PICES XIII S9-1900 Oral
Comparison of synchronous ecological regime shifts in the Humboldt and Kuroshio Currents

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The low frequency dynamics of the Humboldt Current ecosystem are controlled by shifts between alternating sardine and anchovy regimes that involve restructuring of the entire ecosystem. These regime shifts are related to lasting periods of warm or cold water anomalies resulting from the approach or retreat of warm subtropical oceanic waters to the coasts of Peru and Chile. Phases with mainly negative temperature anomalies parallel anchovy regimes (1950s-1970; 1985-up to now) and the rather warm period from 1970-1985 was characterised by sardine dominance. The transition periods (turning points) from one regime to the other were 1968-1970 and 1984-1986. Similarly, the Kuroshio ecosystem (including adjacent waters east of Japan) is characterized by alternating periods of dominance of sardines or anchovies, with transition periods that have been strikingly synchronous to those of their Humboldt congeners. Japanese anchovy catches started to go down in the late 1960s/early 1970s and sardine catches began their increase in 1971 after a period of extremely low catches since 1958. Dynamics of both species reversed again in the second half of the 1980s. In contrast to the Humboldt populations, Japanese sardines thrived during cold and anchovies during warm periods. Interestingly, the mixed layer depth of the Kuroshio extension shifted in the late 1960s from shallow to deep and in 1985 from deep to shallow, almost exactly at the time of the regime shifts in the Humboldt Current. This contribution will describe the ecological regime shifts in the two Pacific ecosystems and discuss commonalities, differences and possible teleconnection patterns.

PICES XIII S9-1856 Poster
Distribution and concentration of ichthyoplankton off the Oregon coast in 2000 and 2002

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The species composition, distribution, and concentration of ichthyoplankton off the central Oregon coast in the Northeast Pacific Ocean were examined in 2000 and 2002 to investigate annual, seasonal, vertical, and cross-shelf variability. Larval concentrations were also analyzed in relation to water temperature and salinity. The 281 samples collected between April and September of the two study years yielded 4944 fish larvae comprising 72 taxa in 30 families. The most abundant taxa collected were: *Sebastes spp.*, *Stenobrachius leucopsarus*, *Engraulis mordax*, *Lyopsetta exilis*, and *Tarletonbeania crenularis*. Total larval density increased from 49.3/1000 m^3 in 2000 to 72.0/1000 m^3 in 2002, with seasonal concentrations highest in August 2000 (90.3/1000 m^3) and April 2002 (151.2/1000 m^3). Relatively few larvae were found at depths >100 m, while highest larval densities generally occurred from 10-50 m. However, *E. mordax* larvae were most often found in the upper 10 m of the water column, while *L. exilis* concentrations were highest from 50-100 m. Larval diversity and concentration were higher offshore (40-72 km) than onshore (8-24 km). Highest concentrations were normally found at an intermediate station 56 km off the coast. Species designated as either on or offshore species by previous studies where predominantly found in their respective coastal regions, except for *Clupea pallasi* larvae (an onshore species) which were taken exclusively at offshore stations. With the exception of *L. exilis*, larval densities were positively correlated with temperature and negatively correlated with salinity ($P<0.0001$).

PICES XIII S9-1936 Poster

Comparing macroparasites of juvenile salmon and associated fish collected off the coast of Oregon and northern California

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Macroparasites indicate a history of host diet due to the complex life cycles of the parasites and their relatively long life within vertebrate hosts. We examined macroparasites to better understand the trophic interactions between juvenile salmon, their prey and other pelagic nekton in the California Current System. Coho salmon (*Oncorhynchus kisutch*), chinook salmon (*O. tshawytscha*), jackmackerel (*Trachurus symmetricus*), Pacific herring (*Clupea pallasii*), Pacific sardine (*Sardinops sagax*), surf smelt (*Hypomeses pretiosus*), and whitebait smelt (*Allosmerus elongates*) were the dominant fish sampled by surface trawls offshore of Oregon and northern California in June and August of 2000 and 2002. Salmon had the highest macroparasite species richness (12 in 2000, and 17 in 2002). For the other fish species, macroparasite species richness ranged from 1 to 4 in both years suggesting higher prey selectivity than salmon. Two nematode species were found in all fish species and an acanthocephalan species was shared between three fish species (jackmackerel, coho salmon and chinook salmon). Trematodes may be more host specific, than nematodes or acanthocephalans, since they were only found in one host species or in phylogenetically related hosts. Seven macroparasite species were common in all sampling periods and 8 were rare. The prevalences of common macroparasites indicated varying abundances of prey and definitive hosts (*e.g.* marine birds and mammals), or a combination thereof. These observations suggest seasonal and interannual differences in ocean conditions such as temperature or upwelling events.

PICES XIII S9-1986 Oral

Upwelling-driven inner-shelf hypoxia and its connection to oceanographic changes in the Northeast Pacific

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In summer 2002, we observed the unprecedented development of severe inner-shelf (<70 m) hypoxia and resultant mass die-offs of fish and invertebrates within the northern California Current System. Severe inner-shelf hypoxia was detected during coastal oceanographic cruises along the 44.00ºN to 44.65ºN portion of the California Current System. Between July and September 2002, bottom dissolved-oxygen concentrations of 0.21–1.57 ml l^{-1} were found to extend from the shelf break to nearshore stations (700 m offshore). At the observed height of hypoxia, dissolved-oxygen-deficient bottom waters occupied up to 40 m of the water column and covered at least 820 km^2 of shelf area inshore of the 70-m isobath. In 2002, water upwelled into the euphotic zone over the shelf from a depth of ~100 m offshore was 1ºC colder and nitrate concentrations were elevated by 11.6 µM (or 64%) over past years. As a result, standing stocks of phytoplankton were two to three times higher than those observed in the four preceding years. So although source waters for the near-bottom water over the shelf were low in oxygen (1.27–1.67 ml l^{-1}) during 2002, further depletion of oxygen occurred as a result of respiration of downward fluxed carbon. Data on sea-surface height, drifter tracks and mid-shelf currents suggest an anomalous invasion of nutrient-rich, subarctic water into the California Current, forced by large-scale wind stress anomalies over the northeast Pacific. Data from 2001 and 2003-2004 suggest that summertime hypoxic bottom waters were present during more than just one year.

PICES XIII S9-1931 Oral

U.S. GLOBEC: Significant findings of climate variability impacts on marine ecosystems in the Northeast Pacific

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The U.S. GLOBEC program in the Northeast Pacific (NEP) began in 1997 with initial modeling, retrospective and long-term observation programs (LTOPs) of the Coastal Gulf of Alaska (CGOA) and northern California Current (CCS) regions. Subsequently, each region has been studied intensively, using multiple survey, process and trawling vessels, in each of two years: 2000 and 2002 for the CCS and 2001 and 2003 for the CGOA. LTOPs in the two regions have continued with sampling 5-7 times per year for 6-7 years. The GLOBEC NEP research program is structured to address three core scientific hypotheses: (1) Production regimes in the CGOA and CCS covary, and are coupled through atmospheric and ocean forcing, (2) Spatial and temporal variability in mesoscale circulation constitutes the dominant physical forcing on zooplankton biomass, production, distribution, species interactions, and retention and loss in coastal regions, and (3) Ocean survival of salmon is primarily determined by survival of the juveniles in coastal regions, and is affected by interannual and interdecadal changes in physical forcing and by changes in ecosystem food web dynamics. The GLOBEC NEP program was fortunate to sample during a period of strong signals in the ocean and atmosphere, including a 1997-98 El Niño, a 1999 La Niña, and a more persistent (regime?) shift to a different climate and ecosystem. A few results from the GLOBEC NEP program that address these hypotheses will be presented, specifically highlighting the large-scale atmospheric forcing of 2001-2002, that had significant impacts on local ecosystems in the CCS, flow-topography interactions that impact productivity and trophic patterning, and the role of mesoscale eddies in structuring coastal marine ecosystems. The legacy of the NEP program will be four-fold: (1) improved knowledge of climate variability impacts on marine ecosystems, (2) better coupled biophysical models, (3) extensive data sets that will provide a basis for future research and guidance to future monitoring programs, and (4) an improved basis for resource management.

