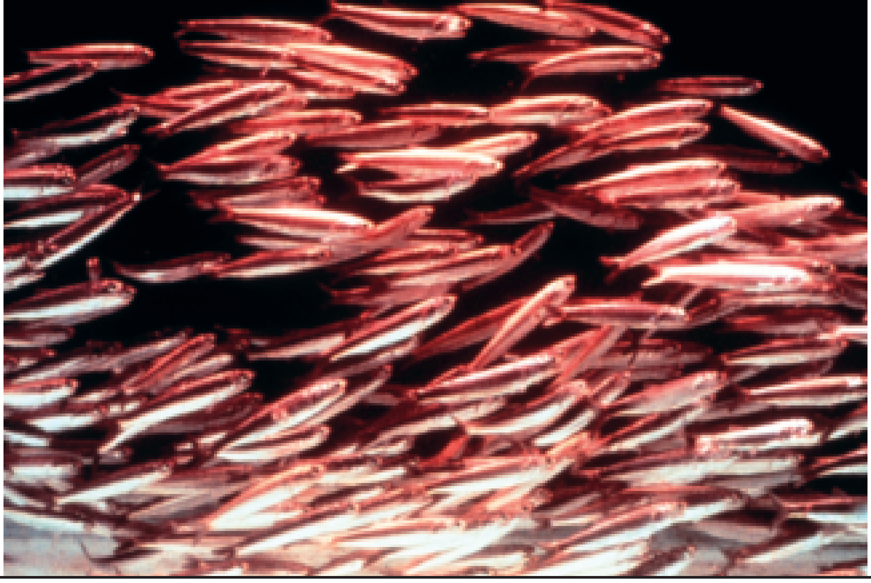
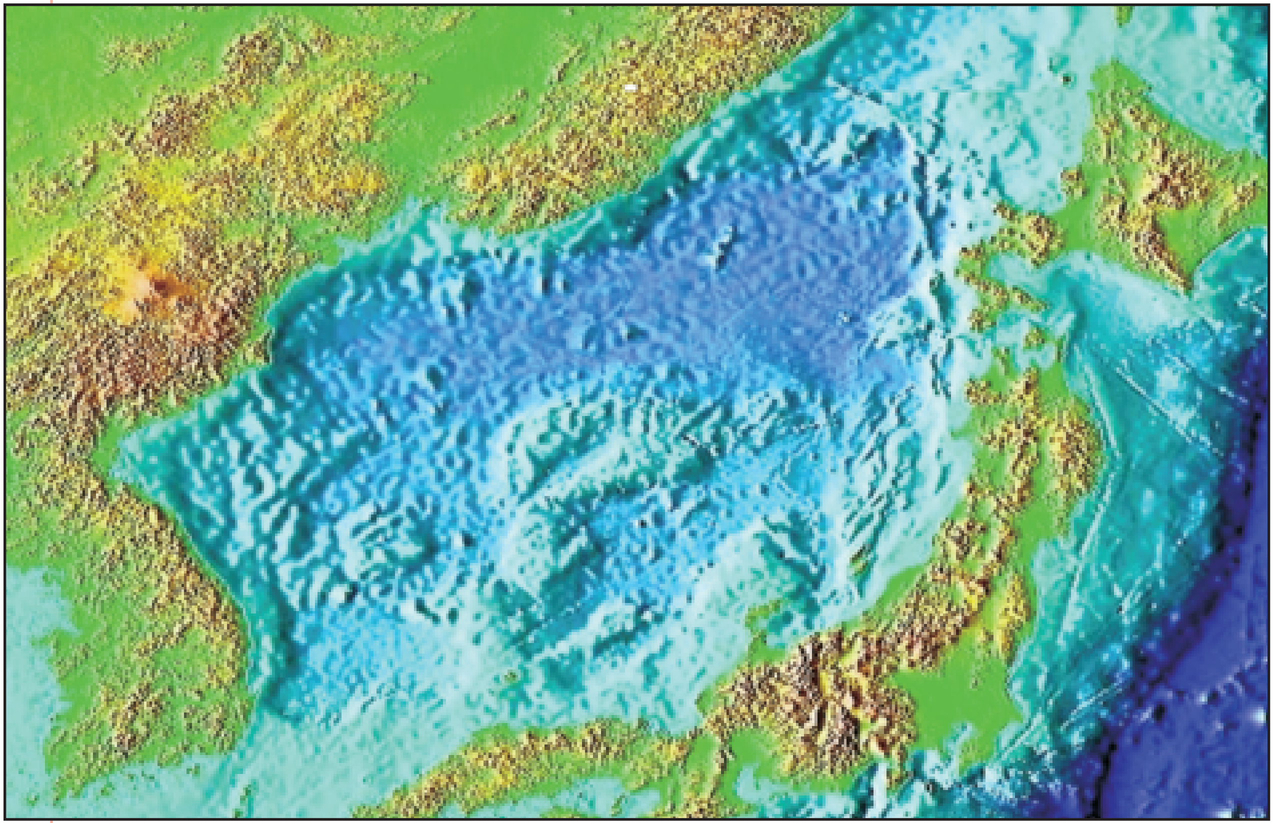


# Japan/East Sea

# highlights



- The Japan/East Sea has one of the clearest, most unambiguous signals of long-term ecosystem change, but as yet there is no good answer for why. The concentration of dissolved oxygen in the deepest bottom waters had been declining for decades. If oxygen is not renewed, it is slowly used up by biological processes that utilize oxygen for respiration. A very cold winter in 2000/2001 produced dense, high oxygen water at the surface that sank to the bottom, providing the first renewal in many years.

- Although its geography suggests a rather well-defined entity, it is not homogeneous. This is particularly evident at the intersection of physics, chemistry and biology where they materialize as primary production. The timing of spring and fall plankton blooms, the species and size composition, and the trophic structure of these ecosystems differ according to location, with major differences among northern, southern, and coastal regions. Even within regions there can be significant variation from year to year.

- Although Pacific sardine once accounted for over 70% of the catch of pelagic species in the Japan/East Sea, they no longer form a significant fraction of the catch. Sardine predators such as seabirds have switched to other species of prey. The winter distribution of Steller sea lion has moved southward along the west coast of Hokkaido resulting in increasing interactions between fishermen and the sea lions.

