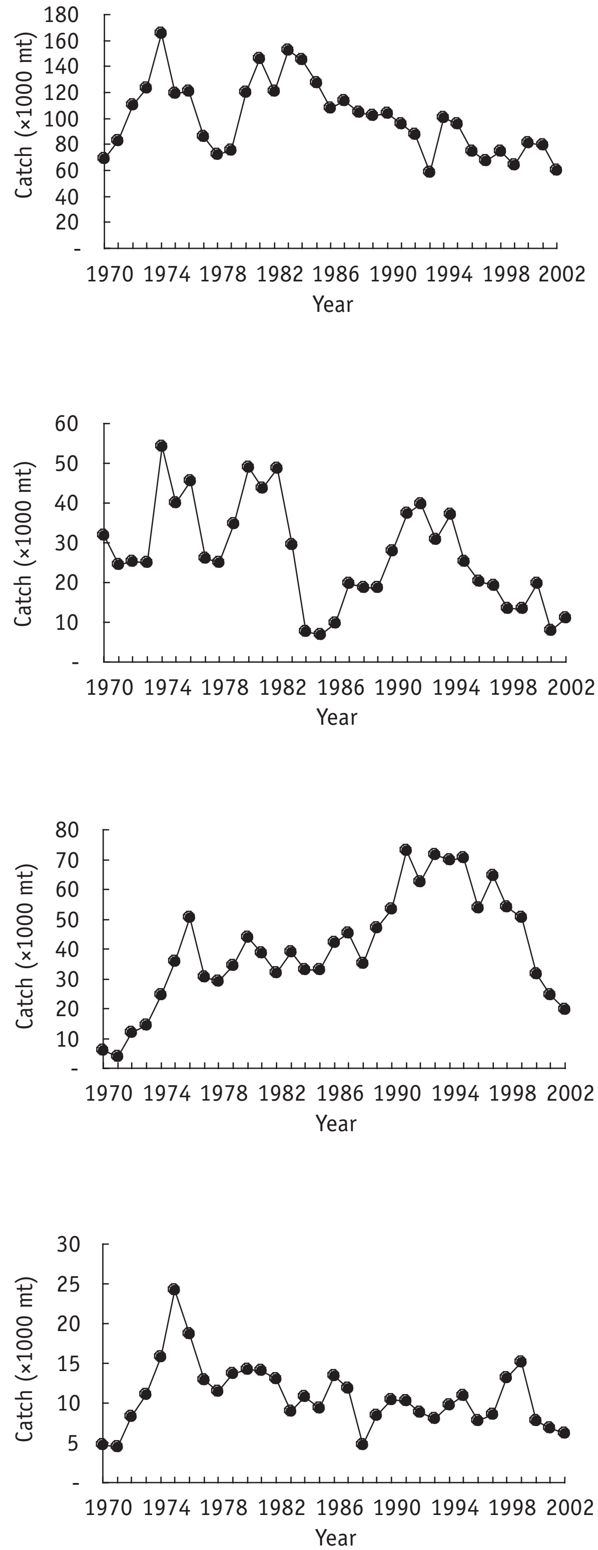
Major fisheries in these areas are large trawls, large pair trawls, large purse seines and offshore stow nets. Major target species of this fishery are hairtail, filefish and common squid. Both catch and CPUE of the large trawl fishery increased continuously from the mid-1970s with the sudden increase in the catch of filefish. The catch showed a peak in 1990 at 170 thousand t, but thereafter decreased with the decreased catch of filefish in the early 1990s. However, the catch started increasing from 1995 with the increase in the catch of common squid (Figure 38). Major target species of the large pair trawl fishery are hairtail, small yellow croaker, corvenia and blue crab. Annual catches were pretty stable at about 110 thousand t in recent years.

Major species of the large purse seine fishery are chub mackerel, horse mackerel and sardine. Annual catch of the fishery showed some fluctuations ranging from 70 thousand t in 1975 to 460 thousand t in 1986, while annual CPUE was fairly constant, compared to catches. After 1986 catches started declining with the decrease in the catches of sardine and filefish. Catches increased again with the rising of chub mackerel catch in the late 1990s (Figure 38).

