# PICES

North Pacific Marine Science Organization (PICES)

Seventh Annual Meeting

# abstracts

## October 14 - 25, 1998

Fairbanks, Alaska, U.S.A.

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7AM1998-SB01 oral

## EL NIÑO SEA LEVEL SIGNAL ALONG THE WEST COAST OF CANADA

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During strong El Niño winters the sea levels along the West Coast of Canada typically rise about 10 to 20 cm above seasonal levels, and remain at this height for several months. During the 1997/98 El Niño, sea levels rose 10 cm in May 1997, 20 cm in the autumn, and 30 cm in January and February 1998. The January one-month average level was an all time high at four ports, and the highest for any January at six ports. Sea levels dropped abruptly at the end of February and have remained low since then.

The spatial variability of this sea level rise in coastal waters is evident in TOPEX/POSEIDON data. Sea levels drop in height away from shore, but the rise due to El Niño is present beyond the edge of the continental shelf. Temperature and salinity profiles along line P, extending from the mouth of Juan de Fuca Strait to Station P at 50°N, 145°W, will be examined to determine the nature of water mass variability during this El Niño compared to long term conditions. Dynamic heights computed from these profiles will be compared with TOPEX/POSEIDON altimetry records.

7AM1998-SB02 poster

## NEW POINT OF VIEW ON EL-NIÑO MECHANISM

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The opinion of some scientists about lack of progress in forecasting El-Niño because of incorrect interpretation of it's mechanism is well-grounded. The essence of large-scale interaction of tropical ocean and atmosphere is in constant water gain from east to west by trade-winds. The wind field is formed by four centers of atmospheric action. Hawaiian and Tahitian centers are stationary (anticyclones). Asian and Australian ones are seasonal. When there is a cyclone above Asia, there is anticyclone above Australian and vice versa. Theoretically the breaching of waters to east (El-Niño phenomenon) can arise in two situations: 1) under simultaneous abnormally weak development of seasonal anticyclone and abnormally deep development of seasonal cyclone (the trade-wind of winter hemisphere becomes critically weaker and monsoon of summer hemisphere becomes stronger on the Western Pacific); 2) in case of asynchronous seasons alternation in Asia and Australia cyclones can exist during some time (trade-winds do not reach the Western Pacific, monsoons can be seen in northern and southern hemispheres). Opposite situations must provoke Anti El-Niño phenomenon. Analysis of depth of development and the continuation of naturally synoptical seasons in Asia and Australia was done based on the numbers of daily atmospheric pressure in Hong Kong and Darwin from 1984 through 1987. During this period one episode Anti El-Niño and one El-Niño was noticed. Analysis confirmed the reliability of theoretical suggestion. Statistical testing of stability of discovered connection at longer numbers of observations.

7AM1998-SB03 oral

## THE EL NIÑO SIGNAL ALONG THE WEST COAST OF CANADA - TEMPERATURE, SALINITY AND VELOCITY

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During the 1997/98 El Niño the temperature and salinity fields off the west coast of Canada changed dramatically. The signal is particularly strong in temperature, but also substantial in the salinity anomaly field. A series of maps and sections will be presented documenting the progression of the El Niño signal in these variables. Data presented derives from extended surveys along Line-P and in the La Pérouse region off southern Vancouver Island.

The surveys along Line-P can be used to compute geostrophic velocity fields. With the assistance of data gathered using the Topex-Poseidon satellite (see previous paper by Crawford, Cherniawsky and Foreman) absolute pressure fields can be estimated. This allows the estimation of the absolute velocity and its anomaly during the El Niño. The techniques for completing this calculation will be outlined, the estimate will be compared with direct current observations, and the implications for the origin of the El Niño anomaly will be discussed.

7AM1998-SB04 oral

## THE STATE OF THE FAR EAST SEAS DURING THE 1997/98 EL NIÑO EVENT

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Oceanographic conditions, mainly temperature fields, in the Bering and Okhotsk Seas in 1997/98 are compared with those in previous, non-El Niño years (1995-1996). The study is based mainly on weekly and monthly sea surface temperature (SST) maps constructed at VNIRO as a part of the program on the use of satellite and ship data to monitor the dynamics of SST in various fishing areas of the world ocean. The main purpose of the program is to provide Russian fishery community with operative and monthly information on the state of environment in regions where Russian fleet operates. Data of several oceanographic surveys conducted in the Sea of Okhotsk and western Bering Sea in 1995-1997 are also used. They show a significant change both in geostrophic circulation and values of temperature at intermediate depths of both seas from 1995-1996 to 1997. Thus, water temperature in the Warm Intermediate Layer off Navarin Cape in the western Bering Sea in 1997 was about 3.9-4.0°C, that was unusual for this area. Dynamics of ice cover (ice cover area, position of ice margin) is also analyzed. Changes in atmospheric circulation including storm tracks over the Northwest Pacific are considered. Finally, the analysis of the impacts of unusual events of 1997/98 on fishery in both seas is made. As a whole, the study will cover the period from January 1995 to September 1998.

7AM1998-SB05 oral

## 97/98 OCEAN CLIMATE VARIABILITY IN THE NORTHEAST PACIFIC: HOW MUCH BLAME DOES EL NIÑO DESERVE?

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The rapid warming of the coastal NE Pacific in the spring and summer of 1997 is viewed in relation to local and remote atmospheric anomalies in the Pacific Basin. North Pacific climate anomalies observed in 1997/98 are compared and contrasted with those observed in past warm episodes in the Northeast and tropical Pacific, respectively.

Of particular interest is the extent to which the tropical ENSO is reliably teleconnected to the ocean climate of the northeast Pacific. This issue is addressed by compositing atmospheric circulation anomalies for events showing coherent and incoherent temperature anomalies between the tropical and northeast Pacific.