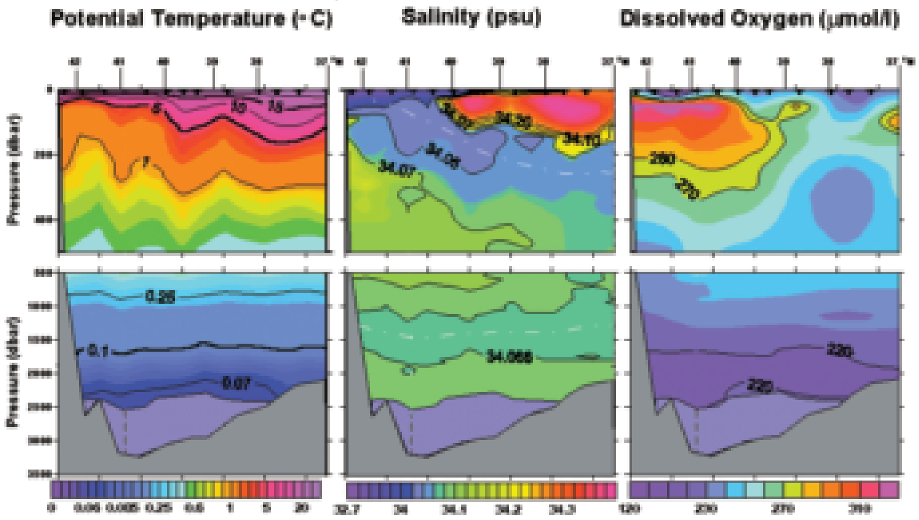
# background

## The Japan/East Sea is formed by the separation of the Asian mainland on the west and the archipelago of Japan on the east.

It spans the latitudinal range from 35°N to 52°N. The coastal states include the Russian Federation, the Democratic Peoples Republic of Korea, the Republic of Korea from north to south on the mainland and Japan. The Japan/East Sea has several deep basins and is connected with the North Pacific Ocean by shallow and narrow straits at the northern and southern extremes. The major influences include the inflow of warm salty water from the south meeting cool fresher water in the north.

The interface between the two forms the Polar Front at about 40°N (Figure 45).

Surface ocean currents tend to flow northward along the coast of Japan, with some water flowing out to the North Pacific through the Tsugaru Strait between the islands of Hokkaido and Honshu and the La Perouse (Soya) and Tartarsky (Mamiya) straits further north. Locations have multiple names because of the different languages in the region[67]. Ocean currents on the western side tend to be southward, creating an overall anticlockwise (cyclonic) surface circulation pattern. Deep waters are very cold because of severe winters that create dense, cold water that sinks. The Japan/East Sea has such varied oceanography that it has been referred to as a World Ocean in miniature.



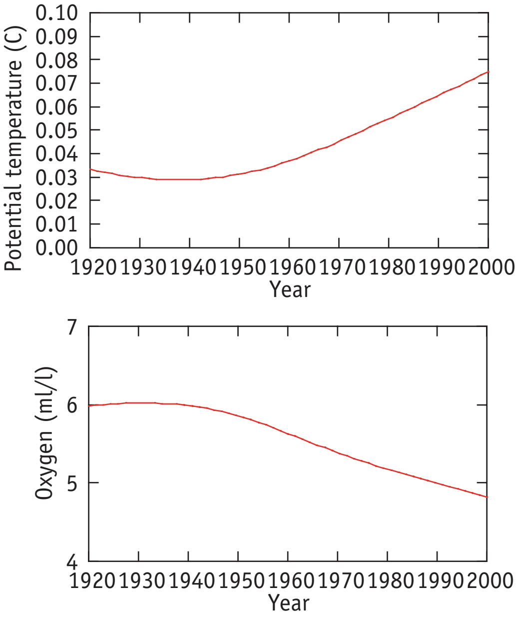
[Figure 45] Imagine slicing the Japan/East Sea along 132°E longitude and pulling apart the two halves (the southern end is on the right in each panel). These are the characteristics of temperature, salinity and dissolved oxygen that would have been seen in the summer of 1995. Red represents high values and purple/violet indicates low values; the scales for each measurement are indicated beneath the bottom panels; °C for temperature, psu for salinity and μmol per liter for oxygen. Note that it is significantly warmer at the surface than at the bottom, that the saltiest waters are at the surface in the south and that the highest dissolved oxygen is in the north. The dashed white line in the salinity panel indicates the presence of a salinity minimum at this depth; salinity is greater both above and below this depth[68].

# Status and Trends

## Hydrography

There is mounting evidence that the annual mean temperature of the mixed layer is increasing over large portions of the world ocean[69], although little is known about the long-term behaviour of subsurface temperature and salinity in most of the world ocean. The nature of changes in the physical state of the Japan/East Sea, as manifested in changes in temperature, is somewhat clearer. Good quality observations at all depths have been collected by the countries bordering the Japan/East Sea since the early 1900s, making the task of examining changes there somewhat more straightforward than for the global ocean.

Despite considerable variability, it is clear that temperatures in the deeper portions of the Japan/East Sea have been increasing nearly monotonically over sizable portions of the sea since the 1930s (Figure 46).[70,71] In some locations, this trend can be seen at depths as shallow as only 250m beneath the surface. In surface waters, the pattern is different. At least in the southern part of the Japan/East Sea, the decadal-scale SST patterns appear to correspond to the path followed by the Kuroshio. The timing of the sudden and persistent decline in SST in the region in 1963[72] corresponds to an equivalently sudden and persistent shoreward shift in the Kuroshio axis in 1963.[73] Likewise, the sudden and persistent upward shift in water density (sigma *t*) at Station 5 on the PM-line corresponds to a dramatic and persistent offshore shift in the Kuroshio axis in the same year. SST observations in Japan/East Sea are correlated with those observed in the East China Sea, which in turn is reflected in the path taken by the Kuroshio.[73]



[Figure 46] Trends in potential temperature and oxygen at 2500 m depth from 1930 to 1995 averaged over the Japan/East Sea.[74]

As salinity has been difficult to measure with sufficient accuracy, it is considerably more difficult, if not impossible, to discern trends from these data over similar timescales. Over the last century, air temperatures have been significantly warmer in winter and spring in the mid-latitude regions of the Japan/East Sea with the greatest rate of warming occurring in the cold season.[75]

In waters deeper than 2000 m there is considerably more evidence of a long-term warming, which appears to be highly correlated with a decrease in oxygen concentration in deep water.[76] The concentration of oxygen in the deep waters has decreased by more than 1 ml $l^{-1}$ since the 1930s and the deep potential temperature has increased by 0.5°C over the same period. Since the generally high values of dissolved oxygen in the deep waters of the Japan/East Sea result from wintertime convection along its western coast, a decrease in oxygen in the deep water (and the corresponding increase in potential temperature) would appear to indicate that the amount of deep convection in winter in the Japan/East Sea must be decreasing over time. Using a simple box model with contemporary measurements of temperature, salinity, dissolved oxygen, and CFCs (chlorofluorocarbons), it was found that by the mid 1990s, less than 1% of the surface area of the Japan/East Sea was subject to deep convection in wintertime,[77] although this value must have been much higher in the 1930s to account for the high dissolved oxygen in the deep water at that time.

The fact that dissolved oxygen is decreasing in the deep layers of the Japan/East Sea implies that insufficient new, dense, oxygenated water is being formed at the sea surface in winter to match the rate of biological utilization of oxygen in the deep water. If this is indeed the case, then one must inquire as to the reason for the decrease in wintertime convection. A number of hypotheses have been offered including:

- an increase in wintertime air temperature over the western region,
- a change in the paths of major atmospheric storms in winter,
- freshening of the surface waters,
- changes in the positions of large-scale atmospheric systems in winter over Siberia and the western subarctic Pacific, and
- changes in the nature of the Japan/East Sea due to increasing human populations around its borders.