PICES XIII S9-2014 Oral

Comparison of the effects of the 1976-77 North Pacific climate shift on the California and Japanese sardine habitats

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We compare the effects of the 1976-77 climate shift on the regional dynamics of the Kuroshio-Oyashio system and the California Current system that led to increased reproductive success for both the Japanese (*Sardinops melanostictus*) and the California sardine (*Sardinops sagax caeruleus)*. Spawning grounds of the Japanese sardine expanded eastward in the late 1970s and 1980s, from coastal waters around Japan, into the oceanic waters of the Kuroshio Current. Favorable spawning conditions for the California sardine expanded northward from more coastal waters south of 34°N latitude and shifted offshore off central and northern California. Important differences were the rapid build-up of the Japanese population compared to the slower recovery off California, and the dramatic decline of the Japanese sardine in the late 1980s and early 1990s during which the California sardine continued to maintain its increased population size. We use an ocean circulation model (OPYC) to investigate simultaneous regional changes in the eastern and western North Pacific through equilibrium runs in which the atmospheric forcing included differences in basin-wide wind stress, wind stress curl, surface heat flux, and turbulent kinetic energy averaged over the 6-year periods prior to and after the 1976-77 shift. The model results reveal fundamental changes in regional circulation that provide important insights into the relationship between the changes in ocean conditions and reproductive success of the two populations. These changes created increased seasonal availability of favorable spawning habitat as well as improved conditions for adult feeding and enhancement of survival of recruits.

PICES XIII S9-2084 Poster
On the origin and evolution of a "minty" water mass anomaly in the Northeast Pacific

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A highly unusual water mass characterized by cool, fresh ("minty") anomalies was observed at several locations within the California Current System in summer 2002. This feature was also characterized by elevated nutrient levels which supported higher primary production, but which also led to increased water column and benthic respiration and ultimately to a severe hypoxic event on the Oregon continental shelf. We use satellite and in situ measurements to describe the conditions and processes that led to the development of this anomalous water mass, and to report on its evolution and current status from a basin- and climate-scale perspective. A large-scale shift in upper-ocean conditions and circulation, away from a positive-PDO phase, occurred following the 1997-98 El Niño event. Broad changes in the gyre-scale circulation in the Northeast Pacific appear to have led to an increased flux of subarctic waters into the California Current as well as an increased equatorward transport within the California Current. We examine the historical observational record to identify periods with similar forcing conditions and/or water mass anomalies. If this minty water mass results from an ongoing process within a new climate regime, the prospects of a more productive California Current ecosystem will continue, as will the possibility of further hypoxic events.

PICES XIII S9-1872 Poster
Interannual and interdecadal variability in juvenile salmon diets in relation to environmental changes in the Northern California Current

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The feeding habits of juvenile coho (*Oncorhynchus kisutch*) and chinook salmon (*O. tshawytscha*) were examined based upon sampling during two different time periods (1980-1985 and 1998-2003) of highly contrasting oceanographic conditions in order to determine environmental effects on interannual or interdecadal changes in taxonomic composition of prey, feeding intensity, or prey size spectra. Fish prey dominated coho and chinook diets by weight during most years, but this was more pronounced during the earlier sampling period. In terms of numerical composition, the diets were more variable on an interannual basis but decapod larvae were important prey most years for coho salmon and either decapods or fishes were important for chinook salmon. Pteropods and copepods were important prey during weak upwelling or El Niño years whereas euphausiids were important during strong upwelling or otherwise highly productive years. Hyperiid amphipods comprised a substantial proportion of the diets of both species only in 2000. Both an index of feeding intensity and prey/predator size ratios for fish prey were highly variable by year but larger than average fish prey were consumed during 1998, leading to the highest feeding intensity observed. These results will be discussed relative to trends in prey availability and early ocean survival of these two species. The highly opportunistic feeding mode of juvenile salmon allows them to be potential indicators of long-term ocean variability.

PICES XIII S9-1807 Oral
Did regime shift occur in the East China Sea?

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Since the 1990s, the regime shift of marine ecosystem has become one of the hot spots in fisheries oceanography. Most studies have focused on subarctic and temperate waters such as the Bering Sea, Oyashio, California and Kuroshio currents in the North Pacific. The regime shifts have been proved to exist in these areas. We ask the question, "Do regime shifts occur in subtropical waters such as the East China Sea (ECS)?" We have investigated the long-term change in the ECS in terms of climatic, hydrological, biological, and fisheries factors and found that regime shifts did occur in the ECS. Sea surface temperature (SST) in the ECS appears to have shifted twice: from warm to cool regime in 1940 and from cool to warm regime in 1992. Japanese sardine (*Sardinops melanostictus*) and Japanese anchovy (*Engraulis japonicus*) have had completely opposite biomass trends since 1960. Sardine shifted from low to high biomass in 1978 and back to a low level in 1998. Anchovy shifted from high to low level in 1978 then shifted to high level in 1998. Jack mackerel (*Trachurus japonicus*) and Japanese anchovy shared the same pattern of biomass trends however mackerel seem to have responded to the regime shift earlier than anchovy. Regime shift of the three fishes are strongly affected by East Asian Summer Monsoon and Pacific Decadal Oscillation. Moreover sardine is closely related to Aleutian Low Pressure Index (ALPI), Siberian-Alaskan Index and North Pacific Index too. Anchovy is closely related to ALPI and extratropical-based North Oscillation Index.

PICES XIII S9-1944 Oral
Decadal scale variation of copepod community structure in the Oyashio based on the Odate Collection

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Based on the 50 yr archival zooplankton collection, the Odate Collection, we investigated seasonal and interannual variation of copepod community structure in the Oyashio. Multivariate analysis methods revealed a distinctive decadal scale variation pattern, and major shift of the community structure roughly coincided with the North Pacific regime shift in 1976/77 and 1988. Major copepod species were classified into 3 groups depending on difference in the timing when the numerical abundance reached its maximum: Spring group, Early-summer group and Summer group, peak abundance of which was observed in April to May, May to June and June to July, respectively. In the 1970s, seasonal variation of copepod abundance was small with relatively high abundance from early spring to summer more or less for all the groups. In the 1980s, abundance in early spring as well as in mid-summer declined especially in the Spring and Early-summer groups, suggesting a short reproductive season compared to the previous decade. In the1990s, on the other hand, abundance in spring months markedly declined while mid-summer abundance increased in the Early-summer and Summer groups. These results suggested that climatic change in the late 1970s might mainly alter upper water environment from winter to spring, and subsequently affect springtime lower trophic level production, while that in the late 1980s might influence springtime to summertime condition. This study presented an implication that different climatic forcing might work between winter and summer. Possible mechanisms of the community structure change observed will be discussed in the presentation.

PICES XIII S9-1850 Oral

The Optimal Stability Window hypothesis and copepod concentrations on the Gulf of Alaska shelf during spring and summer, 1998 - 2002

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The Optimal Stability Window hypothesis (OSW) posits that year class strength of salmon is determined largely by water-column stability. In the northern Gulf of Alaska (GOA) enhanced stability is thought to improve salmon survival by elevating primary production and consequently, zooplankton forage on the GOA shelf. Stability on the GOA shelf is hypothesized to result from lower surface salinity due to elevated precipitation and runoff during periods of a strong Aleutian Low. Although seasonal abundance of the dominant copepod taxa during spring and summer, 1998-2002, was negatively correlated to salinity, correlations between abundance and the stability coefficient were weak or absent. An intense thermocline was observed in July and August across the entire shelf, during years of high and low copepod abundance. Little or no correlation was observed between copepod abundance and mixed-layer temperatures. Lowest copepod abundance was observed when cross-shelf salinity profiles revealed intrusion of oceanic water onto the inner shelf, confining lower-salinity shelf waters to a narrow region along the coast. While data support the contention that greater volumes of freshwater runoff elevates the abundance of zooplankton forage on the shelf, the data are inconsistent with the OSW hypothesis. Rather, the data are more consistent with the hypothesis that mixing of iron-poor, high-nutrient oceanic water with iron-rich waters from coastal runoff elevates phytoplankton production, thus optimizing conditions for growth and reproduction of zooplankton forage when conditions promote expansion of mixed water across the shelf.

PICES XIII S9-1859 Poster

Interannual changes in abundance of dominant euphausiids in the northern Gulf of Alaska

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The interannual changes in abundance of the dominant euphausiids *Thysanoessa inermis, Thysanoessa spinifera, Thysanoessa longipes* and *Euphausia pacifica* were studied in the Northern Gulf of Alaska as a part of U.S. GLOBEC LTOP during the production season from 1998 to 2002. *Thysanoessa inermis* and *T. longipes*, which inhabit the Alaska Coastal Current, showed a significant increase in abundance from 1998 to 2002. In contrast, the abundance of *T. spinifera* and *E. pacifica*, which were common on the outer shelf, did not changed. The spawning of *T. inermis* and *T. longipes* occurred in April-May, while that of *T. spinifera* and *E. pacifica* extended from April through October, and from July through October, respectively. The spawning of *T. inermis, T. longipes* and *T. spinifera* appeared to be closely related to the spring diatom bloom on the inner shelf, while the spawning of *E. pacifica* occurred later in season, when the temperature of the mixed layer increased. A strong association of the extended colder phase in the North Pacific, as reflected by PDO index, with the increase in abundance of *T. inermis* and *T. longipes*, indicated that progressive cooling on the inner shelf in 1998-2002 may have resulted in greater reproductive success of early spawning *T. inermis* and *T. longipes* on the inner shelf.