7AM1998-SB06 oral

## LARGE NUMBERS OF SARDINES RETURN TO BRITISH COLUMBIA WATERS

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In June and July of 1997 we estimated that approximately 60,000 t of sardines were present off the west coast of Vancouver Island, B.C. In late July, sardines were observed in spawning condition and in early February, 1998 large numbers of juvenile sardines were found mixed with juvenile herring off the west coast of Vancouver Island, Canada. Large numbers of sardines have not been found off British Columbia since the mid-1940s. It was believed that the stock which supported the large B.C. fishery of the 1920s, 1930s and early 1940s was currently at such low levels that sardines would not reappear in Canadian waters in any abundance. Not only was this abrupt increase in abundance unexpected but the spawning in British Columbia waters was the first reported in history, as the sardine population supporting the historic fishery spawned off California. It is not known if the reappearance of large numbers of sardines off B.C. is an anomalous event associated with the 1997-1998 El Niño or if it is an indication of a major change in the west coast ecosystem.

7AM1998-SB07 poster

## DID CANADIAN SOCKEYE INVADE THE UNITED STATES? ...ANOTHER STORY FROM THE 1997 EL NIÑO

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The most extreme summer SST and sea level anomalies recorded during this century occurred along the coast of B.C. during the summer of 1997. In August, unusual catches of sockeye began occurring in

rivers in Oregon. In September, sockeye began appearing in the Johnstone Strait test fishery with secondary sexual characteristics that are not normally observed until the fish are close to their spawning grounds. A few weeks later, spawning sockeye were observed in rivers, streams, spawning channels, and even ditches where they had never been seen. They were also reported in high abundance in rivers where they had been rare, particularly on the west coast of Vancouver Island. As Fraser River sockeye are the only abundant populations in the southern part of the sockeye range, and they were abundant in 1997, the popular hypothesis was that these "strayers" were Fraser River sockeye that had spawned in other rivers. One alternative hypothesis was that these were small local populations that had experienced high survival. A call for samples was distributed to field staff around Vancouver Island to try to obtain whole fish, or tissue samples, or scales from these sockeye (during the course of their regular duties). This study describes the results of stock identification analyses that were used to determine the origin of the "straying" sockeye and we examine hypotheses to explain the unusual phenomenon.

7AM1998-SB08 poster

## DISSOLVED $O_2$ AND $N_2$ MEASUREMENTS AT STATION P4 DURING THE 97-98 EL NIÑO

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We present preliminary results and interpretation of measurements obtained at the N.E. Pacific El Niño monitoring station at P4 during September 97 to May 1998. Our time series measurements, recorded at 20 m depth with a 1 hour sampling period, include dissolved oxygen and nitrogen concentrations, total dissolved air pressure or gas tension, Fl, T and S and acoustical back-scatter intensity. A bloom event is identified during mid-March, lasting approximately 10 days. These data may be compared with historical measurements and differences interpreted in terms of the impact of the El Niño on the N.E. Pacific productivity.

7AM1998-SB09 oral

## DATA COMPILATION AND PRELIMINARY TIME SERIES ANALYSIS OF ABUNDANCE OF A DOMINANT INTERTIDAL KELP SPECIES IN RELATION TO THE 1997/1998 EL NIÑO EVENT

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British Columbia coastal waters were significantly warmed during the 1997/1998 El Niño event. This report provides information on intertidal kelp abundance before, during, and after this warm water event. Hedophyllum sessile (*Laminariales, Phaeophyceae*) is a kelp species which can form dense, perennial beds in the intertidal zone. Data included in this report were collected by different investigators at eight sites from June 1991 to May 1998. Four of these sites are located in different positions within the same bay area on Trevor Channel, Barkley Sound, British Columbia. However, these sites were intensively studied throughout the sample period and thus provide a solid baseline

against which population trends during and after the El Niño can be compared. Data collected at this location were: kelp percent cover, adult and juvenile density, reproductive status, a biomass index, and cover of various understory species.

In all years at the single bay area, percent cover, biomass, and adult density seasonally fluctuate; these parameters are high in summer months and low in winter months. Peak recruitment occurs in late spring/early summer months. Despite these normal, seasonal fluctuations, there are trends associated with the 1997/ 1998 El Niño event. Overall, algal biomass and recruitment were negatively affected from June 1997 to February 1998. Specifically, there was recruitment failure at a location which previously had successful recruitment since 1991. However, both of these parameters (biomass and recruitment) appear to be recovering based on April and May 1998 sampling dates. At the most intensively studied site, adult densities in previously dense kelp beds are still low and there is no apparent increasing trend in adult densities. These beds will only recover if the newly recruited juveniles (in May 1998) survive.

Other sites in Barkley Sound were sampled at least once prior to 1997. In May 1998, these sites did not show low adult densities. However, previous years data suggest that these sites were not locations of dense kelp beds. In conclusion, data within this report indicate that a location with previously dense intertidal kelp beds has changed dramatically since the 1997/1998 El Niño event but that this trend was not supported in preliminary samples taken at other locations. Suggestions for future analyses include multivariate analysis of the data to isolate effects of warm water from those of increased storm activity and sampling at other sites which previously had dense kelp beds.

7AM1998-SB10 poster

## IMPACT OF THE 1997/98 EL NIÑO ON SEABIRDS OF THE N.E. PACIFIC

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To a large extent, seabirds are constrained to reside in specific parts of the ocean on the basis of the characteristics of the marine climate. Each water mass or group of similar adjacent water masses has a characteristic assemblage of seabirds. Large-scale events that perturb marine climates should produce changes in seabird community characteristics consistent with the water mass alterations. Because the factors that constrain seabirds to particular water masses are poorly understood, it is difficult to predict their response to large-scale perturbations. In May 1996, the Canadian Wildlife Service began to monitor, using standardized survey techniques, the spatial and temporal variability of marine birds along the 1500 km cruise track to Ocean Station Papa (50°N X 145°W). Since than, five additional surveys have been conducted (August '96, February '97, June '97, February '98, June '98). The El Niño-influenced warming of waters near the coast of British Columbia, the depression of the thermocline, and the northward displacement of the Subarctic Boundary, produced dramatic physical and biological effects.