Major target species of the offshore stow net fishery are hairtail, small yellow croaker, corvenia, pomfret and blue crab. Annual catches of the fishery declined after 1987, and the catch was about 120 thousand t in 1997.




[Figure 38] Yield of major fisheries in the Yellow Sea and the East China Sea: large trawl fishery (top), large pair trawl fishery (upper middle), large purse seine fishery (lower middle) and stow net fishery (bottom).



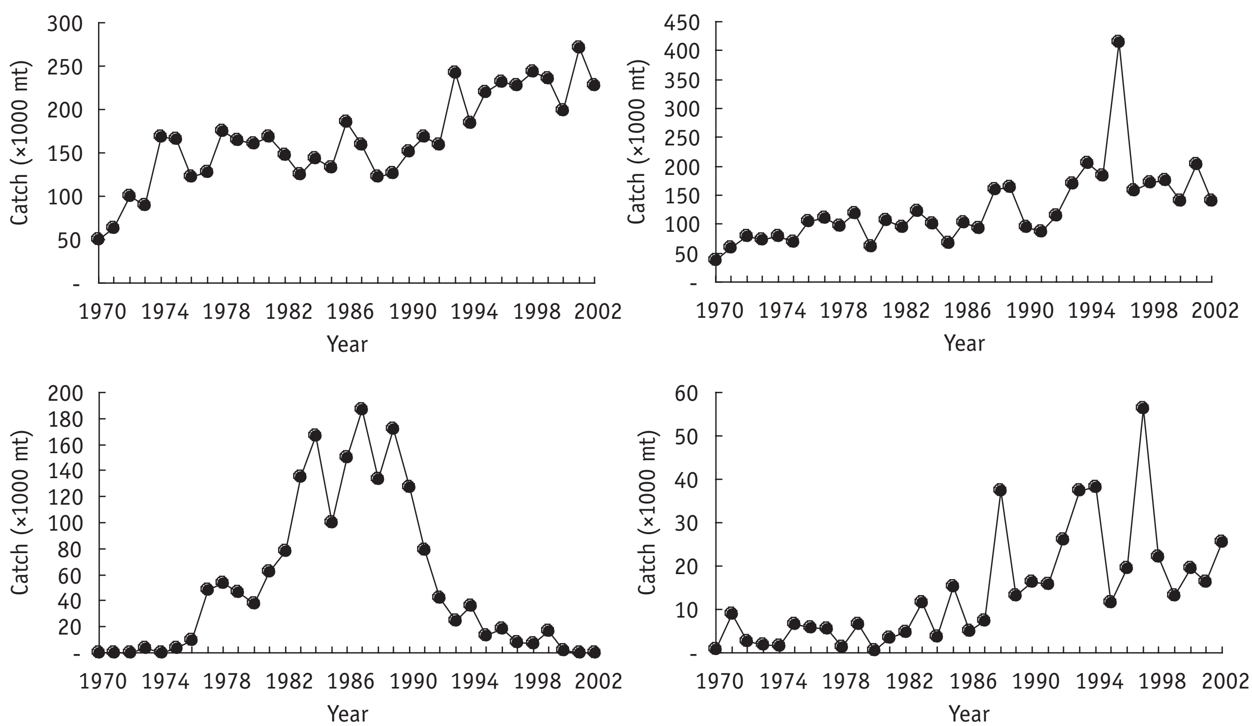

[Figure 39] Yield of major demersal species in the Yellow Sea and the East China Sea: hairtail (top), small yellow croaker (upper middle), corvenia (lower middle) and pomfret (bottom).

Annual catches of small yellow croaker have fluctuated widely (Figure 39). In the early 1970s, the annual catch of small yellow croaker was about 30 thousand t, but it decreased below 10 thousand t after the mid-1980s. Recent catches were about 15 thousand t. The annual CPUE was higher in the 1970s, but lower after the 1980s. Annual catch of hairtail was relatively high, over 150 thousand t, from the mid-1970s to the mid-1980s. The decreasing trend was apparent in the late 1980s. However, the annual CPUE showed a high level in the mid-1970s, and declined continuously until recent years. Corvenia and pomfret catches showed similar patterns.