PICES XIII S9-2158 Oral

The eastern Gulf of Alaska: A 36-year time series along Line-P and implications for biological impact

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Regular observations of ocean properties have been made along Line-P for the past half-century. This line runs about 1400 km from the western end of Juan de Fuca Strait to Ocean Station Papa at 50ºN, 145ºW. Bottle samples and CTD casts by research vessels provide most observations, supplemented by XBT profiles from ships of opportunity. The time series in the upper 400 m is almost continuous since 1968. Temperature anomalies in several

depth ranges are computed for summer and winter. These provide one of the longest-running time series of sub-surface temperatures in the northeast Pacific Ocean. Temperature anomalies in the upper 200 metres in both summer and winter show remarkable correspondence to Los Niños and to the Pacific Decadal Oscillation (PDO). Ocean Surface temperatures (0 to 50 m depth) responded to these events within a single season. Temperature anomalies at 100 to 150 m depth responded more slowly to La Niña events, with cool subsurface anomalies persisting for up to several years following the end of La Niña. Much of the warming of waters midway along Line-P was attributed to mesoscale eddies. Closer to shore the warming and cooling might be due to anomalously warm or cool waters forced by persistent winds of Los Niños, or of longer-period PDO regimes. Many of the biological impacts of these changes in water mass temperatures will be discussed.

PICES XIII S9-1993 Oral

A numerical simluation of large-scale physical events in the North Pacific ocean during the 1997-2003 period

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We present results of a numerical simulation of the circulation in the North Pacific ocean for the period of 1997-2003. This simulation has been carried out in the context of the GLOBEC Northeast Pacific program and overlaps with its field seasons (2000-2003). The North Pacific simulation serves a dual purpose: 1. To generate initial and boundary conditions for high-resolution regional simulations in the observational domains (California Coastal Current and the Coastal Gulf of Alaska) and 2. Investigate the large-scale physical events with potential implications to the biological systems in the Northeast Pacific. We will present results evaluating the model skill in simulating the 1997/1998 El Niño and quantify the influence of this event on the circulation in the Gulf of Alaska. We also show look at the 2002 Northeast Pacific cold anomaly, and comment on the possible regime shift back to pre-1977 conditions. The model used for this simulation is the Regional Ocean Modeling System (ROMS), forced with NCEP daily fluxes and winds. The model domain extends from 30S to 65N, and from 100E to 70W at a resolution of 0.4 degrees.

PICES XIII S9-1907 Poster

Dynamics of the mass pelagic fishes of the Japan/East Sea during the second part of the 20th century and factors responsible for the variation

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Biological parameters of the main subtropical fishes of the Japan/East Sea (sardine *Sardinops melanostictus*, saury *Cololabis saira*, mackerel *Scomber japonicus*, anchovy *Engraulis japonicus*), and environments condition influenced the fish stocks fluctuations are considered. As application of the hypothesis of match/mismatch of terms of planktonivorous fishes spawn with periods of high abundance of zooplankton, mechanisms and consequences of this link for certain species in dependence on their ecology are discussed and explained for last decades. Materials have been collected for all parts of the Japan/East Sea. These data have been used to analyze the entire life cycle of fishes (early ontogeny, prespawn and reproduction period, feeding migration) in connection with environmental factors. Environmental parameters (SST anomalies for spring-winter and summer-autumn periods, EOF1 for summer and winter in the south part, atmospheric processes, development of thermal structures, and dynamics of zooplankton in the southern and northern parts of the Japan/East Sea) at the end of 20th century and the beginning of 21st century were responsible for the decreasing sardine population. Conversely, the environment was favorable for anchovy, saury and mackerel.

PICES XIII S9-1804 Poster
Reorganizations of atmosphere regime over the Far Eastern Seas occurred in 2000-2003

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Charts of sea-level atmospheric pressure, averaged for winter, spring, summer and autumn seasons, were used for the analysis of synoptic conditions over the Far Eastern Seas. The condition of the atmosphere action centers and wind circulation over each of the seas (Japan, Okhotsk and Bering) were considered. To estimate quantitatively the intensity and direction of wind transfer, Katz meridional and zonal indices were calculated. Long-term fluctuations of the atmosphere regime over the Far East region were explained as changes of types atmospheric processes (using the author's classification developed for the Japan, Okhotsk and Bering Seas separately).

The Siberian High and Aleutian Low weakened gradually in the cold seasons in 2000-2003, and the Aleutian Low shifted southwestward from its climatic position. As a result, the winter monsoon became weaker and climate in all Far Eastern Seas warmed, and this led to a decrease of ice cover. The greatest warming was in the Bering Sea in 2003. Simultaneously, gradual amplification of the summer monsoon was noted over the Far Eastern Seas in spring and summer.

The analysis of repeatability of the types of atmospheric processes for the period of 1980-2003 has shown periodic variability, with substantial variation at 8-10-year periodicities. In 2000-2003 there was an appreciable reduction of repeatability of the "cold" winter types, while the frequency of the "warm" winter and "monsoon" summer types increased.

The weak winter and strong summer monsoons caused a regional "warming". The last such regional warming event occurred in the mid-1990s. Maximum warming in the current cycle is expected in 2003-2005, and then the atmospheric regime should shift to a cooling phase.

PICES XIII S9-2035 Oral
Effects of marine habitats on growth, condition and survival of juvenile pink salmon in the coastal Gulf of Alaska

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Juvenile pink salmon are produced from four hatcheries in Prince William Sound (PWS). During their first summer at sea they occur in PWS, the Alaska Coastal Current (ACC) and in shelf water seaward of the ACC front. In July, fish are in PWS and in ACC water, but rarely in shelf water. By August, they also occur in shelf water. In August, fish size differed among habitats. In 2002 and 2003 fish in shelf water were larger than those in the ACC or PWS; whereas in 2001 fish in shelf water were smaller than in ACC or PWS. Habitat-related size differences were usually found in all hatchery cohorts. Fish condition varied in a similar way. Fish in shelf water were in better condition than ACC fish in 2002 and 2003, but were in poorer condition in 2001. Habitat use, size and condition patterns may have been related to feeding and zooplankton availability. The habitat differences we observed in fish size and condition may have important implications for marine survival. There are indications that juvenile salmon reaching a critical size by the start of their first winter at sea have higher over-winter survival. If the critical size hypothesis holds for pink salmon, larger individuals in August may be more likely to return as adults in the following summer. Our observations are consistent with this hypothesis - hatchery fish that were released in 2001 had very low survival, whereas those released in 2002 had exceptionally high survival. These observations suggest that conditions in shelf water during late summer affect overall survival of juvenile pink salmon.

PICES XIII S9-2131 Oral

A new international research project: Integrated Marine Biogeochemical and Ecosystem Research (IMBER)

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The need to understand and prepare for the impacts that global change will have on the Earth System has lead to the development of a new multidisciplinary, global scale research programme called IMBER. Jointly developed and sponsored by IGBP and the SCOR, IMBER will focus on marine biogeochemical ecosystems and their interactions. IMBER will investigate the impacts changing environmental conditions, forced by natural and anthropogenic factors will have on the worlds oceans, and what effect a changing ocean will have on other components of the Earth System. IMBER will focus in 4 domains, the euphotic and mesopelagic layers of the ocean, the continental margins, and high-latitude and polar oceans. IMBER will also identify key feedbacks from marine biogeochemical cycles and ecosystems to other components of the Earth System. The goal of the IMBER project is: *'To understand how interactions between marine biogeochemical cycles and ecosystems respond to and force global change'.*

To address this goal, four scientific themes, have been identified:

1. What are the key marine biogeochemical cycles, ecosystem processes, and their interactions, that will be impacted by global change?
2. Sensitivity to Global Change: How will key marine biogeochemical cycles, ecosystems and their interactions, respond to global change?
3. Interactions with the Earth System: What is the role of the ocean biogeochemistry and ecosystems in regulating climate?
4. Responses of Society: What are the relationships between marine biogeochemical cycles, ecosystems, and the human system?