This presentation describes preliminary observations of the impacts of the 1997/1998 El Niño on the distribution and abundance of seabirds in a region of the Northeastern Pacific Ocean, and suggests possible causal mechanisms. Many of the monitored seabirds feed on the same prey as eaten by salmonids. Therefore, the results of this study may provide further insight into the links between large-scale events and commercial fish stock variability.

7AM1998-SB11 oral

## THE 1997-98 EL NIÑO IN THE BERING SEA AS COMPARED WITH PREVIOUS ENSO EVENTS AND THE "REGIME SHIFT" OF THE LATE 1970'S

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The Bering Sea undergoes exceptional seasonal as well as extreme interannual variability. In the mean, winter sea ice advance exceeds 1000 km while in summer the Bering Sea is ice free. Interannual ice variability is as great as 400 km. The interannual variability of the Bering Sea depends in large part on the winter variability of the Aleutian low. Results of analyses of the Aleutian low, monthly mean ice cover from the Bering Sea, and the Southern Oscillation Index (SOI) show that before a regime shift in the late 1970's, below normal ice cover in the Bering Sea was typically associated with El Niño. That is, El Niño conditions caused the Aleutian low to move eastward of normal carrying warm Pacific air from the south over the Bering Sea. Conversely, above normal ice cover was associated with La Niña conditions which caused the Aleutian low to move westward of normal allowing higher pressure to move over the Bering Sea. However, since the regime shift, the Aleutian low has been moving even farther to the east during El Niños causing winds to blow from the east and north off Alaska resulting in above normal ice. This Aleutian low movement has caused the correlation of ice with the SOI to change sign compared to before the "regime shift". The effect of the El Niño of 1997-98 on the Bering Sea is framed against this scenario, as is the developing La Niña of 1998.

7AM1998-SB12 invited

## THE BIG PICTURE IN THE NORTH PACIFIC IN 1997-98

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By most accounts we have experienced the largest El Niño in this century in 1997-98. This talk will review the life cycle of winds over the past decade and sea surface temperature anomalies. We will demonstrate the connectivity of the Aleutian low anomalies to the equatorial El Niño. It is also possible to visualize Ekman upward pumping of cold water in the Alaskan gyre. Recent ideas concerning the demise of the Alaskan Stream by the remotely equatorial Kelvin waves.

7AM1998-SB13 oral

## ATMOSPHERIC ANOMALIES IN 1997: LINKS TO ENSO?

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Positive SST anomalies occurred in the North Pacific in 1997, across the Gulf of Alaska beginning in May, and extending to the eastern Bering Sea (EBS) in June-August. For April-August there were higher 700 mb heights, lower 925 mb humidities (RH) and warmer 925 mb temperatures over the EBS.

Associated reduced cloud cover and increased insolation are consistent with increased SST due in part to atmospheric causes. While anomalies were generally of the same sign for all months for all variables, May and August showed largest values for temperature and height fields, while June showed a minimum RH and a maximum net short wave flux anomaly. All fields were obtained from NCEP. The March-August period resembled the positive phase of the North Pacific (NP) oscillation with a weakening of the westerlies over the EBS. There has been a trend toward the positive phase since 1980. Recent modeling suggests that the NP pattern can be associated with ENSO. The March-May atmospheric anomalies occur before the major equatorial warming, and are associated with an atmospheric blocking pattern, but an equatorial influence in August cannot be ruled out.

7AM1998-SB14 poster

## SHARP CHANGES OF HYDROMETEOROLOGICAL CONDITIONS IN THE NORTH-WESTERN PACIFIC IN PERIOD OF 1997/1998 EL NIÑO EVENT

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Unusual development of the last El Niño (for the first time event have appeared in April, 1997 instead of November or December as a rule) must be reflected on natural conditions of remote regions of the northern N. Pacific Ocean. In present work the separate facts of anomalous changes of hydrometeorological conditions in the northwestern Pacific, including the Far Eastern seas, are shown. The significant weakening of cyclonic activity was observed within the region 30-70°N and 130-180°E in January-March, 1997. So, a number of cyclone days at the earth, counted on 5° squares, was minimum (247) relatively of previous three years (337 in 1994, 335 in 1995, 296 - in 1996). It was especially expressed for the western part of the circulation was timed for minimum solar activity (data of V.F. Chistyakov, Ussuriskaya Observatory). Low ice conditions were revealed in the Okhotsk and Bering Seas. Unusual warm summer was observed in Primorye. Positive temperature anomalies were registered at the northern Okhotsk Sea shelf, the Western Kamchatka and also in the north of the Bering Sea. As a result, based on data of TINRO-Centre specialists, the unusual distribution of marine hydrobionts was found: appearance of *Eumicrotremus soldativi* low abundant year-class (Melnikov, 1997), displacement of *Paralithodes camstehatica* to the south (Myasoedov, 1997), spreading of *Chionocetes opilio* to the north near the cape Navarin and even in Anadir Bay (Slizkin, 1997). In January-March,1998 the meteorological situation has changed sharply on the contrary. A number of the cyclone days has increased relatively 1997 (319). The ice area in the Sea of Okhotsk (84% for 9 March) was significantly larger than during previous years with low ice conditions. In February, 1998 practically not one cyclone went to the sea of Okhotsk. In January-March, 1998 the ice edge at the Bering Sea was on 90-100 miles more south than in 1997. All above mentioned facts reflect indirectly the impacts of the 1997/98 El Niño event on the N. Pacific Ocean and its marginal seas.