Since it is now clear that there is a long-term trend of increasing temperature at all levels of the Japan/East Sea, it is imperative to begin to understand the cause of this change and the specific mechanisms that are driving it.

There is new *in situ* evidence that, at least in the winter of 2000-2001, deep convection occurred east of Vladivostok.[78,79] This was by far the best-documented case of wintertime convection and bottom water renewal. The results suggest that deep convection has not stopped altogether, however it is impossible to estimate the areal extent of the convective region or whether it is large enough to begin to replenish the dissolved oxygen in the deep water. Again, a simple model suggests that considerable deep convection must occur over many winters for the dissolved oxygen values to increase and the potential temperature to decease back to pre-1960 levels in the deep water. Whether or not this will occur is unknown, and only sustained, high quality observations of the physical processes at all depths of the Japan/East Sea in wintertime in the coming years will help to understand this problem.

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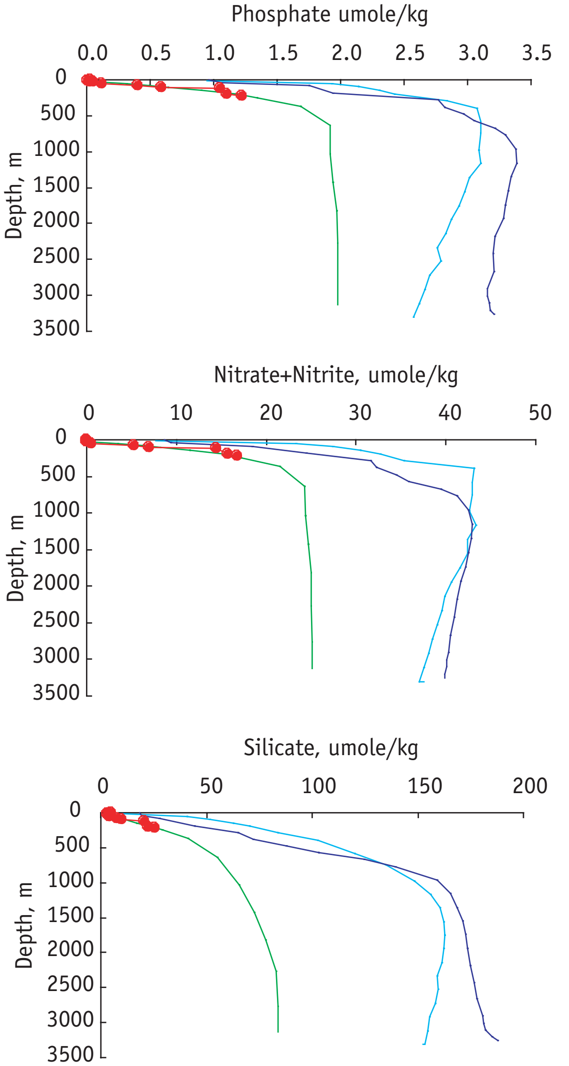
## Chemistry

The chemical properties of the Japan/East Sea have been measured for many years but both the methods and their accuracy have changed over the years, making historical data difficult to interpret. Recent measurements, however, indicate that the chemical properties of the Japan/East Sea are more similar to the chemical properties of than to other regions in the western the East China Sea subarctic Pacific (Figure 47).[80] The Tsushima Current, originating in the East China Sea, is a major source of water. The Japan/East Sea is exhibiting some of the classical signs of eutrophication, including increasing nutrient concentrations (perhaps from local rivers as well as the East China Sea) and reduced oxygen concentrations in deeper waters.[81]

Sampling along the PM line (a transect running in a northwesterly direction from Wakasa Bay in the southeastern Japan/East Sea) by the Maizuru Marine Observatory of JMA has revealed decadal-scale variation in the ecosystem. From 1982 to the early 1990s, surface mixed layer phosphate concentrations were high in winter and low in spring indicating that nutrient depletion occurred earlier than before or after this period. Water density profiles indicate that water column stability was stronger during these years, suggesting that nutrient supply to the surface waters was more restricted during this period.



[Figure 47] Concentrations of nutrients (phosphorus, nitrogen, and silicon) by depth in the East China Sea (🟥), Japan/East Sea (🟩), Okhotsk Sea (■), and Western Subarctic gyre (🟦)

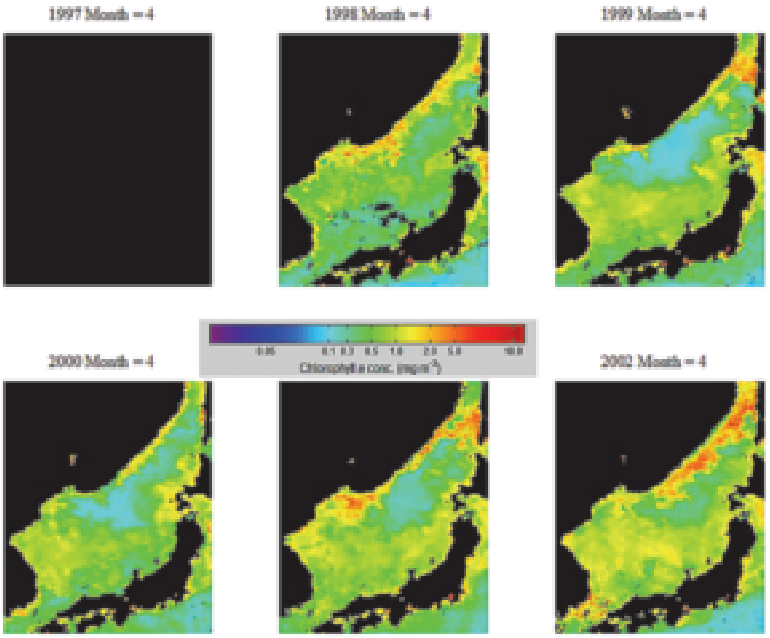
## Plankton

**Phytoplankton** The basis of most biological production begins with transformation of sunlight and nutrients by single celled phytoplankton. There is not enough sunlight to promote rapid plankton growth during the subarctic winter because strong winds over the ocean cause deep circulation of water that takes the phytoplankton cells away from the light. Only when the surface water temperatures warm in spring and vertical circulation is restricted to the surface layers, can phytoplankton grow and multiply. Because of their pigments (e.g. chlorophyll), the colour of the ocean changes with increasing abundance. Since 1978, it has been possible to estimate the amount of chlorophyll at the ocean surface with ocean-colour sensing satellites.