PICES XIII S9-2040 Poster

A comparison of remote versus local influence of El Niño on the coastal circulation of the Northeast Pacific

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A set of nested circulation models has been used to explore the remote and local influence of the 1997-1998 El Niño on the circulation and temperature fields of the Northeast Pacific. Our nested set includes a basin-scale model of the North Pacific at ~40 km resolution (NPac), and a regional model of the Northeast Pacific at ~10 km resolution (NEP). The NEP model spans an area from Baja California through the Bering Sea, from the coast to ~2000 km offshore. In this context, "remote influence" refers to effects driven by changes in ocean velocity and temperature outside of the NEP domain; "local influence" refers to direct forcing by winds and runoff within the NEP domain. We have performed a series of sensitivity runs with the NEP model, which analyze the effects of: 1) hindcast winds (from NCEP reanalysis) and coastal runoff, as compared to monthly climatologies; and 2) hindcast boundary conditions (from the NPac model), as compared to monthly climatologies. Results indicate penetration of SSH and associated upwelling/downwelling anomalies from the basin-scale model into the NEP domain (*e.g.* "remote influence"), with propagation as Coastal Trapped Waves from Baja up through British Columbia. Most of the SSH anomaly off Alaska in El Niño years appears due to direct forcing by winds ("local influence"). We quantify such

effects, including the penetration of anomalous temperatures through the southern boundary of the NEP domain, and suggest how they might impact patterns of primary production.

PICES XIII S9-2032 Oral
Annual variability in condition factor of sockeye salmon (*Oncorhynchus nerka*) from 1915-1972 in British Columbia, Canada

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Studies of sockeye salmon (*Oncorhynchus nerka*) life history characteristics typically consider interannual variability in salmon mass and length at maturity separately, ignoring the strong positive correlation between them. However, interannual variability in the relation between mass and length may have important fitness consequences. For example, larger mass at a given length (*i.e.* higher condition factor) may confer reproductive and survival advantages. The paucity of individual length and mass data has previously been an obstacle in examining temporal and spatial variability in condition factors in Pacific salmon. We used a unique long-term data set of individual masses and lengths to examine intra- and inter-annual variability in condition factor in two sockeye salmon stocks, Rivers Inlet and Nass River, British Columbia, Canada from 1915 to 1972. We also considered the spatial scale of covariation and proposed potential environmental drivers. Notably, the temporal variability in condition factor was dominated by interannual variability instead of long-term multi-year trends that have been identified in North Pacific salmon catch records. Furthermore, interannual variability was similar between stocks, for certain age-classes. For fish that spend the same number of years in fresh water, we found strong positive correlations between stocks and among age-classes, but this was not the case for fish spending different numbers of years in fresh water. These results suggest differences in ocean distribution or migration rates among age-classes of different stocks. In addition to inter-annual variability, we found some evidence for intra-annual patterns in condition factor from the strong positive correlations in condition factor among fish sampled in consecutive weeks.

PICES XIII S9-1902 Poster
Varying climate-driven ocean conditions and the growth of juvenile salmonids in the California Current system

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Climatic-driven ocean conditions have been linked to the survival of coho salmon (*Oncorhynchus kisutch*). Growth of juvenile salmon during their initial months at sea is believed to be a major factor influencing marine survival. Marine growth is influenced by food availability, fish health, and many other factors. As part of a comprehensive research program we have begun to identify which factors predominate each year, and how marine growth of juvenile salmonids affects survival. We collected juvenile coho salmon, yearling and subyearling chinook salmon (*O. tshawytscha*) off Oregon and Washington in June and September from 1998-2002. This period included a variety of climatic and ocean conditions including, the 1997-1998 El Niño, the 1999-2000 La Niña, the 2001 drought, and a cold subarctic water intrusion in 2002. Based on the assumption that size differences reflect differences in growth rates in addition to differences in size-specific survival, we observed interannual differences in growth between species and life history types. Subyearling chinook salmon were largest in September 2001 and smallest in September 2000. In contrast, juvenile coho salmon were smallest in September 2001. Yearling chinook salmon were small in September 1999 and 2001. High marine growth of juvenile coho salmon was observed in 1998 and 2002. Yearling chinook salmon also appeared to grow best in 2002, during persistent low sea surface temperatures and high zooplankton abundance. The observed variation in salmon growth seems to be climate driven. Mechanisms remain to be defined.

PICES XIII S9-1894 Oral

The latitudinal differences of mesozooplankton distribution in the Northeastern Equatorial Pacific under El Niño, La Niña and normal condition

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To investigate the effects of physical structures induced by climate change on the mesozooplankton distribution, we measured water temperature, salinity, concentrations of nitrate and chlorophyll-*a* (chl-*a*), and abundance of the mesozooplankton above 200 m depth along the meridian line (5°N-12°N, 131.5°W) in the summer of 1998, 1999, and 2003.

Regions of upwelling and downwelling shifted in association with climate change, and this affected the spatio-temporal variation of mesozooplankton latitudinal distribution by changing the concentration of nitrate and chl-*a* as well as the physical conditions. Abundance of mesozooplankton in 1999 (La Niña year) was higher than that in 1998 (El Niño year) and 2003 (normal year), and it increased as going to the north, whereas decreased in 1998 and 2003. At the study area, the locations of convergence and divergence zones and the magnitude of upwelling and downwelling differed in 1998, 1999 and 2003. A strong upwelling in the divergence zone in 1999 (from 10.5°N to 11°N) might have increased the chl-*a* concentration and in turn the abundances of the calanoid-, cyclopoid copepods, chaetognaths, ostracods and radiolarians. Upwelling was not clearly detected at the study area in 1998, which might be responsible for the low concentrations of nitrate, chl-*a*, and mesozooplankton. Upwelling was observed in 2003, but was located at lower latitude (9°N) than that in 1999, and was weaker. Concentrations of nitrate, chl-*a*, and mesozooplankton in 2003 were lower than in 1999, but higher than those in 1998.

This evidence suggests that the intra- and interannual heterogeneity of mesozooplankton latitudinal distribution was related to the shift of divergence and convergence zones, which might be affected by the scales and positions of South Equatorial Current (SEC), North Equatorial Current (NEC) and North Equatorial Countercurrent (NECC) in relation to the climate change during the study period.

PICES XIII S9-2075 Poster

Biological patterns in years of contrasting upwelling-favorable winds

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Global warming, through increased wind-forcing, is hypothesized to lead to increased upwelling along the west coast of the United States. Increased upwelling may enhance productivity through supply of nutrient-rich deep water, but upwelling increases mixing and advection, so therefore could negatively impact the retention of organisms in productive nearshore areas.

Wind-forcing of the northern California Current system contrasted in summers 2000 and 2002. Winds became predominantly upwelling-favorable earlier in 2002 and were stronger and more persistent over much of the summer compared to 2000. Due to anomalously strong basin-scale winds and equatorward transport the preceding winter/spring, the California Current in summer 2002 was characterized by unusually low temperatures, low sea level height, and high equatorward transport. During cruises conducted as part of the U.S. GLOBEC Northeast Pacific program, we found that nutrient and phytoplankton concentrations were 1.5-2 times higher throughout the study area (41.8 – 44.8°N) in August 2002 compared to August 2000. However, copepod biomass was nearly 2X lower in 2002 than 2000. Data from bi-weekly sampling at a nearshore station off Oregon (44.6°N) suggest that copepod biomass followed the typical seasonal cycle in 2000; in contrast, biomass peaked very early (mid-May) in 2002 and had declined by August compared to the long-term average. We hypothesize that the atypical seasonal pattern of copepod biomass seen in 2002 was a result of the anomalously strong winds and advection during that

year. Contrasts in the biological responses between years of contrasting winds may aid understanding of potential effects of global-warming on upwelling ecosystems.

PICES XIII S9-1855 Poster

Spatial and temporal variability patterns in the nitrogen and carbon stable isotope composition of sub-arctic Pacific biota during the GLOBEC long-term observational program: Implications for interpreting long-term records

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Natural abundance of the stable isotopes of carbon and nitrogen may reflect change in ecosystems because their variability, which is driven by primary producers, is transferred in a predictable manner to higher trophic levels. A multi-decade stable isotope time-series measured in whale baleen has recently been suggested to reflect change in Bering Sea productivity. The data, however, are open to multiple interpretations due to the lack of supporting lower trophic level data. An immediate goal was thus to establish spatial and temporal patterns, especially inter-annual isotopic variation, across multiple trophic levels. There were both meso-scale spatial gradients and inter-annual isotopic variations measured in primary consumer level zooplankton. Inter-annual variations varied among fish taxa suggesting differential higher trophic level utilization of carbon resources across the continental shelf. Inter-annual variability measured in the long-term record was similar to that observed here in zooplankton. Nevertheless, shifts in feeding area could also explain trends. More value would be ascertained if an observation time-series comprised several trophic levels or sample types that underwent parallel shifts. The inter-annual isotopic patterns observed in zooplankton may reflect recent climatic shifts of recent years, which appeared to have more than one mode. The planned integration of the stable isotope results with the gamut of other GLOBEC observations, including physics, chemistry, biology, and modeling, may lead to a better understanding of their meaning. It may be possible to relate isotopic shifts with concordant shifts in these parameters with the goal to understand processes associated with climatic shifts.