7AM1998-SB14 oral

## HYDROGRAPHY AND ZOOPLANKTON OFF THE CENTRAL OREGON COAST DURING THE 1997-1998 EL NIÑO EVENT

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I had the good fortune to initiate monitoring of hydrography and zooplankton offshore of Newport, Oregon prior to the 1997-98 El Niño event. Stations 1, 3, 5, 10 and 15 miles off Newport were sampled biweekly beginning in May 1996. In 1997, upwelling began as usual in late March indicating the onset of the spring transition. A boom in zooplankton production followed in April. In May, northerly winds weakened, upwelling relaxed, Columbia River plume water moved onto the shelf, and zooplankton numbers began to decline. A second upwelling event lasting five weeks occurred from 12 July through 19 August, but with little biological response; subsequently, upwelling ceased altogether. Sea surface temperatures on the shelf warmed from 12-17°C during the period of extended relaxation from May until mid- July. Surface waters cooled to 10°C during the July/August upwelling event. In late August surface waters warmed to a record temperature of 18.5°C, warmer by 1 degree than any observation made during the 1983 El Niño event. Secchi depths were deep during both the early and late summer warm events, averaging 10 m during June/July and exceeding 15 m during the late-summer warming event. Usual secchi depths are on the order of 3-5 m during the summer upwelling season.

The copepods captured in shelf waters during April/May and during the July/August upwelling events were boreal species. During relaxation of upwelling in May/June and August/September, species captured were those normally found in waters offshore of Oregon. During the winter months of 1997/98, the zooplankton were typical of those expected with the Davidson Current -- i.e., species with southern and offshore affinities. In spring 1998, these same southern and offshore species continued to dominant the zooplankton through at least mid- June, chiefly because upwelling had not become established. In contrast to the 1982-83 El Niño, very few "unusual" zooplankton, fish or bird species were seen in Oregon's coastal waters. Thus, the greatest effect of the 1997/98 El Niño on the coastal zooplankton community was a reduction in biomass and production of local zooplankton species due to a shortened upwelling season in 1997 and a delayed start of upwelling in 1998, and changes in community structure due to advection onshore of species which are normally found off Northern/Central California and/or in waters well offshore of Oregon.

7AM1998-SB16 poster

## BIOLOGICAL EFFECTS OF THE 1997/98 EL NIÑO IN LOWER COOK INLET, ALASKA

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We have been studying the biology of seabirds in relation to forage fish abundance at three colonies in lower Cook Inlet since 1995. Parameters measured at colonies for five seabird species include population size, breeding success, chick feeding and growth rates, diets, foraging effort, and

physiological stress. The distribution and abundance of potential forage fish have been measured using hydroacoustic surveys, mid-water and benthic trawls, beach seines, and SCUBA transects. Oceanographic measurements include continuous SST's near colonies, CTD profiles across the inlet, and AVHRR imagery of SST's. In 1997 we initiated sampling of nutrients, phytoplankton and zooplankton. Data collected in 1995-1997 reveal a consistent pattern. Upwelling and tidal mixing of deep GOA water at the east entrance to Cook Inlet and advection north to Kachemak Bay support high production of plankton, forage fish and seabirds. Juvenile pollock dominate in offshore waters around the Barren Islands, while sand lance dominate near shore of the Kenai Peninsula and Kachemak Bay; and these are the prey most eaten by seabirds. At Chisik Island, on the west side of Cook Inlet, southbound currents are warmer, fresher, and support low production of plankton, fish and seabirds. Despite warmer than average SST's in 1997 and a large die-off of seabirds in the Bering Sea, we observed no effects on fish or seabirds in Cook Inlet. Warm waters persisted through winter, however, and we observed a large die-off of seabirds in Cook Inlet in May. At this writing (June 30), several signs suggest that forage fish are scarce in Cook Inlet and seabirds will have difficulty breeding at any colony. In any case, we are poised to assess effects, if any, of the 1997/98 El Niño at several trophic levels in Cook Inlet.

7AM1998-SB17 oral

## THE ENSO SIGNAL IN THE NORTH WEST PACIFIC

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The oscillations of ENSO scale (3-6 years) in the oceanographic and meteorological characteristics in the Northwest Pacific were studied. We analyzed the time series of Southern Oscillation Index, air temperature and precipitation at the coastal meteorological stations for the 20th century as well as water temperature profiles and ice extent in the Japan and Okhotsk Seas for the second part of the 20th century. We also considered the time series of meteorological situations in the atmosphere over the North Pacific using systematization and calendar developed by Polyakova (1988, 1996). The calendar includes number of days with certain types of meteorological situations from 1949 to 1997. Six types of typical meteorological situations are associated mainly with different positions of cyclone tracks over the North Pacific.

Some features of the ENSO scale variations in different oceanographic and meteorological characteristics are revealed. It is shown that the total duration of the certain meteorological situations in the cold season is well correlated with both Southern Oscillation Index and temperature of the Okhotsk Sea cold intermediate layer along 149°E. The warm anomaly of the Okhotsk Sea cold intermediate layer in 1983 is associated with a substantial ENSO signal in the atmosphere over the North West Pacific. These phenomena accompany the major equatorial El Niño observed in late 1982 and early 1983. Features of the ENSO signal in 1997-1998 are discussed.

7AM1998-SB18 oral

## COASTAL HYDROGRAPHIC RESPONSES IN THE NORTHERN GULF OF ALASKA TO THE 1997-8 ENSO EVENT

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Temperature and salinity versus depth to 250 m at the mouth of Resurrection Bay, Alaska (60°N, 149°W) (GAK 1) have been measured since December 1970 with various temporal sampling intervals, ranging from hours to months. The ocean climatology suggests that, seasonally, the upper 100 m is fluctuating differently than the lower 150 m. The temperature and salinity signals propagate downward from the surface to about 100 m.