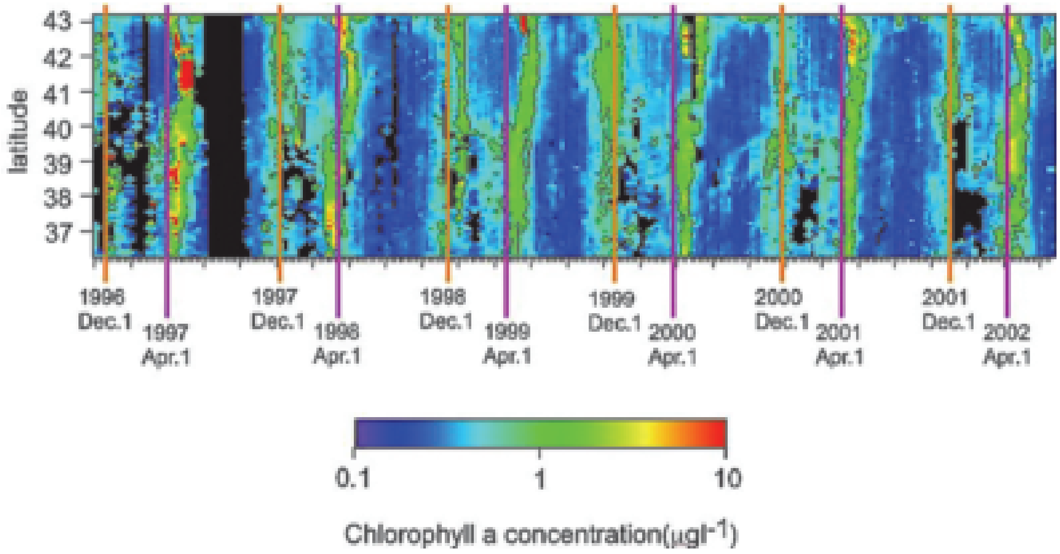
Various satellites with different sensors have been used over the years, often making it difficult to compare some results among sensors. Interference from clouds also limits the ability of satellites to measure chlorophyll, as does contamination by factors other than chlorophyll that can affect ocean colour.

Satellites cannot distinguish which species are responsible for the chlorophyll nor can they see beneath the surface. Nevertheless, some salient features of surface plankton growth are revealed. Comparing Aprils of 1998-2002, it is immediately apparent that there are both annual and spatial differences in chlorophyll distribution throughout the Japan/East Sea (Figure 48). At this time of year, there is a large region of chlorophyll minimum in the central northern part of the Japan/East Sea and this feature is conspicuous in all years. The southwestern coast of Sakhalin and the Primorye coast appear to have the highest chlorophyll concentrations in all years.

The timing of chlorophyll blooms at the ocean surface varies seasonally and annually (Figure 49). The Japan/East Sea has both spring and fall blooms that vary in timing and magnitude. The spring bloom begins in the south and progresses northward and its timing can vary by up to 1 month. The bloom also starts along the Russian coast of Primorye and moves seaward as spring progresses. Comparing chlorophyll concentrations with JMA meteorological buoy data indicated that stratification had developed by the onset of the spring bloom.



[Figure 48] Spatial patterns of surface chlorophyll (mg $m^{-3}$) in the Japan/East Sea in April, 2000 to 2002.[82]



[Figure 49] History of chlorophyll at the ocean surface along 134°33′ E longitude estimated by ocean colour sensors located on satellites. Vertical lines at regular dates are intended to emphasize differences in bloom timing among years and regions. Blooms occur in spring and fall, the spring bloom tends to be later north of 40°N. The larger peak in April 1997 could also be due to differences between sensors (OCTS and SeaWiFS). The scale ranges from violet to red (0.1-10 mg $m^{-3}$). Blackened areas indicate no data.[83]

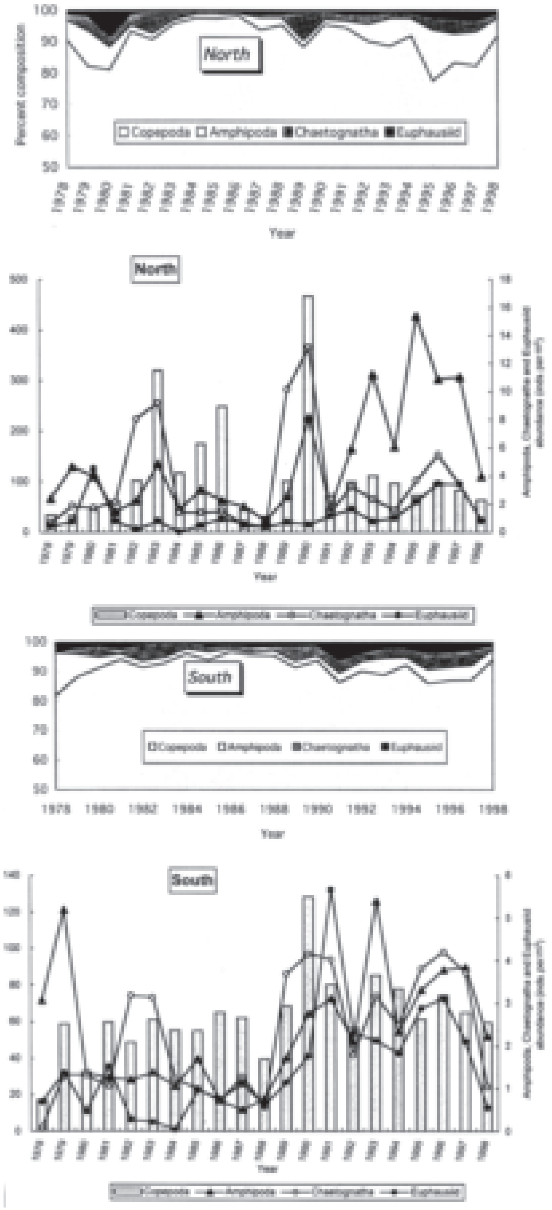
A particularly early spring bloom in 1998 occurred when winds were lower and insolation higher than in other years. The geographic pattern for the fall bloom is less regular but it occurs almost simultaneously from south to north. Melting sea ice in Mamiya (Tartar) Strait between Primorye and the west coast of Sakhalin is responsible for freshening the surface waters in the region. When combined with seasonal warming in spring, a less dense surface layer increases water column stability and allows for the development of the spring bloom in that area.

Over the short period of record described here, there is no apparent trend. Longer timeseries are available but attempts to interpret these properly are challenged because of difficulties with the precision and accuracy of colour sensors and their intercalibration.

**Zooplankton** Warm water species are present in areas of the Japan/East Sea that are under the influence of the Tsushima Current that enters from the East China Sea between Korea and Japan. Subarctic species inhabit the northern part of the Japan/East Sea where subarctic-origin water dominates. So the Japan/East Sea includes a mixture of warm and coldwater species. Extensive Japanese sampling by vertical net hauls from 150m to the surface from 1966-1990 indicated that the average biomass in the coastal areas had minimum values in daytime sampling in winter (< 50 mg $m^{-3}$) and peaked in June (125 mg $m^{-3}$).[84] In the offshore, the mean biomass was greatest in April (day/night: 72/147 mg $m^{-3}$) and lowest in winter. Day/night differences were greatest in 1976/77 and 1983/84. The highest annual mean values were associated with areas north of the Polar Front. The dynamics of the warm Tsushima Current at the surface and the cold subsurface region play important roles in determining yearly community structure and biomass.[85]

The general shift to a warmer regime (SSTs and winter air temperatures) during the late 1980s occurred at the same time as a significant increase in zooplankton abundance along the Korean peninsula (Figure 50). The response was most notable in an increased relative abundance of amphipods and euphausiids after the shift.[87] This was also a period of significant increases in common squid (*Todarodes pacificus*) abundance.[86]

Although the colder regions of the Japan/East Sea are characterized by higher zooplankton concentrations, there is also lower species diversity. The small and medium size fractions, largely copepods and younger stages of larger species, are food for larger zooplankton and fish larvae. The larger fractions include large copepods, hyperiids, euphausiids and chaetognaths. The latter are the main zooplankton predators.