PICES XIII S9-2030 Poster

Interannual variations in diatom abundance during winter and summer in western tropical to subtropical Pacific

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There has been accumulating evidence that lower trophic levels in the marine ecosystem responds to climate impacts in different regions of the Pacific. However, we have little information on long-term changes in phyto- and zooplankton in western subtropical to tropical Pacific. Thus, interannual variations in diatom abundance were investigated on a time-series collected at stations along 137˚E during winter and summer from 1972 to 1992 by R/V *Ryofu Maru* of the Japan Meteorological Agency. The stations extended to 5 sub-areas including Coastal Kuroshio Region (CKR), Kuroshio Region (KR), Subtropical Counter Current Region (SCCR), North Equatorial Current Region (NECR), and North Equatorial Counter Current Region (NECCR). 116 species were identified throughout the study period. Diatom cell numbers showed a mid-latitude minimum around the SCCR and the latitudinal pattern was correlated with surface phosphate concentrations. The yearly fluctuations of diatom abundance in winter and summer revealed quasi-decadal oscillation patterns, which were high during the late 1970s and 1980s and low during the early 1980s. The oscillation signals were similar in the KR, SCCR, and NECR, and diminished in the northernmost (CKR) and southernmost subareas (NECCR). According to Spearman rank correlation coefficients, significantly positive correlation was observed for 3-year running means of diatom abundance and N* during both winter and summer in the SCCR and NECR. However, other environmental parameters (SST, nitrate, phosphate,

Southern Oscillation Index) were of minor importance for the interannual variations in diatom abundance. From these results, a possible mechanism of the interannual variations in diatom abundance will be discussed.

PICES XIII S9-1987 Oral
Climate variations and changes in the state of the main Northern Hemisphere fish stocks

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To isolate objectively the most important factors of common variability in the 100 physical and biological time series in the North Pacific and North Atlantic for the 1970-2003 period, the principal component analysis (PCA) was used. The first three PC account for about 43% of the total variance. Despite, the first principal component (PC1) being associated with the North Atlantic Oscillation (r=-0.74), the temporal variations of some Far East fish stocks are highly correlated with PC1 scores. The PC1 was mostly positive until 1982 and strongly negative beginning from 1983. High loadings (r>|0.4|) on PC1 occur for 37 of the time series. In particular, PC1 shows the in-phase fluctuations of some haddock and saithe stocks in the Northeast Atlantic and Kamchatka sockeye salmon stocks. The PC2, related to the Pacific Decadal Oscillation (r=-0.80), shows three regimes, with abrupt shifts in 1977 and 1989, but it is interesting that high loadings on this component occur for some herring and saithe stocks in the North Atlantic. The PC3 is characterized by four distinct regimes, with abrupt transitions in 1974, 1983, and 1991. This component reveals coherent variations of Northwest Atlantic haddock and cod stocks. The results of PCA show a good correspondence between shifts in the state of climatic characteristics and biological parameters of most North Pacific and North Atlantic fish stocks on decadal and interdecadal time scales. However, the correlations between the basin-scale or regional atmospheric and oceanic indices and survival indices on the interannual time scale in most cases are weak, especially for moderate conditions of survival. As to the extreme cases of favorable or unfavorable survival conditions sometimes it is possible to distinguish a large-scale factor which may influence the formation of the year-class strength. But even in this situation the sign of relationship may be opposite to that observed on decadal time scale.

PICES XIII S9-1881 Poster
A coastal ocean monitoring program along the Baja California coastline: Climate change, internal waves and the kelp forest ecosystem

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The kelp forest ecosystem is an excellent indicator of climate change in the coastal ocean as it integrates changes from the benthos through the water column, and incorporates primary producers to top feeding predators. This ecosystem is highly dependant on ocean temperature and the inversely correlated nutrients in the coastal zone. In this contribution, monitoring of both biological and physical parameters in this ecosystem along the Baja California coastline over the past ten years will be presented. The time series will be discussed with specific attention to oceanographic regime shifts, ENSO events, and global climate change. Because the Baja California coastline exists within a strong biogeographic transition zone between temperate and subtropical conditions, and because of the kelp ecosystem's integrative nature, the monitoring of this ecosystem along this coast may be particularly important in elucidating the complicated effects of climate change along temperate coasts.

PICES XIII S9-1949 Poster

The effects of El Niño events on sea water temperature variation and squid catch in the Korean coastal and off-shore waters

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It has been widely accepted that there is a strong link between El Niño events and the changes of oceanic and fisheries environments. In order to understand key processes related to the relationship in the coastal waters of Korea, Southern Oscillation Index for El Niño events and sea water temperature as well as fishery data were analyzed. SOI data from 1900 to 2000 were collected from National Oceanographic and Atmospheric Administration. Temperature data from 1961 to 2000 and fishery data from 1980 to 2000 were also collected from Korean Oceanographic Data Center and Japan Meteorological Agency. It was found that two periods of about 4 to 8 years and 16 years were dominant in temperature variations. These periodic temperature variations were highly correlated with El Niño events whose dominant periods were about 4 to 8 years and 16 years. The time lag between temperature variations and El Niño events of about 4.8 and 16.3 years were 1.3 and 4.5 years, respectively. In particular, period of about 16 years observed both in temperature and El Niño events showed very good relationship with temperature variations, especially from 1980 to 2000. It was also found that these temperature variations from 1980 to 2000 possibly resulted in the different pattern of squid catchments in the East Sea and West Sea of Korea. In case of West Sea (East Sea) of Korea, squid catchments increased (decreased) in the 1980s, but decreased (increased) in the 1990s. This phenomenon suggested the possibility of decrease or increase in squid catchments due to longer period of temperature variations rather than decadal period. This can be explained by gradual temperature increase (decrease) in the West Sea (East Sea) of Korea.

PICES XIII S9-2052 Poster

Spatio-temporal distributions of small pelagics around Korean waters using a neural network pattern recognition approach

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Shifts in the habitats of small pelagic fishes were triggered by climatic events, such as ENSO and climatic regime shifts (CRS) around Korean waters (Zhang et al., 2004). In the post-1988 CRS, the distribution area of jack mackerel expanded and shifted southward to 27°N, while the confidence region for the habitat of chub mackerel moved to west of 128°E. As a result, the joint confidence regions of jack and chub mackerels became more narrow. These shifts in the habitats of chub and jack mackerels resulted in Pacific sardine occupying a habitat area separate from the shared mackerel distributions. We examined the role of spatio-temporal oceanographic variability on the distribution patterns of small pelagics around Korean waters. A neural network pattern recognition technique, called a self-organizing map (SOM) was applied in this study to seek clusters in the data using this unsupervised learning methodology over a twenty-year time series of CPUE distribution data of major small pelagics for the Korean large purse seine fishery. A two-step process of training SOM was used: first crude initial patterns were formed, following by a refinement, constructing monthly and annual frequency maps. Frequency maps have the dimensions of the SOM output array and show the frequency of occurrence of each pattern in the data set.

PICES XIII S9-1789 Oral
Population dynamics of Japanese pink salmon: Does climate change explain the recent increasing trend?

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Understanding the mechanisms that regulate fish production is a central issue in fisheries science. We examined the joint effects of density dependence, climatic variation, and hatchery release on the population dynamics of the pink salmon *Oncorhynchus gorbuscha* around Hokkaido Island, Japan, from 1969 to 2002. The number of fry released by hatcheries, winter temperatures, and abundance of pink salmon increased significantly during this period. For the analysis of population dynamics, we used the stochastic Ricker population model considering climatic effects. The results indicated that density dependence and climatic variation, but not hatchery release, are important for understanding the population dynamics of pink salmon. The patterns of covariation between climatic variables and population growth were consistent with previous hypotheses: the population growth rate was enhanced by mild winters, high rainfall during fall seasons, and an intensified Aleutian Low. The Monte-Carlo simulation showed that recent increases in pink salmon catch are explained by climate change alone without necessarily involving increased hatchery release. Although it has been believed that Japanese salmon increased as a result of intensified hatchery programs, our findings are inconsistent with this legend.

PICES XIII S9-1971 Poster
Climate, ocean ecosystem, and sustainable fisheries

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Variations and changes of the Earth biosphere are generally related to climate variations, which can be forced by extraterrestrial (mainly of solar origin) and intraterrestrial factors, such as electromagnetic, magnetic and gravitation fields.