Amplitudes of the interdecadal temperature fluctuations decrease from more than 6°C at the surface to about 3.6°C at 250 m. Fluctuations in the lower 150 m are coherent. Using a threshold level of one standard deviation, below 100 m, positive temperature anomalies since 1974 have corresponded to ENSO events. The 1997-8 ENSO event corresponded to the largest temperature anomaly yet seen at 250 m (1.4°C) (Feb. 1998), more than 3 SD (1 SD = 0.41 C) above normal. The peak took place in February 1998 with first warming arriving in January. This signal first appeared in Jan. 1998 but by May 1998 had subsided to 0.38°C, below the ENSO threshold.

An ENSO salinity anomaly signal is absent at this location suggesting that regional ocean circulation changes do not accompany these events. Changes in the California Undercurrent or atmospheric teleconnections are possible causes of this ENSO signal propagation.

7AM1998-SB19 oral

## OBSERVATIONS OF EL NIÑO OFF OREGON: JULY 1997 TO PRESENT

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Every few months since July 1997, we have made CTD/ADCP sections along the historic Newport Line (44.6°N) from the coast to 150 km. These show anomalous warming and strong northward flow associated with El Niño. In July 1997, classical upwelling structure was observed (isopleths rising toward coast) but all waters above 500 m were warmer than normal, with largest anomalies (3°C) occurring in offshore surface waters. In September 1997, the surface layer was everywhere warm (> 17°C) with low salinity; subsurface slope waters were >1°C above normal with isotherm slope indicating northward advection. In November 1997, surface layer was 1C warmer than normal; subsurface waters over the slope were even warmer than in September and steric height rose steeply toward shore over 60 km, consistent with strong northward flow on shelf. In February 1998, all water on shelf was > 12°C (>2°C above normal); surface temperature decreased from 12.5°C inshore to 10°C at 150 km from coast. In April 1998, isopleths were nearly flat but temperatures in the upper 100 m remained 2°C above normal, similar to April 1983; temperature anomalies at depths below 150 m were <0.5°C. In June 1998, isopleths sloped upward toward the coast less steeply than normal for the upwelling season; temperatures continued to be >1°C above normal only near the coast and in layer

between seasonal and permanent haloclines (30-150 m). Surface salinities over the outer shelf in June were above normal, probably because of weaker-than-normal southward advection of Columbia River water.

7AM1998-SB20 oral

## PHYTOPLANKTON COLLECTED BY A SEDIMENT TRAP DEPLOYED IN THE MIDDLE SHELF DOMAIN OF THE SOUTHEAST BERING SEA DURING 1997

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A swimmer-excluding, time-series sediment trap was deployed in the middle shelf domain of the southeastern Bering Sea from late April, 1997, until February, 1998. Diatom frustules were the most abundant, identifiable components of the trapped material during spring and early summer. *Fragilariopsis* were the most numerous diatoms in the early spring sample (22 April to 6 May), which represents material that sank at the end of the spring bloom. Few diatom frustules were seen in the samples from 20 May to 1 July, probably because of nutrient depletion of the water column. Another peak in diatoms was seen in mid to late July, but this was dominated by Detonula and Odontella. Several samples from July and August also contained numerous small falgellates. No coccoliths were seen in samples from the first deployment, which ended 2 September. However, coccoliths were very abundant in the first three samples of the second deployment, from 22 September-27 October. The timing of the trap coccolith collections coincided with the onset of fall mixing. The stable nitrogen isotope composition of the sediment trap samples was relatively depleted in N-15 from 22 April to 6 June, and from 22-29 September, when peaks in diatom frustule and coccolith abundance occurred. This suggests that the trapped material consisted mainly of ungrazed phytoplankton at those times.

7AM1998-SB21 oral

## REDISTRIBUTIONS OF CETACEANS IN THE SOUTHEAST BERING SEA RELATIVE TO ANOMALOUS OCEANOGRAPHIC CONDITIONS DURING THE 1997 EL NIÑO

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During the summer of 1997, anomalous oceanographic conditions occurred in the Southeast Bering Sea. By mid-July, sea surface temperatures were 2-4°C warmer than in 1996 and an extensive coccolithophore bloom, approximately 380 km wide, developed over the middle shelf. Both the occurrence of the bloom and the unusually warm temperatures have the potential to alter the trophic dynamics and prey availability in the region. Results of a cetacean survey across the Southeast Bering Sea shelf from July 17 - August 5, 1997, suggest that redistributions of some cetacean species may have occurred. Five species of large whales occurred in or near the bloom: fin whale *Balaenoptera physalus*, humpback whale *Megaptera novaeangliae*, minke whale *Balaenoptera acutorostrata*, sei

whale *Balaenoptera borealis*, and northern right whale *Eubalaena glacialis*. The relatively high abundance of large whales south of the Inner Front (50 m isobath) and near the coccolithophore bloom, suggests that conditions on the middle shelf provided productive foraging for cetaceans and their principal prey, euphausiids and copepods. This distribution however contradicts the historical pattern of higher whale biomass associated with the "Green Belt" of the shelf edge. This redistribution is consistent with either a shift in foraging ecology linked to anomalous oceanographic conditions during an El Niño year, or is indicative of a longer-term change in the regional productivity and trophic structure of the Bering Sea ecosystem.

7AM1998-SB22 oral

## PREDICTABILITY AND FORECAST VERIFICATION IN THE EL NIÑO EVENTS

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The 1997-98 El Niño prediction and natural disaster over the coastal areas are reviewed in China. The 97-98 El Niño prediction was very successful in National Research Center for Marine Environment Forecasts. In fact, the El Niño predictions have better skill level, as it is usual in other countries. The strong marine disasters had occurred in the coastal areas of China in 1997. For example, the strongest storm surge in this century was occurred, the sea ice cover was lighter than during the normal years in the Bohai Sea and so on. How can we be certain that the El Niño prediction should have better skill level or not?

A method of forecast verification was made. For each test factor, the following factors was tabulated: average deviation, mean absolute error, tendency correlation, anomaly correlation, absolute correlation, skill index, ability index. The most successful skill was found in El Niño predictions, correlation coefficients were 0.5 - 0.7 with six or more months lead by using statistical - dynamic methods. But, it is still suffered from the predictability barrier in Feb. - Apr.