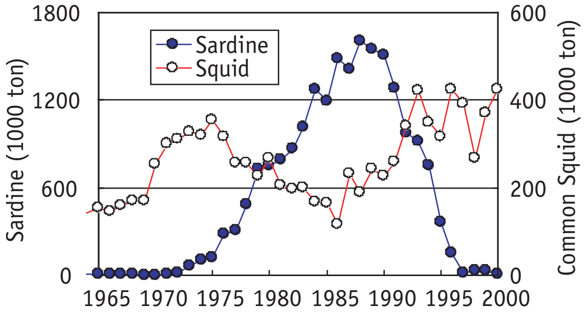


[Figure 50] Longterm changes in percent composition and abundance of four major zooplankton groups in the northern and southern region of the Japan/East Sea.[87]

## Fish and Invertebrates

Common squid (*Todarodes pacificus*), Japanese sardine (*Sardinops melanostictus*), chub mackerel (*Scomber japonicus*), horse mackerel (*Trachurus japonicus*), anchovy (*Engraulis japonicus*), filefish (*Navodon modestus*), and walleye pollock (*Theragra chalcogramma*) are major targets for commercial fisheries in the Japan/East Sea, depending upon their abundance. Common squid and the Japanese sardine have been the most important target species, so they have been the focus of many life history and stock assessment studies over many years (Figure 51).

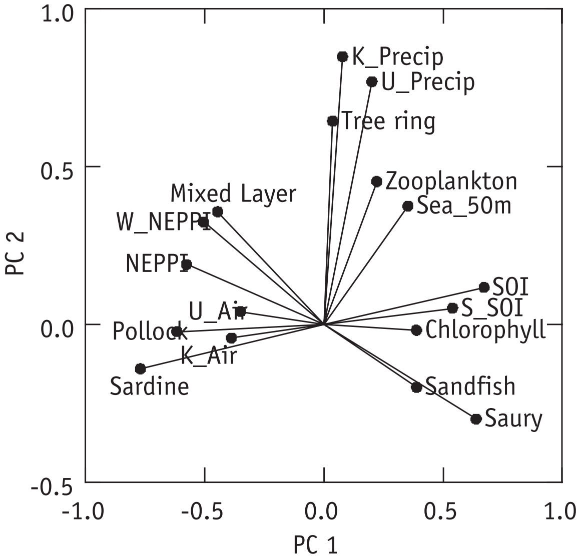
Japanese sardine occur throughout the Japan/East Sea when they are abundant. Spawning grounds exist along most of the western shore of Honshu and the fishing grounds are along all coastal margins. Fishing in the north is seasonal, taking place primarily during the summer and fall, whereas fishing in the south occurs year-round. The abundance of sardines has fluctuated dramatically in the past and is currently at very low levels.



[Figure 51] Total catch of common squid by Japan and Korea and Japanese sardine by Japan.

Common squid are particularly abundant around the main Japanese Islands, in both warm and cold waters. The migration routes and spawning areas of common squid in the Japan/East Sea vary with abundance. In autumn, common squid usually undergo a southward spawning migration. In the 1970s, adult squid usually migrated westward along the northern edge of the sub-arctic front to an area east of Korea, and then migrated southward to spawn in the East China Sea. But in the 1980s, adult squid often migrated southward to the coast of Honshu Island, crossing the sub-arctic front. In the 1990s the migration route returned to the pattern observed in the 1970s.

The main countries fishing for squid in the Japan/East Sea are Japan, North Korea and South Korea. Assuming that catches are correlated with abundance, it appears that common squid abundance is maintaining a relatively high level and there is some indication of an inverse abundance relationship between common squid and sardine.



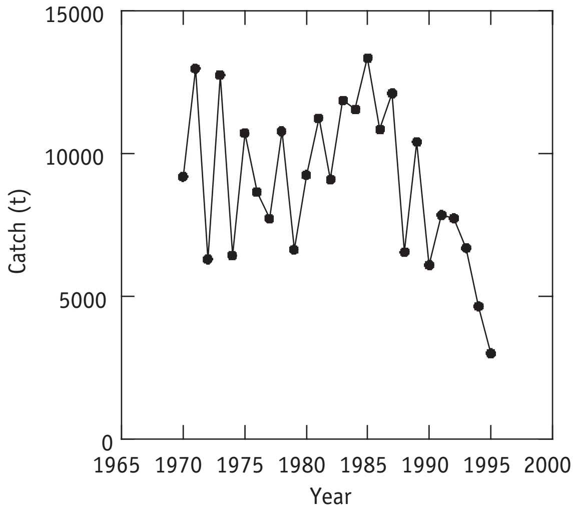
[Figure 52] Principal component ordination of correlations between fish catches and ocean/climate variables in Korean waters from 1960-1990. NEPPI (annual North East Pacific atmospheric pressure index), W_NEPPI (winter only), SOI (annual Southern Oscillation Index), S_SOI (spring only), U_Precip and U_Air (spring precipitation and air temperature at Ulleung Island), K_Precip and K_Air (spring precipitation and air temperature at Kangrung on the east coast of Korea), Mixed Layer (depth of the mixed layer), Zooplankton (NORPAC vertical hauls from 100m), Chlorophyll (estimated from Secchi depth), Tree ring (red pine tree ring widths) and catches of different species.

Correlation studies have found that Pacific saury and sandfish catches occurred during periods when the Southern Oscillation Index was generally positive (La Niña conditions), when spring chlorophyll in the Japan/East Sea was high, and when the air temperatures were cooler, the mixed layer depth more shallow, when the Northeast Pacific Pressure Index was low, and when catches of Pacific saury and walleye pollock were low (Figure 52). The tree ring growth data were related to spring precipitation and to a lesser extent with zooplankton biomass and sea surface temperature, but were largely independent of catches of the four fish species.[88]

In the Russian zone, chub mackerel were known to appear as far north as the coast of Primorye at the beginning of 1920s but annual catches did not exceed 25 t. In the 1930s larger catches indicated that the species was present in greater numbers. Increased abundance during the 1940s allowed a specialized fishery to operate. Catches steadily increased until 1951 when catches exceeded more than 10,000 t in Primorye. However at the end of the 1950s, chub mackerel catches decreased and the fishery became unprofitable. Strong year-classes at the beginning of the 1990s were reflected in sharp in short-term increases of mackerel catch near the coast of the Korean peninsula and the appearance of mackerel eggs in the more northern part of its range in 1996.