Direct influence of these factors on the Earth living matter is well known, but till now interrelations between climate, ecosystems and external and internal factors are not clearly understood. A scheme of such interrelations is constructed, that takes into account the following processes: 1) atmosphere and its characteristics perturbations caused by solar activity fluctuations; 2) changes of heat content of oceanic waters due to solar radiation and atmospheric characteristics fluctuations; 3) ocean-atmosphere interactions displaying themselves in a very wide range of space-time scales; 4) large-scale ocean currents, transporting heat content anomalies from tropics to middle and high latitudes and thus affecting atmosphere circulation over the globe; 5) direct influence of electromagnetic and magnetic field fluctuations on biota and spreading their effects up trophic chains and inside populations; 6) feed-back of biota anomalies on the ocean and atmosphere physical properties.

Analysis of the above named processes using existing models and observations shows that influence of forcing factors on ecosystem changes can be realized by two ways: 1) globally in different parts of trophic chains; 2) locally with delays corresponding to times of climatic anomalies transport a) by currents from tropics to the local areas, b) trophic chains up and inside populations. As a result, some ecosystem changes may follow climate changes, but some of them may precede climate changes and be used to forecast them. In any case, large stochastic variations are inherent for climate as well as for biota systems, leading to rather quick transitions between different mean conditions in both systems. Such transitions, generally named as *regime shifts,* and random fluctuations of environment and biota parameters, give new properties to interrelations between contradicting demands of stability and effectiveness of fisheries, which are explored in the paper.

The most prominent changes in biota will arise in key regions and in key periods of time when there is resonance between external forcing and internal cycles. Using existing models for ocean circulation, comparisons of observed recurrence in some important fish populations with several known forcing cycles are made.

PICES XIII S9-2142 Poster
Decadal variations of demersal fish populations in relation to climate/oceanic regime shifts in the waters off the northeast coast of Japan

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Many demersal fish populations in the waters off the northeast coast of Japan were examined for the period 1976-2001. They decreased in the 1970s, remained low during the 1980s and rapidly increased in the 1990s. The increase of demersal fish populations in the 1990s was dramatic for species living in the continental shelf area, shallower than 200 m depth. However, species living on the slope, at 200 m to 800 m depth, did not increase in the 1990s, but started to increase after 2000. Many strong year classes of flounders appeared after 1994. Species that increased in the 1990s spawned in winter to spring. The most southern position of Oyashio intrusions into this area in spring shifted to the south in 1972/1973, and shifted to the north in 1986/1987. Zooplankton biomass also increased in the 1990s. Relations between water temperatures, zooplankton biomass and the recruitment of willowy flounders were examined. Zooplankton biomass was related to the survival of the pelagic stage of flounders and water temperatures were related to the survival of the metamorphosis stage flounders. Why did the appearance of dominant year-classes of flounders and the increasing of the zooplankton biomass late for the Oyashio intrusion shift of 1986/1987? Japanese sardine recruitment failed after 1988, but adult sardines were still abundant in the early 1990s and aggregated in this area from winter to spring, where they consumed large quantities of zooplankton. After sardine adult biomass declined in the mid 1990s, the flounder larvae experienced greater zooplankton prey, and higher survival.

PICES XIII S9-2186 Oral
Korea GLOBEC

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In 1998, a Korea GLOBEC committee was jointly established by the Korean Society of Fisheries Resources and the Korean Society of Oceanography, and was chaired by Prof. Suam Kim of Pukyong National University. The first phase of Korea GLOBEC started with a project entitled "Investigation on the relationship between climate change and fisheries resources in the Japan/East Sea" supported by the Ministry of Maritime Affairs and Fisheries from 2001 to 2003. Prof. Suam Kim was a principal investigator of the project. The research focused mainly on retrospective analyses of historical data in Korea. In August 2000, we organized the first Korea-Japan Joint GLOBEC Symposium on "Long-term variations in the northwestern Pacific ecosystem" at Busan, Korea. Selected papers from the symposium were published in a special session of Fisheries Oceanography. In December 2002, we organized the first China-Japan-Korea Joint GLOBEC Symposium on "Processes and dynamics in the northwestern Pacific ecosystem" at Ansan, Korea. Selected papers from that symposium will be published in the Journal of Oceanography.

A second phase of Korea GLOBEC began in January 2004. A new chairperson, Prof. Im Sang Oh of Seoul National University was elected. For this second phase of Korea GLOBEC, a new 9-year project titled, "Long-term change of the biogeochemical cycling and biological processes in the East China Sea: Observation and Prediction" was initiated. The project is supported by the Ministry of Science and Technology. Recently, the Korea GLOBEC committee decided to encourage young scientists by supporting their travel expenses to relevant scientific meetings. This program will continue for 10 years.

PICES XIII S9-2076 Oral
Progresses and achievements of GLOBEC research projects in Japan

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Serial GLOBEC research projects started in 1989, with the grant-in-aid of the Japanese Ministry of Agriculture, Forestry and Fisheries. The projects have steadily unveiled the linkage between climate changes and small pelagic fish population dynamics in relation to plankton communities. As the first step, BIO-COSMOS project was conducted from 1989 to 1999 with the aim of understanding the recruitment processes of the Japanese sardine. Two major findings were obtained: 1) a positive correlation between the decadal SST change and the mortality of pre-recruitment sardine and 2) a positive feedback loop as a mechanism of the interdecadal fluctuation of the sardine abundance. Accordingly, the next project, VENFISH program (1997 - 2001), targeted bottom-up control processes from the phytoplankton production to the recruitment of Pacific saury (*Cololabis saira*) and walleye pollock (*Theragra chalcogramma*). As the output of this project, the NEMURO.FISH model was developed based on the lower trophic marine ecosystem model NEMURO constructed by the PICES MODEL Task Team. Concurrently, the FRECS program aimed to understand the survival mechanism of jack mackerel (*Trachurus japonicus*) and Japanese common squid (*Todarodes pacificus*) during the transportation from the spawning grounds in the East China Sea to Japanese coastal areas. At the termination of VENFISH project, DEEP project was launched in 2002 as the five years research project, focusing on meso-pelagic micronekton species. The other GLOBEC-like research projects, to understand the climate impacts on fisheries, have also been started for improving the accuracy of forecasts of small pelagic fish population.

PICES XIII S9-1868 Oral
Is the Bering Sea ecosystem stuck in a warm phase?

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The southeastern Bering Sea was subject to a change in the physical environment and an ecosystem reorganization after 1976 associated with the Pacific Decadal Oscillation (PDO), a minor influence from shifts in Arctic atmospheric circulation in the early 1990s, and persistent warm and ice-free conditions over the previous 4 years. Weather and tree-ring proxy data suggest that the Bering Sea was generally cool for at least 170 years before 1977, with sufficient time for slow growing, long-lived, cold-adapted Arctic species to adjust. Thus the last few decades appear to be a major transition period for the Bering Sea from an ice-dominated Arctic system to a sub-Arctic ecosystem. Fisheries surveys and model calculations show a shift in the importance of pollock to the ecosystem, to over 50% of the energy flow at mid-trophic levels in the 1980/90s from near 10% in the 1950/1960s, although biological information for the earlier period is limited. There was an accompanying reduction in recruitment of Greenland turbot and yellowfin sole and a northward shift in the Pacific walrus population. Although ecological conditions appear mostly stable over the last decade, the warmest water column temperatures on the southeast Bering Sea shelf have occurred in 2001-2003 (6 deg summer mean temperature relative to 4 deg summer mean temperature in 1995-1997), despite considerable year-to-year variability in the Arctic Oscillation and PDO. We hypothesize that the overall climate change occurring in the Arctic, as indicated by warmer atmospheric and oceanic temperatures and loss of 15 % of sea ice and tundra area over the previous two decades, is making the Bering Sea less sensitive to intrinsic climate variability of the North Pacific. Thus we project that the Bering Sea will more likely continue on its current warm trajectory, with biomass transitioning northward allowing pollock a larger productive domain at the expense of cold and ice-adapted species, rather than transitioning back to a cold regime. Bering Sea indicators should be closely watched over the next five years to confirm or reject this hypothesis.