The central task of El Niño prediction is improving the ability to predict the SSTA. The analyses indicate that the correlation of SST between two or three continuous months is strong, and it shows that the regions with the strongest SST persistence are concentrated on the specific areas. We have to pay attention to it.

It is possible that the operational El Niño predictions in the next few years should be as usual based on the statistical - dynamic methods rather than on the dynamic models.

7AM1998-SB23 oral

## BIOLOGICAL EFFECTS OF THE 1997-1998 EL NIÑO EVENT OFF OREGON: NUTRIENT AND CHLOROPHYLL DISTRIBUTIONS

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As part of the west coast GLOBEC long-term observation program we began measuring nutrient and chlorophyll distributions off the Oregon coast in July 1997. Three types of sampling have been conducted: a broad scale sampling in July 1997 (with R. Emmett, NOAA/NMFS) included eleven transects extending from the shore to 120 miles offshore, high frequency sampling along the Newport hydroline (with B. Peterson, NOAA/NMFS), and additional sampling along 1-3 other transects every few months (with R. Smith et al. Oregon State University). General features of the broad scale survey include evidence of more upwelling, increased nutrients and higher chlorophyll in the southern half of the region compared with the northern half. High frequency sampling along the Newport hydroline showed less upwelling, lower nutrients and lower chlorophyll compared to non-El Niño years. Comparison of the nutrient and chlorophyll distributions with physical data will be presented to suggest the magnitude of the impact of changes in upwelling dynamics on primary production.

7AM1998-SB24 oral

## IMPACTS OF THE RECENT AND PAST EL NIÑO EVENTS ON NUTRIENT SUPPLY, PRIMARY PRODUCTION AND PLANKTON DISTRIBUTION OFF THE B.C. COAST

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On the West Coast of Canada, the warmest surface seawater temperatures ever measured were recorded during the recent El Niño. Elevated SST has been the norm for most of the 1990s, and is coincident with a prolonged 1991-4 and a strong 1997 El Niño. Warming (anomalously high T) is observed to several hundred meters depth in coastal and shelf waters along Line P (a section running westward from the mouth of the Juan de Fuca Strait, out to Ocean Station P); advection from the south is the probable source of the subsurface warm signal. Other T/S sections, further north in the Gulf of Alaska, will be reviewed to look for similar warm waters.

With the increased buoyancy of surface waters in winter (due mainly to warming) comes a thinning of the mixed layer and a reduction in the resupply of nutrients to the euphotic zone. New production rates (nitrate based primary production), calculated from the observed spring/summer removal of nitrate from waters off the coast of Vancouver Island, show a large year to year fluctuation. The results from summer 1998 will be compared to observations made over the past decade, to estimate the impact of this most recent El Niño on primary production and zooplankton species compositions. Information on advective transport is also obtained from zooplankton distributions.

7AM1998-SB25 oral

## STOCK ABUNDANCE AND SIZE COMPOSITIONS OF THE NEON FLYING SQUID IN THE CENTRAL NORTH PACIFIC OCEAN DURING 1979-1998

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The Neon flying squid, *Ommastrephes bartrami*, was the target of the Japanese squid driftnet fishery in the Central North Pacific Ocean during 1979-1992. Interannual variability in catch-per-unit-effort (CPUE) of this fishery was highly correlated with that of the autumn cohort *O. bartrami* of the Hokusei Maru's research driftnet surveys along 175-30°E in July which coincided with the peak of the commercial fishery. The research net CPUEs were 3.6 to 4.6 times higher in 1979, 1994-96 and 1998 than in other years (average 0.58 squid per a 50m net), suggesting effect of the fishing on the stock abundance. In 1997, most prominent El Niño year in this century, the CPUE of research driftnets was lowest (0.53) during 1994-1998 and modal mantle length of the autumn cohort was considerably larger than in other years. Similar trends in CPUE and size composition of the autumn cohort were found in a driftnet survey in April and May and in the newly developed jig fishery during 1997 and 1998.

7AM1998-BIOtopic01 oral

## PHYTOPLANKTON FALL BLOOMS IN THE OPEN WESTERN AND EASTERN SUBARCTIC PACIFIC: ADDED IRON OR RELAXED GRAZING?

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The offshore subarctic Pacific and the deep parts of the Bering Sea, in contrast to their coastal or seasonally ice-covered waters, appear to be High Nitrate-Low chlorophyll (HNLC) areas without spring or summer blooms, the phytoplankton biomass being dominated by small cells. Near the former OWS "Papa", much observational, experimental, and modeling work has shown that the ultimate cause is scarcity of iron, while the proximal cause is grazing by small, principally unicellular zooplankton.

For parts of the offshore regions, however, earlier Soviet studies, focusing on the larger phytoplankton and the larger grazers, and recent Coastal Zone Color Scanner observations have commonly recorded material increases of phytoplankton concentrations in fall. I will discuss seasonal advection of iron from the coast, dust falls, and relaxation of grazing as possible causes.

The overriding issue seems to be: Is our understanding of the offshore eastern subarctic Pacific applicable to the offshore western subarctic Pacific, or are large new shipboard studies required for the latter?