Japanese anchovy appeared in Primorye waters at the beginning of the 1920s, but fishing was limited to incidental catches of about 200-300 kg per day. Systematic catch data have been collected in Russia since 1944 as fisheries reacted to an earlier collapse of the sardine population. In the 1960s anchovy catches reached 16.8 t annually. During this period, anchovy were spawning in southern Primorye but from the middle of the 1970s, the abundance of anchovy in the Russian zone declined. In the 1990s, anchovy were the first species that reacted to changes in nekton. One to two year old anchovy accounted for 30% of the bycatch during sardine expeditions in the open waters of the Russian 200-mile zone in 1989. The high level of anchovy stocks and active spawning in northern regions has placed anchovy in the leading role in ichthyoplankton surveys of the Japan/East Sea during the last years.

Hokkaido-Sakhalin herring were once very abundant. A peak catch of 972 thousand t occurred in 1897. Catches gradually declined and by the 1950s herring were no longer spawning in the region. Konoshiro gizzard shad (*Konosirus punctatus*) were rare in Russian waters until 1996, but since then the spawning of gizzard chard has been increasing in the coastal waters of the northwest part of the region. Eggs and larvae of this species and anchovy were numerous and in some years it practically dominated in ichthyoplankton samples.

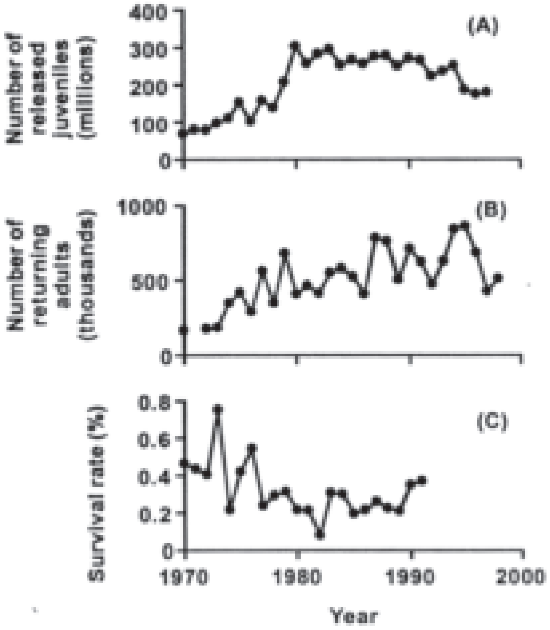


[Figure 53] Total catch of pink salmon in the Japan/East Sea by Japan, South Korea and Russia.[89]

Japanese fisheries harvest Pacific salmon in the Japan/East Sea, while Russian fisheries operate in rivers. Pink salmon (*Oncorhynchus gorbuscha*) are the most abundant species of Pacific salmon in the Japan/East Sea. Unlike chum salmon (*O. keta*) they remain in the area and become vulnerable to its fisheries. Masu salmon (*O. masou*) are also resident in the Japan/East Sea but in far fewer numbers. Catches of pink salmon declined during the early part of the 1990s (Figure 53). Long time series of historical catches in Russia indicate that pink salmon catches were higher during first half of the 20th century than in the latter half.[89] Pink salmon catches in North Korea showed a similar pattern to catches in Alaskan waters, though the two stocks were geographically separated: high catches in 1930s and 40s, low during 1950s through mid-1970s, and high again since the late 1970s.

Chum salmon (*O. keta*) are released in large numbers from Japanese hatcheries located as far south as Ishikawa Prefecture (~36.5°N). The number released in recent years is of the order of 200 million fry (Figure 54).[90] The mean fry-to-adult survival for these fish (0.32%) is about one tenth that of chum salmon released from hatcheries in Hokkaido and lower than that found on the Pacific side of Honshu.

It appears that the years of best survival occurred before the 1976/77 regime shift. Chum salmon survival was negatively correlated with SST in May off Fukura (~39°N) in Yamagata Prefecture. In Korean waters, chum salmon propagation started in the mid-1980s. Around 15 million salmon fry were released annually in recent years. The returning rate, however, was lower than that of Hokkaido salmon. The survival seems to be related to the seawater temperature in spring when they enter the sea from the hatchery. Catches of masu salmon (*O. masou*) in Japan have declined since 1973. Prior to 1973, they were included in catches of pink salmon.



[Figure 54] Annual numbers of juvenile chum salmon released from hatcheries in Honshu, the numbers of adults returning and their survival[90]

The status of invertebrate fisheries in the Japan/East Sea was a subject of consideration by PICES Working Group 12.[91] As the status of fisheries for various species differed among areas, each is reported separately. For most species, the long-term trend in abundance is either declining or unknown and the fisheries for these species are fully developed.

[Table 9] Status of Invertebrate fisheries in the Japan/East Sea

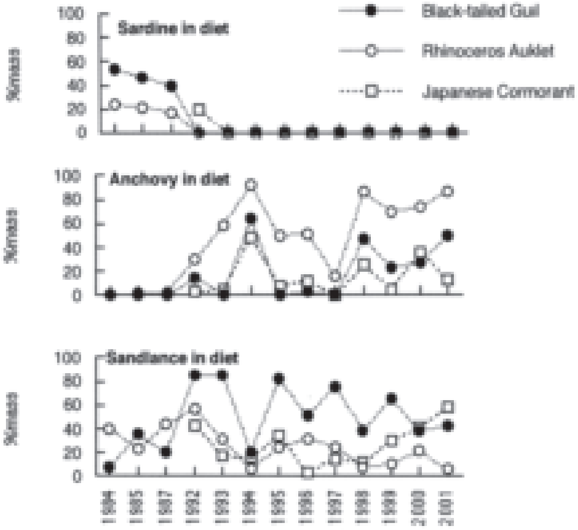
| Area | History[1] | Now[1] | Trend[2] | Status[3] |
|---|---|---|---|---|
| **Snow crab** (*Chionocoetes opilio*) | | | | |
| | L | M | D | F |
| **Benizuwai Tanner crab** (*C. japonicus)* | | | | |
| East JES | L? | M? | ? | F? |
| West JES | L | L | ? | D |
| **Hair crab** (*Erimacrus isenbaeckii*) | | | | |
| East JES | M | L | ? | F |
| West JES | M | M | ? | F |
| West SakHalin | M | S | ? | F |
| Korea | M | S | D | F |
| **Red King crab** (*Paralithodes camtschaticus*) | | | | |
| West Sakhalin | S/M | S | D | F |
| **Blue King crab** (*P. platypus*) | | | | |
| West JES | S | S | D | F |
| West Sakhalin | S | S | D | F |
| **Golden King crab** (*Lithodes asquispinus*) | | | | |
| West Sakhalin | M | S | ? | F |
| **Northern shrimp** (*Pandalus borealis/eos*) | | | | |
| West Sakhalin | M | M | ? | F |
| **Humpy shrimp** (*P. goniurus*) | | | | |
| South Sakhalin | S/M | S | ? | U/D |
| **Hokkai shrimp** (*P. latirostris*) | | | | |
| South Sakhalin | M | S/M | P | D/F |
| West JES | M | M | P | D |

1. Abundance (relative to historical): L= Large, M= Medium, S= Small, ?= Unknown
2. Longterm Trend: D= Declining, P= Periodic fluctuations, ?= unknown
3. Fishery status: F= Fully developed, D= Developing, U= Undeveloped.