PICES XIII S9-2204 Oral
GLOBEC Canada: Results and follow-on activities

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The Canadian national GLOBEC program ran from 1996 through early 2001, funded by Fisheries and Oceans Canada (DFO) and the Canadian Natural Sciences and Engineering Research Council Research (NSERC) Partnerships program. GLOBEC Canada brought together a large number of marine scientists (45) and students/PDFs (35) affiliated with both universities (7) and DFO laboratories (5), and included work in both the NE Pacific and the NW Atlantic. The key motive for GLOBEC Canada was a growing perception (since become a firm knowledge) that biological productivity covaries strongly and for prolonged periods with the physical state of the ocean. To better recognize where, when, and why present and future changes will occur, we designed the program to include:

- Collaboration between biologists and physicists
- Interaction and feedback between:
  - retrospective analysis of long time series,
  - focussed process studies, and
  - numerical modelling.
- Comparisons among different species and regions.

Research activities spanned time and space scales ranging from interdecadal changes affecting the full North Pacific and North Atlantic to process studies of local interactions between topography, currents, and plankton and fish distributions. What did we learn?

Retrospective and ongoing time series documented important decadal changes. In the NE Pacific, the surface layer of the Alaska Gyre became more stratified, leading to reduced annual re-supply of nutrients by winter mixing and to a zone of summer nutrient depletion along the eastern margin. The seasonal cycle also changed: surface layer warming and restratification, and the annual peak of zooplankton biomass moved earlier in the calendar year. A recalibration of zooplankton nets improved the reliability of the Stn P time series. El Niño events became more frequent and prolonged, and included a major and well observed El Niño/La Niña in 1997-1999. Along the British Columbia continental margin, there were low-frequency changes in zooplankton community composition, with a 1990s trend toward a more southerly zooplankton fauna that reversed abruptly in 1999. Stocks of all five BC salmon species initially increased, but declined steeply in the 1990s due in large part to decreased marine survival rate and poor growth. Seabird colonies in southern BC showed similar trends. There were large 1990s changes in hake abundance and distribution, and a major resurgence of sardine in Canadian waters.

Process studies showed how zooplankton and fish are aggregated and retained by flow patterns at the shelf break, in submarine canyons, and around mid-shelf banks. Hotspots in primary productivity and phytoplankton biomass were related to nutrient supply rates and mechanisms. Isotopic and biochemical tracers helped discriminate feeding history, especially for taxa that move between shelf and offshore. Effects of 10-50 km scale topography on continental margin winds and currents were measured and modeled.

Other *numerical modeling* studies included development of basin-scale coupled models to map the response of plankton productivity to seasonal and "regime" changes in circulation and vertical mixing, neural network methods for forecasting ENSO events, and a high resolution continental shelf circulation model to follow the movement of passive and active "tracers".

Most participants felt that GLOBEC Canada ended too soon, but many have continued with "GLOBEC-like" research in smaller groups and from other funding sources. Present examples include the ongoing west coast time series, intensive field and modeling studies of the Strait of Georgia, of *Pseudo-nitzschia* (HAB) blooms off southern Vancouver Island, and of zooplankton aggregation near abrupt topographic edges.

PICES XIII S9-2108 Oral

The importance of regional-scale (< 700 km) environmental processes in driving temporal variation in recruits per spawner in Northeastern Pacific salmon (*Oncorhynchus*) populations

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Substantial evidence has been gathering over the last six years that regional-scale environmental processes (those that are coherent across less than about 700 km) are more important drivers of temporal variation in recruits per spawner for salmon (*Oncorhynchus spp.*) populations than more-frequently-referred-to large, ocean-basin-scale processes. We report new results here that further substantiate this relative importance of regional-scale mechanisms in the dynamics of over 100 stocks of pink (*O. gorbuscha*), chum (*O. keta*), and sockeye (*O. nerka*) salmon in the Northeastern Pacific. We used both within- and between-species comparisons across stocks. For each salmon stock, we used time series of abundances of spawners and resulting adult recruits as input to a Ricker stock-recruitment model that we cast in the context of a Kalman filter. We previously demonstrated that this filter is effective at estimating underlying systematic changes over time in the Ricker *a* parameter (the signal) amid random variation (noise) that is independent of that trend. The resulting reconstructed time series of productivities (Ricker *a* parameters) were highly correlated among stocks that have ocean entry points within several hundred km of one another. Across-species comparisons for pink and chum stocks showed very similar regional scales of positive covariation in their reconstructed time series of productivities. These results suggest that to better understand mechanisms causing temporal variation in productivity of salmon stocks, scientists should emphasize more research on regional scales than in the past. Better management may also result from this shift in perspective.

PICES XIII S9-2081 Oral

The climate shift of 1998: Something old or something new?

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Peterson and Schwing (Geophys. Res. Letters, 2003, 30,17) suggested that a climate shift was initiated in the northeast Pacific in August 1998, and that this new climate state might resemble the previous "cool regime" observed between the years 1947-1977. Six years have elapsed since the 1998 climate shift, and thus far a variety of physical and ecological data sets confound our ability to definitively categorize currently observed ocean climate conditions. In this paper, we ask, "Are we in a cool regime?". If so, how closely does this regime compare to the cool regime observed before 1977? Key differences include the following: (1) this particular regime seems better related to the second mode of the PDO rather than the first mode, corresponding to what is being called the "Victoria Pattern"; (2) wind direction is more westerly than northerly, leading to (3) stronger eastward transport in the Transition Zone. Increased eastward transport may in turn explain our observations that (4) copepod biodiversity has increased dramatically since the 1998 regime shift, to values higher than observed during the two massive El Niño "events of the century" (1983 and 1997/98). Lastly, (5) fish stocks are responding differently as compared to the pre-1977 period: salmon stocks in both the Gulf of Alaska and the California are productive, and both anchovy and sardine stocks continue to do well in the northern California Current. Based on these observations we conclude that current conditions are dissimilar from the pre-1977 "cool regime".

PICES XIII S9-1842 Oral
Russia in scientific collaboration in programs related to the GLOBEC International

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In the post-socialist epoch, the involvement of Russia in the international collaboration in studies of structure, functioning, and response to physical forcing of the global ocean ecosystem occurred in several ways. Russian Academy of Sciences has contributed to IGBP projects: PAGES, SOLAS, and biodiversity conservation in tropical latitudes together with GLOBEC Ukraine. There are two regional GLOBEC programs in the Pacific region: the PICES-GLOBEC CCCC, and ESSAS – at its strategic planning stage. Fishery science leads among Russian institutes in this activity. In recent years, TINRO-Center created contemporary managed database on nekton and zooplankton of Far-Eastern seas. First results occur in publication of the "Atlas of quantitative distribution of nekton species in the Okhotsk Sea", which is the first book in a planned series. The following conclusions (Shuntov *et al.*, 2003) were recently made: 1) the interannual and long-term dynamics of marine ecosystems is primarily controlled by climate-oceanological processes, in spite of the increasing anthropogenic influence. Despite the importance of greenhouse effect on the Earth climate, the ocean regime in the northwestern Pacific since 1997 has been relatively cold; 2) moving factors of the differently directed dynamics of common fishery stocks and decrease in total biological and fish-productivity of the ecosystems of far-eastern seas should be searched for in the natural processes. Pelagic fish under-utilized the food supply formed by crustacean zooplankton. Zoobenthos biomasses have grown against the background of demersal fish biomass reduction. Besides, the specialists of Russian fishery science participate in ACIA, BASIS, and NPRB scientific plan elaboration.

PICES XIII S9-2072 Poster
A warmer and fresher Northern Gulf of Alaska?

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The 33-year time series of temperature and salinity versus depth to 250 m at the mouth of Resurrection Bay, Alaska (60 N, 149 W) (GAK 1) is used to establish the climatic conditions for the Northeast Pacific GLOBEC Long Term Observation Program (LTOP) and to determine the hydrographic conditions during the GLOBEC sampling (October 1997-2004).

The water temperature and salinity are forced by solar heating, freshwater discharge, winds and El Niño-Southern Oscillation (ENSO) events. The amplitude and phases of the hydrographic responses to the recent ENSO events of 1997 and 2002 are compared with earlier events. These hydrographic responses are also compared with indices of North Pacific atmospheric forcing such as SOI (Southern Oscillation Index), PDO (Pacific Decadal Oscillation, NOI_x (Northern Oscillation Index), Nino3, North Pacific Index (NPI) and the Arctic Oscillation (AO). The seasonal variations of the water temperature and salinity are compared with the seasonal solar heating, coastal freshwater discharge, and winds to investigate the possibility of significant changes in their seasonal amplitude and phase during the GLOBEC LTOP period. The hydrographic data and the coastal air temperature and precipitation for Southcoast Alaska will be investigated for summer-winter climate change differences. It appears that the record low temperatures observed in the early 1970s were a winter phenomenon. Are there other influences that are confined to either the summer or winter alone?