Yields of some major pelagic species (anchovy, chub mackerel, and horse mackerel) are shown in Figure 40. Annual catches of anchovy started increasing from 1970 and they remained around 150-200 thousand t from 1975 to 1993. The catch increased to about 240 thousand t in recent years. However, CPUE was remarkably low after showing a peak in 1975. Annual catches of chub mackerel showed an increasing trend in recent years.

The trend of annual CPUE was similar to that of catch. Filefish catches increased from 1975 and recorded a higher level in the mid-1985. But the catch has decreased rapidly since the early 1990s. Annual catches and CPUE of horse mackerel reached their highest levels in 1988, and then declined markedly. In the early 1990s, they increased again until 1994, and then declined again.

In summary, fisheries resources of the Yellow Sea and the East China Sea decreased in general. The annual CPUE of the Yellow Sea declined from 3.46 t $hp^{-1}$ in 1962 to 0.03 t $hp^{-1}$ in 2001, and the annual CPUE of the East China Sea declined from 1.89 t $hp^{-1}$ in 1961 to 0.01 t $hp^{-1}$ in 2001.

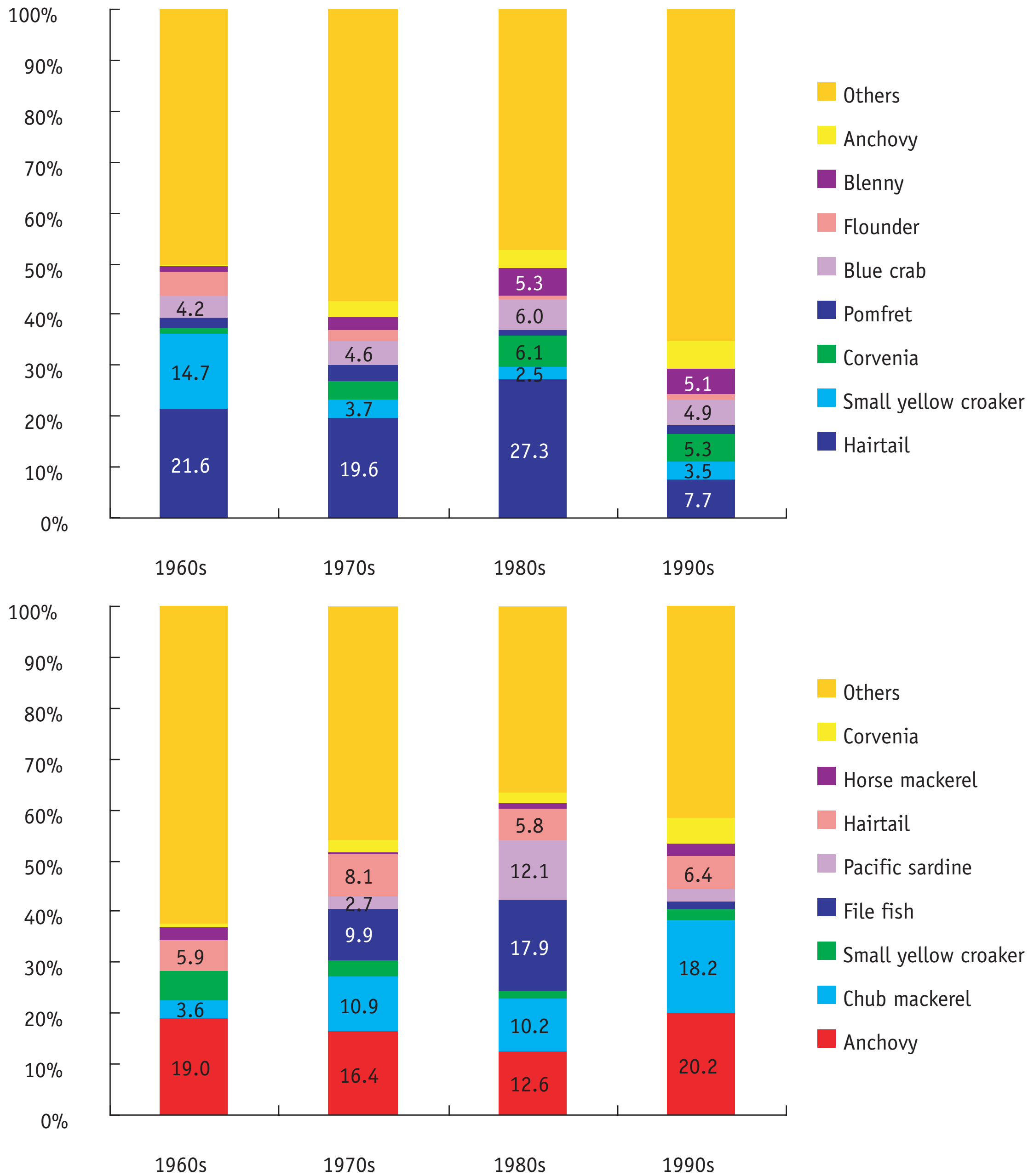



[Figure 40] Yield of major pelagic species in the Yellow Sea and the East China Sea: anchovy (Upper left), chub mackerel (upper right), Pacific sardine (lower left) and horse mackerel (lower right).

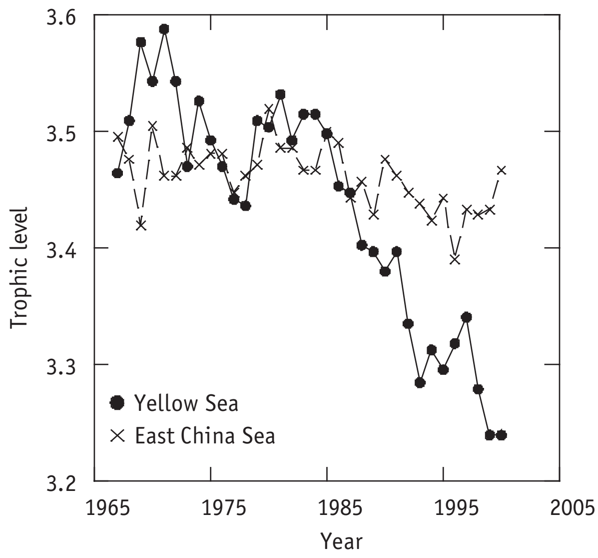
Demersal fish were more important fisheries resources in the Yellow Sea, but pelagic fish were dominant in the East China Sea. The seven major target species in the Yellow Sea during the last 40 years were as follows: (1) hairtail, (2) corvenia, (3) anchovy, (4) small yellow croaker, (5) blenny, (6) pomfret, and (7) flounder. The species composition in the catch of small pelagics has changed remarkably during the period of the 1960s to the 1990s. Hairtail were most dominant, followed by small yellow croaker in the 1960s and the 1970s. Thereafter, the catch of small yellow croaker decreased with an increase in corvenia, flounder and anchovy in the 1980s and the 1990s (Figure 41).

The seven major target species in the East China Sea during the last 40 years were as follows : (1) anchovy, (2) chub mackerel, (3) filefish, (4) hairtail, (5) Pacific 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 in the composition after the 1960s. The relative compositions of chub mackerel, filefish and Pacific sardine increased in the 1970s and the 1980s. In the 1990s, filefish and Pacific sardine disappeared and anchovy, chub mackerel, and common squid dominated in the composition (Figure 41).

The trophic levels of resource organisms in the catches from the two seas showed significant decreasing trends from 1967 to 2000 (Figure 42). Mean trophic levels were 3.43 and 3.46 in the Yellow Sea and the East China Sea, respectively. The decline was steeper in the Yellow Sea than in the East China Sea. This result showed that demersal fish such as small yellow croaker, which were at higher trophic levels, gradually decreased, while small pelagics such as anchovy, common squid and blenny, which were at relatively lower trophic levels, increased during the four decades.




[Figure 41] Catch percentages by species (1961-2000) in the Yellow Sea (Upper) and East China Sea (Lower).




[Figure 42] Trophic level of resource organisms in the catches of the Yellow Sea and the East China Sea.