## Marine Birds and Mammals

**Seabirds** Studies of seabirds populations on Teuri Island (Hokkaido) have been conducted since 1984. The diets of black-tailed gull (*Larus crassirostris*), rhinoceros auklet (*Cerorhinca moncerata*) have been conducted since 1984 and Japanese cormorant (*Phalacrocorax capillatus*) since 1992. Gulls and auklets foraged on Japanese sardine when they were abundant during the 1980s. The diets changed abruptly with collapse of the Japanese sardine population in the early 1990s.

The rising abundance of anchovy in 1992 was reflected in the seabird diets, particularly that of the rhinoceros auklet. Black-tailed gulls initially switched from sardine to sandlance, although with increasing fractions of anchovy beginning in 1998. The role of the Tsushima Current on seabird diets is an active area of investigation.



[Figure 55] Year to year changes in diet composition of seabirds breeding on Teuri Island (Hokkaido). Modified from Deguchi, Watanuki, Niiguchi and Nakata (2004). Interannual variations of the occurrence of epipelagic fish in the diets of the seabirds breeding on Teuri Island, northern Hokkaido, Japan. Progress in Oceanography 61 (2-4), 267-275.

Slaty-backed gull (*L. schistisagus*), black-tailed gulls and Japanese cormorant were observed in the Syokanbetsu River (Hokkaido) estuary eating juvenile chum salmon (*O. keta*) in April 1999 after the fry were released from the hatchery. The increased abundance of gulls in the estuary during this period was dramatic.[92]

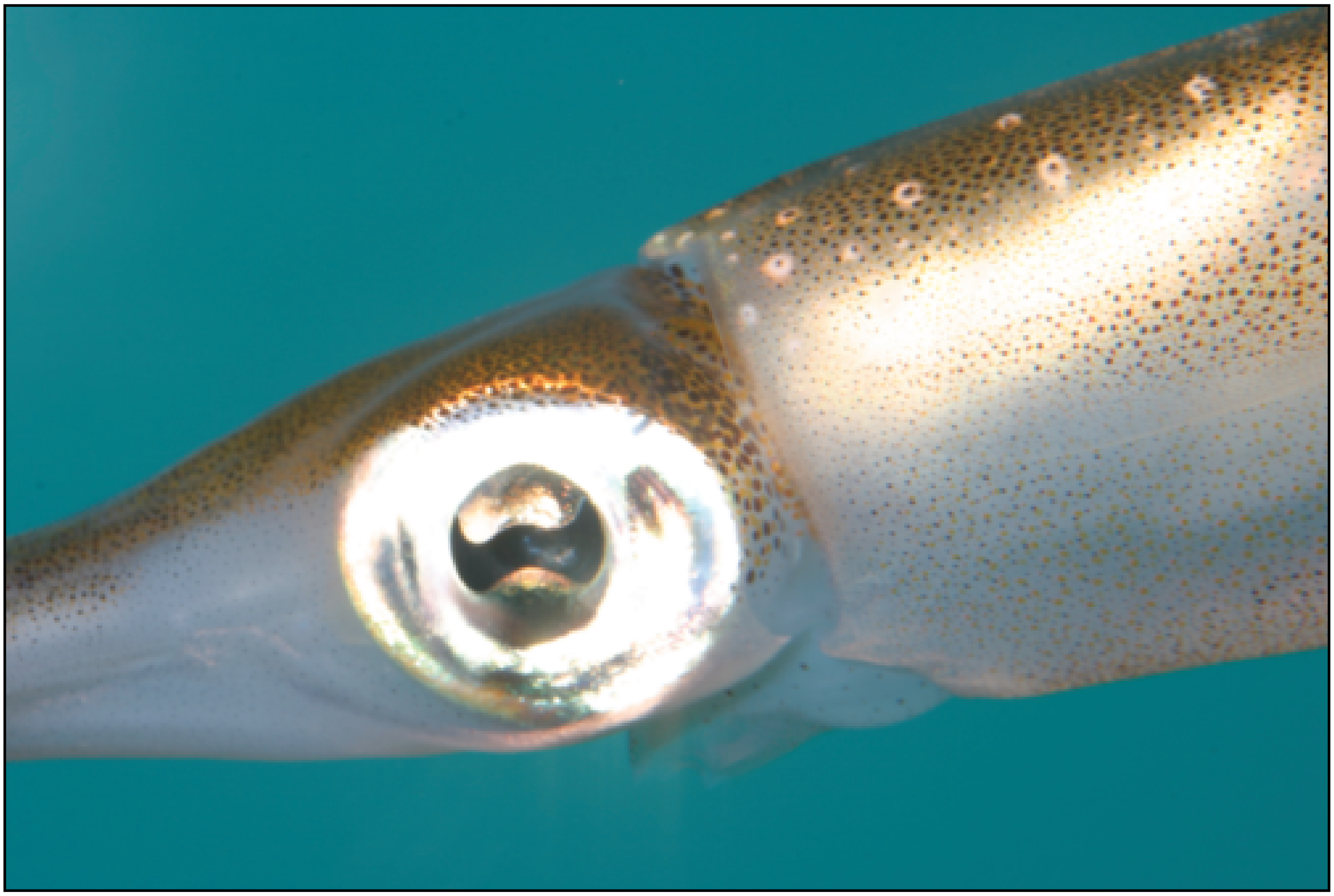
Pinnipeds Largha seals (*Phoca largha*) aggregate in Peter the Great Bay (Primorye, Russia) to mate and to molt. Early records of largha seal catches suggest that its abundance in Peter the Great Bay in the 19th century may have been as high as several thousand, decreasing considerably by the 1930s[93]. The local population size was recently estimated to be about 1,000 individuals with further growth limited by incidental take in the trap net fishery.

**Cetaceans** No data specific to the Japan/East Sea were presented.

# critical factors causing change

Strong winter winds associated with cold-air outbreaks from Siberia cause large-scale changes at the ocean surface which have significant effects on the Japan/East Sea. The winter of 2000/2001 was anomalously harsh in this regard.

There has been a large increase in fishing effort in the Republic of Korea[94].



# issues

Better models are required to investigate forcing mechanisms. There is an urgent need to maintain observations, as several scientific programmes in the region are ending.

The physical processes that are responsible for stratifying the water column are the most critical for primary biological production in the Japan/East Sea. The strength and timing can be monitored by satellite using ocean colour data, and with careful calibration of new data and recalibration of archival data, it may be possible to make better use of historical satellite observations.