PICES XIII S9-1968 Oral
Interannual variations in developmental timing of *Neocalanus* copepod populations in the Oyashio waters of western subarctic North Pacific

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In order to clarify the interannual variations in biomass and production of *Neocalanus* copepod in the Oyashio waters, we analyzed mesozooplankton samples (the Odate Collection) collected in offshore waters of northeast Japan from 1970 to 2000. The interannual variation in the developmental timing was determined by the date when copepodite stage 5 made up 50% of the copepodite abundance (Mackas *et al*. 1998). The developmental timing of *N. flemingeri* populations showed decadal scale oscillation which was late in the mid-1970s, mid-1980s, and mid 1990s. On the other hand, the developmental timing in *N. plumchrus* and *N. cristatus* populations showed bidecadal scale oscillations which were very late in the late 1970s and late 1990s. Differences in the patterns suggested that mechanisms of the interannual variations in *N. flemingeri* populations developmental timing are different from that of *N. plumchrus* and *N. cristatus*. We will discuss the possible causes of the interannual variations in the developmental timing of *Neocalanus* copepod populations in the Oyashio waters including physical environmental variations and abundance of mesozooplankton predator as Japanese sardine.

PICES XIII S9-1880 Oral
The overview of Chinese National GLOBEC Program

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Chinese GLOBEC studies carry through the national science program from 1997, which is titled "Ecosystem Dynamics and Sustainable Utilization of Living Marine Resources in China Coastal Seas". It is regarded as a contribution providing a regional study of coastal ecosystems and its living resources dynamics. The scientific objectives of the program is to

- ◊ determine impacts of key physical processes on biological production
- ◊ determine cycling and regeneration mechanisms of biogenicelemen
- ◊ determine basic production processes and zooplankton role in the ecosystem
- ◊ determine food web trophodynamics and shift in dominant species.

There are 6 key scientific questions establish by Chinese GLOBEC. They are

1. energy flow and conversion of key species
2. dynamics of key zooplankton population
3. cycling and regeneration of biogenicelement
4. ecological effect of key physic processes
5. pelagic and benthic coupling
6. microbial loops contribution to main food web.

Chinese GLOBEC studies in the East China Sea and the Yellow Sea are examples of regional contributions to GLOBEC studies of shelf ecosystems. In the past five years studies have focused on anchovy spawning ground and recruitment mechanism, *Calanus sinicus* dynamics and its over-summering strategy, mechanisms that determine the over-wintering ground of anchovy, biogenic element cycling, and decadal change of the East China Sea and the Yellow Sea ecosystems. 18 multidisciplinary surveys, totaling about 340 days at sea were completed from 1999-2004 to investigate these key dynamic processes. The major progress and results achieved by Chinese GLOBEC are:

1. Anchovy spawning ground surveys
    - Anchovy larvae are mainly distributed in inshore tidal front zones, in the upper 10 m layer; no distinct vertical migration was found.

- No clear distributional relationship was found between anchovy larvae and its prey.
- The percentage of dead eggs was very high rate with the mean of 83% and maximum of 97%.
- New insights obtained on prey and predator relationship.
- Regions of dense anchovy larvae are more related to physical effects than trophic (biological) effects.

2. Over-summering strategy of *Calanus sinicus*
    - *C. sinicus* spawn around the whole year, but concentrated mainly in spring and summer.
    - C. *sinicus* has marked spawning rhythm; its fecundity and hatch rate was not significantly affected by temperature, but hatching duration was affected.
    - Adult copepods collected in field spawn and hatch in the laboratory
    - Feeding activity is with high digestive enzyme and metabolism activity at low temperature.
    - Activity of digestive enzyme decreases 3-4 times and respiration rate halved at high temperature.
3. Ecological efficiency of high trophic level
    - Basic framework model of food web simplified for the spawning ground off Qingdao was developed.
    - Data on daily consumption, feeding periodicity, ecological conversion efficiency of some key species was obtained.
    - Experiment for bioenergetics studies on pelagic species (Spanish mackerel, chub mackerel, red-nose anchovy, dotted gizzard shad, sand lance) was devised.
    - Bioenergetics parameters have been estimated for about 20 fish and invertebrate species, and are quite dynamic and variable among species.

PICES XIII S9-2138 Invited
Ecosystem structure and function on the Gulf of Alaska shelf

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This talk provides an overview of the Coastal Gulf of Alaska GLOBEC Program by drawing upon results of the monitoring, process, mesoscale, and retrospective components.

The seasonally-varying Aleutian Low induces large annual cycles in air-sea heat flux, runoff, and winds, which with complex shelf bathymetry and coastal orography, form the physical basis of this environment. These effects establish substantial cross- and along-shelf circulation and hydrographic gradients reflected in stratification, nutrient transport pathways, and the production, distribution, and community composition of phytoplankton, zooplankton, and fish. Cross-shelf variability in phytoplankton and zooplankton appear linked to freshwater dispersal processes and along- and cross-shelf transports. Nutrient ratios, phytoplankton size distributions, and the greater abundance of *Neocalanus* in low-salinity waters, possibly reflect bottom-up control. Pink salmon distribution and size also depend upon salinity, with greater fish abundance in low salinity, nearshore waters, but larger size juveniles in saltier, offshore waters. Both bottom-up and top-down controls appear to influence fish recruitment.

Interannual and longer-term physical variability is manifested in fall-winter heat fluxes and runoff associated with the position and strength of the Aleutian Low. These influence biological production through variability in the onset of springtime stratification, transports, and possibly through iron availability via runoff. Interannual variability in the summertime frequency of wind-mixing and/or weak upwelling affects nutrient replenishment in the surface layers and summer productivity. The talk concludes with speculations on how a warmer and wetter winter environment, as envisioned under global warming scenarios, might affect this ecosystem.

PICES XIII S9-1871 Oral
Changing ocean conditions in the Northern California Current: 1997-2003

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GLOBEC sampled the northern California Current (42N to 45N) seasonally from July 1997 to November 2003, experiencing a rich variety of ocean conditions: strong El Niño (1997-8), moderate La Niña (1998-2001), weak El Niño (2002-3) and an invasion of Subarctic water (2002). Meanwhile coho salmon survival recovered from record low rates of <1% of smolts released during 1992-7 to >3% for smolts released since 2000. In 1999, the North Pacific atmospheric pressure pattern changed from the positive PDO pattern that characterized the region since 1976-7; we compare recent conditions to those during 1961-72. El Niño in 1997-8 was the strongest of the century. The effects of the following La Niña and El Niño were subtler. The unusual invasion of Subarctic Pacific water into the northern California Current in summer 2002 produced dramatic results: water in the halocline, which supplies much of the upwelling along the Oregon coast, was unusually cold and enriched in nutrients; southward flow was unusually strong; chlorophyll concentrations were exceptionally high. Colder water and high integrated chlorophyll were again present in summer 2003. In the halocline, the competition between the warming influence of El Niño in 2002-3 and the cooling influence from the Subarctic was won by the Subarctic during summers 2002 and 2003. However, effects of El Niño became apparent at depth by fall 2002 and in the upper 100 m during winter and spring. Whether the increased influence of the Subarctic will continue is a matter of conjecture at this time.

PICES XIII S9-2175 Poster
Seasonal and interannual variability in the distribution and dynamics of nutrients and chlorophyll across the Gulf of Alaska shelf: 1998-2000

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The northern Gulf of Alaska shelf is a productive coastal region that supports several commercially important fisheries such as salmon, halibut, and pollock. The mechanisms supporting such high levels of productivity over this shelf however are not understood since it is a downwelling-dominated shelf. In an effort to understand the mechanisms driving such high biological productivity, the cross-shelf nutrient distributions were sampled 18 times throughout 1998, 1999, and 2000. Nitrate, silicate, and phosphate were positively correlated with salinity indicating an offshore nutrient source. Throughout the summer months, the upper 10-20 m across shelf was depleted of nitrate, silicate, and phosphate over the inner and middle shelves and depleted of nitrate and phosphate over the shelf break and slope; however, just below this nutrient- poor layer the water column was nutrient-replete. During each summer, there was an onshore flux of dense nutrient-rich bottom water onto the shelf when the downwelling relaxed. This seasonal flux created a nutrient reservoir near the bottom of the inner and middle shelves. The reservoir was eventually mixed throughout the water column during the winter months. There was a large degree of interannual variability among the three years, which included El Niño (1998) and La Niña (1999) years. Nutrient concentrations and phytoplankton biomass were generally highest in 2000, except in May 1999, when a large eddy traveling along the continental slope greatly enhanced phytoplankton biomass. Daily new production estimates based on nitrate disappearance averaged over the spring-summer season ranged from 2.5-7.0 mmol nitrate m^{-2} day^{-1}.