7AM1998-BIOtopic02 oral

## IS THERE A CONNECTION BETWEEN DUST AND FISH?: HOW IS BOTTOM UP AND TOP DOWN CONTROL TURNED ON AND OFF?

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In the subarctic NE Pacific at Station P, ambient iron concentrations generally control the growth of large phytoplankters. If 2 nM Fe is added in shipboard carboy experiments, mainly large diatoms quickly grow up and nitrate, silicate and iron are used up in 5-7 days. When these large cells become nutrient limited (especially due to low Si and/or Fe), their sinking rates increase dramatically (up to 5 times). Even when large mesozooplankton are near their maximum abundance in May, they are not able to crop down this increase in biomass of large phytoplankters in these carboy experiments. In fact, doubling the numbers of large copepods such as *Neocalanus* did not control the increase in these large cells. These shipboard experiments suggest that any rapid increase in large phytoplankters caused by a sudden increase in ambient Fe (e.g. episodic dust event) would not be passed on to fish via mesozooplankton. Instead, this increase in phytoplankton is likely to sink out of the photic zone. Thus a spike addition of Fe is likely to increase export production at Station P. However, if the increase in ambient Fe was gradual over several decades, due to either a decrease in the mixed layer depth as shown by Freeland et al., or due to increased supplies of iron (increased dust storms in Asian deserts due to increased desertification, or horizontal transport from the Alaskan Gyre), then the biomass of mesozooplankton may gradually increase over several years and this increase might be passed on to fish.

7AM1998-BIOtopic03 oral

## CHANGE IN THE CONCENTRATIONS OF IRON IN DIFFERENT SIZE FRACTIONS DURING A PHYTOPLANKTON BLOOM IN CONTROL ECOSYSTEM ENCLOSURES

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To observe the micro-nutrient and carbon dynamics in the plankton ecosystem, controlled ecosystem enclosure (CEE) experiments were conducted in Saanich inlet, B.C., Canada.

Two CEEs (2.5m in diameter, 16m in length, one for Fe study and the other for biological study) were launched for the period 22 July to 5 August 1996 and enriched with 10 $\mu$M nitrate and 5.2 nM iron on day 1. Sampling from three integrated depth, intervals 0-4, 4-8 and 8-12m, was done for the same hours, about 11 am, on days 0, 1, 2, 3, 4, 5, 7, 9, 11 and 14. Fe concentrations were measured for five size fractions; > 20-30 $\mu$m particle, 2-20 $\mu$m particle, 0.2-2 $\mu$m particle, 0.2 $\mu$m-200 kDa small colloidal-particles and < 200 kDa dissolved species. The sediment in the iron enclosure was also collected on every sampling day after day 2 and its iron was also determined. Size-fractionated particulate organic carbon and total chlorophyll *a* were also analyzed.

Of all the size fractions of Fe, the small colloidal-particle fraction decreased most significantly during a phytoplankton bloom. The rate of decrease amounts of Fe in small-colloidal particles was larger than

that of total Fe, from day 1 to day 4. In contrast, the > 20-30 $\mu$m Fe particles increased over the same period. The results suggest that Fe in small colloidal-particles changed to > 20-30 $\mu$m Fe particles during phytoplankton growth. A large amount of Fe was kept in surface layer with phytoplankton, and transported to deep layer by phytoplankton sedimentation, at the end of bloom.

7AM1998-BIOtopic04 oral

## THE CHANGE OF CHLOROPHYLL *A*, NUTRIENTS AND PHOTOSYNTHESIS FROM SUBTROPICAL TO TRANSITION REGION IN JUNE AROUND KUROSHIO EXTENSION

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Larvae of Pacific saury are known to feed on warm-water small copepods around Kuroshio Extension (KE) when they move from subtropical to transition area through KE. We examined the distributions of chlorophyll *a*, nutrients and photosynthesis as well as physical elements such as water temperature in June 1996 around KE at 149°E in order to elucidate the feeding condition for Pacific saury. We estimated serial vertical distributions of chlorophyll *a* from CTD fluorescence and chlorophyll *a* data, nutrients from the relation between water temperature and nutrients, photosynthesis from the relation between natural fluorescence and photosynthesis. Chlorophyll *a*, nutrients and photosynthesis were abundant in upper 40 m at the immediate northern part of KE and these elements distributed relatively uniformly in the upper 60 m at the 60 miles apart south from KE, while they were few in the upper 100 m at the 120 miles apart south from KE. When examined the relation among nitrate (N), phosphate (P) and silicate (Si), N seemed to be consumed firstly. N/P consumed ratio was nearly equal to Redfield Ratio (16) at all station but N/Si ratio was 1.5 in the northern part and 0.5 in the southern one. We concluded that the feeding condition for Pacific saury larvae changed from scarce to productive area and from non-diatom to diatom system. The remaining problem may be the clarification of the meaning of this change for the larvae.

7AM1998-BIOtopic05 invited

## CONTROLLING FACTORS FOR PHYTOPLANKTON BIOMASS IN THE SUBARCTIC NORTH PACIFIC

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Phytoplankton biomass in the surface waters changes little throughout the year and shows a relatively steady annual level of about 0.4 $\mu$gChl-*a*/l for the past three decades in the eastern subarctic North Pacific (Station P). The low biomass has been explained by grazing pressure, iron limitation, or the iron-grazing theory. In contrast, high biomass values have been reported in spring and summer seasons in the western region. Little is known about the year-to-year variation in phytoplankton biomass in the western and central regions.

To clarify the regional and year-to-year variations in phytoplankton biomass and elucidate controlling factors of these variations, chlorophyll *a* concentration was monitored in summer and winter in the subarctic North Pacific, especially in the western and central regions.

In the summertime, in the Western Subarctic Gyre, high phytoplankton biomass was observed in 1993 and 1994. The average chlorophyll *a* concentration (1 $\mu$gChl-*a*/l) in the upper layer was about three times larger (0.4 $\mu$gChl-*a*/l) than that in the Alaskan Gyre, Station P. This observation suggests that iron limitation of phytoplankton growth is weaker in the western gyre.

In the wintertime during the trans-Pacific cruise in 1992, high phytoplankton biomass contributed by large phytoplankton was occasionally observed in the western and central region, but not in the east. The high biomass of the large phytoplankton was likely to be caused by the more turbulent condition of water column induced by stronger winds.

Based on the summertime observations in the central region from 1985 to 1994, phytoplankton biomass tended to be higher in the odd-numbered years and lower in the even-numbered years. It is possible that the grazing effect by higher trophic levels plays an important role in the year-to-year variation.