## Marine birds and mammals

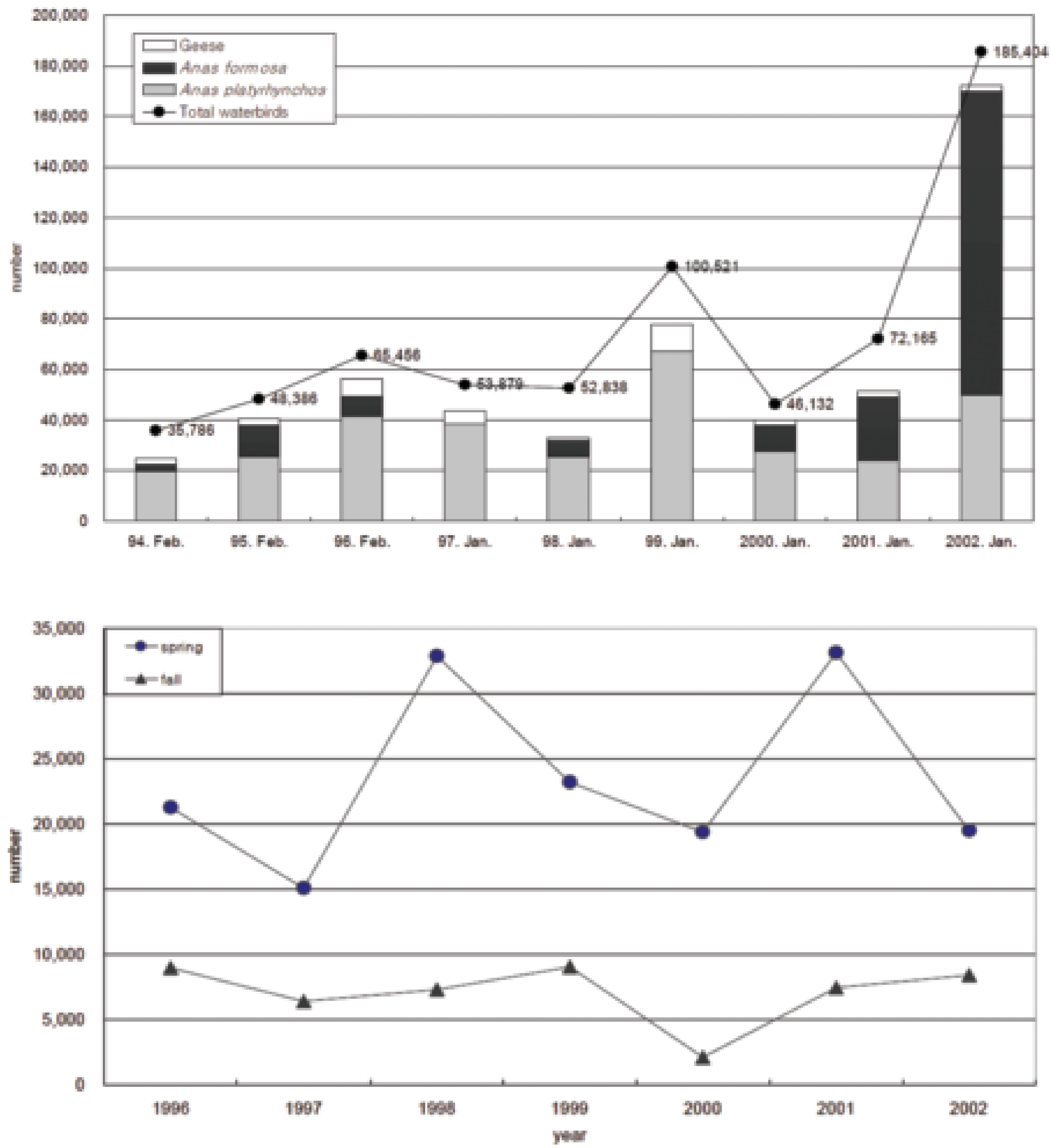
**Seabirds** The intertidal areas and coastal wetlands of the Yellow Sea support more than 2,000,000 shore birds during their northward migration; about 40% of the all migratory shorebirds in the East Asian-Australasian Flyway.[63] A total of 36 shorebird species have so far been found to occur in internationally important numbers at one or more sites in the Yellow Sea, representing 60% of the migratory shorebird species occurring in the Flyway. Two of the species are classified as globally threatened, the spotted greenshank *Tringa guttifer* and spoon-billed sandpiper *Eurynorhynchus pygmeus,* whilst two are near-threatened, the eastern curlew *Numenius madagascariensis* and Asian dowitcher *Limnodromus semipalmatus*. While the South Korean coastline has been well surveyed, only about one-third of the Chinese coasts has been surveyed and little is known from the North Korea.