How is stratification controlled? To determine this there is a need for monitoring programs in the Japan/East Sea, particularly now that the JMA buoy has been terminated.

Satellites cannot sense subsurface chlorophyll so it is important to understand the dynamics of the subsurface chlorophyll maximum to determine its role in important primary production in the Japan/East Sea? How is the physiological parameter of primary production controlled?

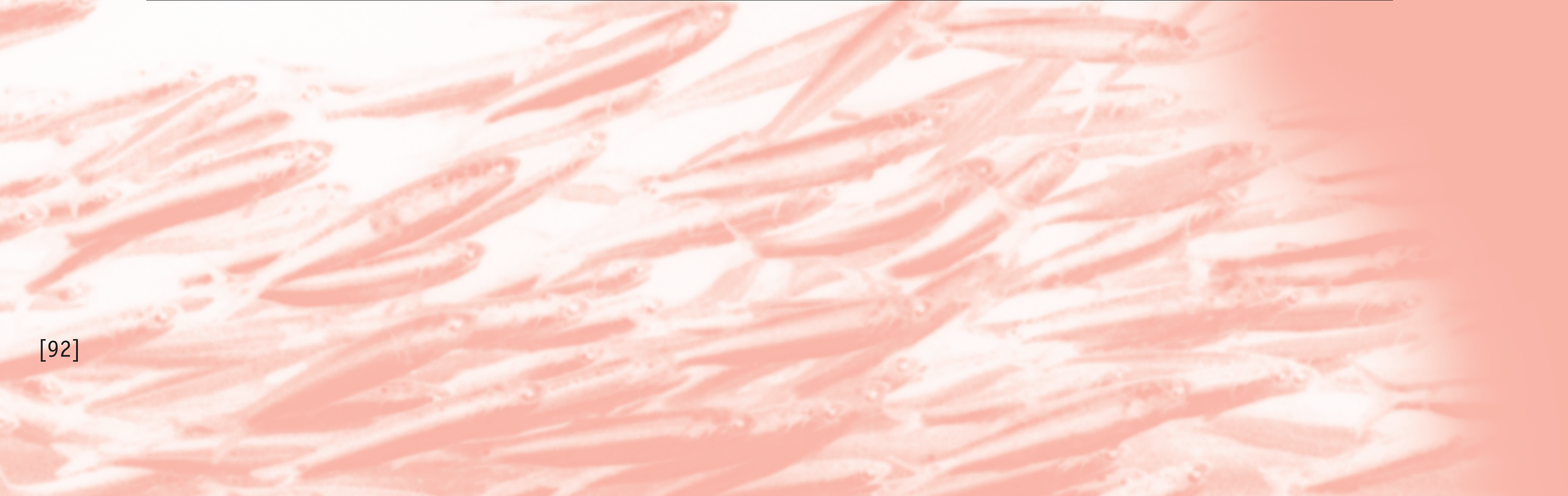
Can satellites accurately estimate magnitude of primary production during short blooms. There is a need for *in situ* optical monitoring from buoys.

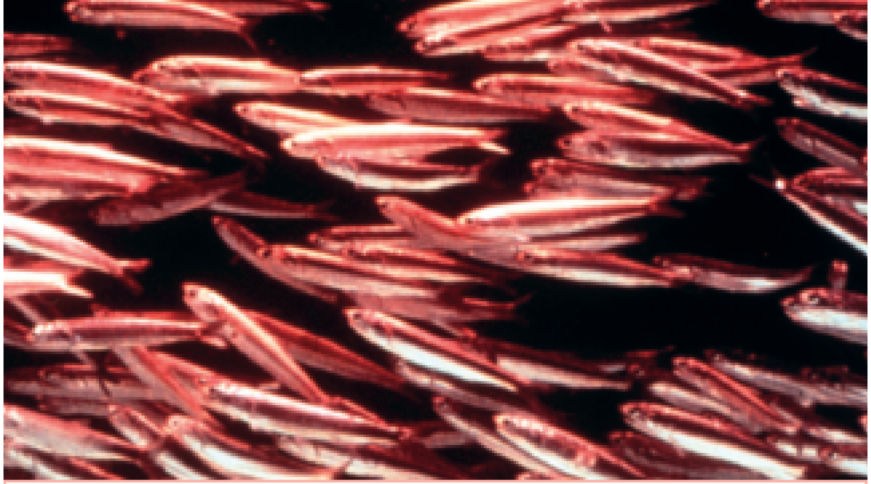
How is the lower trophic level foodweb in the Japan/East Sea structured? To begin to answer this, there is a need for size-fraction data and information on functional groups.

The long-term study was based on small datasets (3 stations, 4 times $y^{-1}$ ). Extensive monitoring program is needed including satellite observation and minimum of one station in the north and one in the south.

Long time series of zooplankton samples from 150 m to the surface may not adequately represent long-term trends because of the deep diel migrations of some of the dominant species.

The frequency of red tides and ichthyotoxin incidents in the Japan/East Sea is increasing. In fact, during the CREAMS/PICES 2002 workshop in Seoul, one of the largest outbreaks of the fish-killing alga, *Cochlodinium polykrikoides*, occurred of southern and eastern Korea and resulted in huge losses of farmed fishes. Outbreaks of this and closely related species seem to be predominantly problems in Korea (where it is the main source of severe losses).[95]





## Contributors

Much of the information contained in this chapter was presented at the CREAMS/PICES Symposium on *Recent Progress in Studies of Physical and Chemical Processes in the East/Japan Sea and their Impact to its Ecosystem* held 22-24 August, 2002 at Seoul National University in Seoul, Korea. In 2004, a special issue of *Progress in Oceanography* Volume 61(2-4) was published containing some of the work presented there.

**Sanae Chiba**
Frontier Research System for Global Change, Yokohama, Japan
**Svetlana Davidova**
TINRO-Center, Vladivostok, Russia
**Natalia Dolganova**
TINRO-Center, Vladivostok, Russia
**Naoki Iguchi**
Japan Sea National Fisheries Research Institute, Niigata, Japan
**Joji Ishizaka**
Nagasaki University, Nagasaki, Japan
**Young-Shil Kang**
East Sea Fisheries Research Institute, Busan, Korea
**Hideaki Kidokoro**
Japan Sea National Research Institute, Niigata, Japan
**Suam Kim**
Pukyong National University, Busan, Korea
**Skip McKinnell**
PICES Secretariat, Victoria, Canada
**Steven Riser**
University of Washington, Seattle, USA
**Yasunori Sakurai**
Hokkaido University, Hakodate, Japan
**Pavel Tischenko**
Pacific Oceanological Institute, Vladivostok, Russia
**Alexei Trukhin**
Pacific Oceanological Institute, Vladivostok, Russia
**Yutaka Watanuki**
Hokkaido University, Sapporo, Japan
**Sinjae Yoo**
KORDI, Ansan, Korea
**Chang-Ik Zhang**
Pukyong National University, Busan, Korea