A total of 160 species and about 634,773 individuals of water birds were reported to overwinter on the Korean coast in 2001-2002. Dominant species were geese, mallards *(Anas platyrhynchos)*, and ducks *(A. poecilorhyncha, A. formosa)*. Migratory birds that use Korean coasts as stopover sites consisted of 305,887 individuals in 25 species during the spring and of 269,317 individuals in 33 species during the autumn in 2002.[64] Dominant species were lapwings *(Vanellus vanellus)*, plovers *(Charadrius dubius)*, and sandpipers *(Tringa hypoleucos)*. More species of migratory birds stop over at Heuksando Isalnds (remotely located in the southern Yellow Sea) during spring and autumn. The number of species was 112 while the number of individuals was 3,448 in 2002.

Time series of the number of overwintering birds during 1993-2002 showed no particular trends, although they were different depending on locations (Figure 43). In the Keum River estuary (located at ~36°N latitude), for example, the total number is largely determined by a couple of dominant species, such as *Anas formosa*. There was no particular trend in the time series of the number of spring-autumn migratory birds (Figure 43, lower panel).

**Mammals** A total of 16 cetacean species have been recorded. Amongst them, fin whale *(Balaenoptera physalus)*, minke whale (Balaenoptera acutrostrata), killer whale *(Orcinus orca)*, Blainville's beaked whale *(Mesoplodon densirostris)*, and finless porpoise *(Neophocaena phocaenoides)* have commonly been observed. Catching whales was banned in Korea in 1986 and some of the whale populations have increased. In the Changjiang River estuary, two endangered migratory freshwater cetaceans can be found, baiji *(Lipotes vexillifer)* and finless porpoise. The former, listed as a critically endangered species in IUCN Red Book, lives only in China.[57]

Larga seals, *Phoca larga,* inhabit many coastal areas of the Yellow Sea. Since the 1960s, populations have been decreasing due to heavy catch and habitat destruction and only small groups can now be found. Both in China and Korea, larga seals are designated as protected animals.




[Figure 43] Upper panel: The number of overwintering birds in the Keum River estuary (Korean Yellow Sea coast). Lower panel: The number of birds that stopped over at the Asan reclamation area during their migration in spring and fall.[64]

# issues

Although there is disagreement on the possible impact of the Three Gorges Dam on the Yellow Sea-East China Sea ecosystems, it could be far-reaching. As the dam was completed in 2003, the change in the adjacent ecosystems should be monitored.

Aquaculture production has increased more than ten-fold in Korea during the 1970-1995 period. Aquaculture production by China accounts for 63% of the world total production in 2002. Despite the intensive aquaculture activities along the coasts of the Yellow Sea and East China Sea, the impact on natural ecosystems has seldom been assessed. Aquaculture in these areas is also vulnerable to spreading of pathogens and parasites due to heavy sea traffic.

While the Yellow Sea and the East China Sea are one system from the viewpoint of fish migration, they are separate systems in terms of various environmental factors. As a consequence, there is high spatial and temporal variability in ecosystem properties. However, there have been very limited monitoring activities to assess long-term changes in the Yellow Sea and East China Sea ecosystems. Establishing an observing system for a consistent time series of essential ecosystem properties is vital in evaluating the ecosystem status of the Yellow Sea-ECS ecosystems in the future.

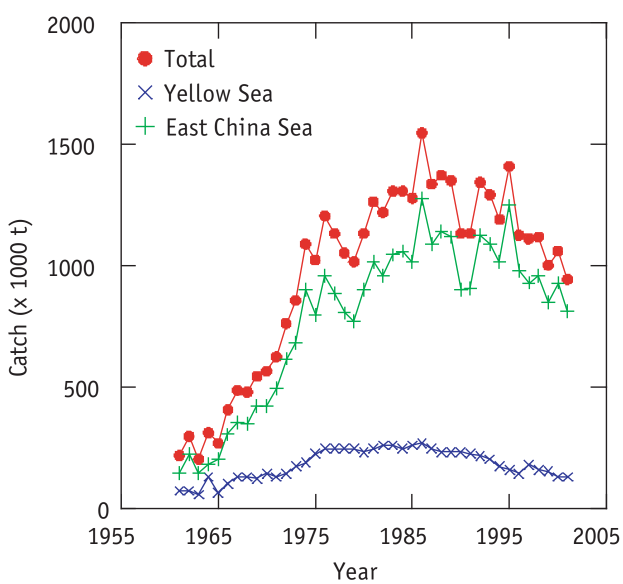
Biological diversity in Korea is declining mainly due to habitat loss due to coastal development. The Korea Association for the Conservation of Nature listed 179 species as extinct, endangered and protected species. Among them, 29 species are endangered or reserved wild marine animal species, which consist of 2 mollusks, 23 waterfowls, and 4 mammals including spotted seal *Phoca largha*.

Many invertebrates might be endangered, but the exact status is unknown. A total of 16 species, two mammals and 14 birds, are protected as natural monument species. The bird group includes cranes, spoonbills, swans and oystercatcher. The main threat to the coastal habitats is land reclamation especially in estuaries and shallow bays. During past decades, many sites have been reclaimed, resulting in the loss of approximately 25% of the total tidal flats in Korea.

These seas include the EEZ of four countries which make basin-wide monitoring activities all the more difficult. To synthesize the survey data from different countries, sampling and analysis methodologies must be comparable. One example that illustrates this point is that zooplankton biomass has increased on the Korean side of the Yellow Sea since the late 1980s, while it decreased on the Chinese side during the same period. Part of this discrepancy could be due to differences in sampling methods.

# critical factors causing change

**Contamination and eutrophication** Increasing population in the coastal regions is especially significant causing severe stress on the marine environment in the Yellow Sea. The coastal regions on either side of the Yellow Sea are densely populated; approximately 600 million persons are living in the region and most of the by-products from human activities are drained into the Yellow Sea. Various chemical species related to human activities are transported to the seas via various routes: river discharges, air, oil spills, sewage, etc. Chemicals include nutrients, heavy metals, synthetic organics, and volatile organic compounds. These chemicals could affect the productivity and viability of marine organisms.




[Figure 44] Annual catch in Korean waters of the Yellow Sea and East China Sea.

**Habitat destruction** Many years of aggressive landfill and reclamation work have filled out the curvatures and straightened the coastal lines. Approximately 2,393 km$^2$ of the tidal flats exist in the western and southern coastal areas of Korea, and many of them are recognized as internationally important wetlands. The total area of the coastal wetland continues to shrink, particularly on the western coast of Korea.

During the last three decades, this area of remarkable biological diversity has been intensively developed for industrial, agricultural and commercial uses. Large areas of tidal flat existed near many rivers that flow into the Yellow Sea. If the Saemangum Reclamation Project takes place as is planned, the Han River estuary will be left as the only extensive estuarine tidal flat in its natural state.

**Overexploitation** Most commercial fisheries resources in these waters seem overexploited and cannot be sustainable under the current level of catch. Due to the intense Chinese fishing activities since the 1980s, annual catches in the region have increased rapidly. For example, the Chinese catch in the Yellow Sea and the East China Sea was 1.5 million t in 1970, but it had doubled by 1990.[59]

Furthermore, recent Chinese statistics indicate that the total catch of pelagic fish was 5.8 million t in 2000, which was about 40% of the total Chinese marine catch.[62] Annual Korean catches in the Yellow Sea and the East China Sea were only 210 thousand t in the early 1960s; however they grew rapidly and exceeded 1,000 thousand t by the mid-1970s due to increased fishing intensity. The annual Korean fisheries production in the Yellow Sea and the East China Sea ranged from 213 thousand t in 1961 to 1,537 thousand t in 1986. But total catches started to decrease after mid-1980s, and recently settled at a level of 1,000 thousand MT (Figure 44). Average annual Korean fisheries production in the Yellow Sea and the East China Sea were 184,181 t and 785,113 t, respectively, which were 15.7% and 67.0% of the total fisheries production in Korean waters.

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