Based on these results, iron and wind may play an important role in the regional variation in phytoplankton biomass, whereas grazing may be related to the year-to-year variation.

7AM1998-BIOtopic06 oral

## MICROZOOPLANKTON IN THE SUBARCTIC PACIFIC: TEMPORAL VARIATION AND ITS SIGNIFICANCE FOR GRAZING CONTROL OF PHYTOPLANKTON

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Microzooplankton in the open subarctic Pacific are demonstrably the major source of grazing mortality for phytoplankton, as well as the major source of nutrition for calanoid copepods. Little is known, however, about this key trophic link. This paper presents results of a GLOBEC retrospective analysis of subarctic microzooplankton standing stocks, size structure, and taxonomic composition over an 11-year period (1987 to 1998). Preliminary results indicate that seasonal cycles in microzooplankton biomass are minimal, with winter biomass levels equaling those typical of midsummer. This contradicts model predictions for this region, which indicate that seasonal cycles in primary productivity should translate into seasonal cycles in microherbivore biomass.

In contrast to the seasonal near-constancy in biomass, pronounced seasonal cycles in population size structure (cells larger, on average, in the winter) and taxonomic composition are evident. This suggests that physical forcing of the microplanktonic food web in this region may occur more through shifts in community composition than through gross changes in biomass. Further, the absence of summer microzooplankton biomass increases suggests a tight coupling between primary production and higher trophic level consumers (i.e. copepods). An analysis of interannual variability in microzooplankton biomass and community structure will also be presented.

7AM1998-BIOtopic07 oral

## INTERDECADAL VARIATIONS OF PLANKTON BIOMASS IN THE NORTH PACIFIC

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In the central and western subarctic Pacific, zooplankton biomass and chlorophyll concentrations during the later 1960's to mid 1970's were a few times higher than those in the preceding and following decades, which corresponds to higher values of the atmospheric northern hemisphere zonal index (NHZI). In the Alaskan Gyre, however, it was reported that biomass of zooplankton and nekton doubled after the atmospheric regime shift in the mid 1970's. In the subtropical North Pacific, chlorophyll *a* concentration drastically decreased after 1980, although a decrease of zooplankton biomass was clear only in the northern part of the subtropical gyre. Chlorophyll concentration in the central subarctic Pacific and zooplankton biomass in the Oyashio have been decreasing since early 1980's, and chlorophyll concentration in the western subarctic Pacific and eastern Bering Sea, and zooplankton biomass in the central subarctic Pacific and eastern Bering Sea since late 1980's have also been decreasing. In these regime shift-like phenomena, there is a general tendency that intensification of the wind speed or destratification causes plankton biomass to decrease in the region where the upper mixed layer is deep, such as the western subarctic and northwestern subtropical water, but to increase in relatively stratified areas, such as in the eastern subarctic and southwestern subtropical water.

7AM1998-BIOtopic08 oral

## IMPORTANCE OF LOW SALINE ADVECTED WATER FROM THE OKHOTSK SEA FOR SPRING BLOOMING OF PHYTOPLANKTON IN WEST SIDE OF THE NORTH PACIFIC OCEAN

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At the previous PICES meeting we had investigated west-east comparison of phytoplankton seasonality in the subarctic North Pacific Ocean and suggested that formation period of seasonal pycnocline controls spring blooming magnitude. Here, we expand the survey area in west side of the North Pacific, and considered causes of the seasonal pycnocline formation. Decreasing in the salinity affected not only spring blooming in the Oyashio water, but also in the Transition water. In both waters, decreasing upper layer salinity causes the seasonal pycnocline formation in April. We considered that two factors attribute the salinity decrease, one is precipitation and another one is advection of low salinity water from the Okhotsk Sea. The maximum precipitation is in July, and in April is not so large in west side of the North Pacific, hence, the role of precipitation is small. Upper layer of the Okhotsk Sea is of low salinity concentration relatively to Pacific side waters. Satellite images indicated the Low salinity, high Chl-*a* concentration water intrude in the offshore of the Oyashio water from the Okhotsk Sea in April. We hypothesis that the advection of the low salinity water from the Okhotsk Sea guide to the seasonal pycnocline formation, and the early start pycnocline formation may play important role in the spring blooming in the Oyashio and Transition water.

7AM1998-BIOtopic09 oral

## DEEP PHYTOPLANKTON UPTAKE AND GROWTH ON THE SOUTHEAST BERING SEA SHELF IN 1997 AND 1998

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Prior studies of nutrient-phytoplankton dynamics of the Southeast (SE) Bering sea shelf during PROBES observed a regular sequence of weather events that produced water column stratification for the initiation of a phytoplankton bloom over the middle and outer shelf regions. Field studies of the Southeast Bering Sea Carrying Capacity (SEBSCC) and Inner Front programs in 1997 and 1998 occurred during periods of anomalous weather which in turn produced unusual phytoplankton dynamics over the SE Bering Sea shelf. The weather during the late spring and summer 1997 was very calm with light winds that produced a strong shallow pycnocline that allowed phytoplankton to occur in the bottom layer. In contrast, the weather during the early summer of 1998 was windy which only allowed the formation of a weak pycnocline for short time periods. The well mixed water column hindered a strong phytoplankton bloom so the nutrients were slowly depleted over the entire water column and phytoplankton biomass increased very slowly. These two anomalous years apparently producted different phytoplankton species and/or size classes. The highly unusual coccolithophorid bloom in 1997 probably resulted from the relatively warm waters, low concentrations of nutrients and atypical nutrient ratios. The oceanographic conditions during the summer of 1998 are different but the oceanic conditions for another unusual phytoplankton bloom may exist.

7AM1998-BIOtopic10 poster

## PHYTOPLANKTON IN THE NORTH-EAST PART OF THE OKHOSK SEA AFTER ICE THAWING

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Main factor controlling phytoplankton development during winter in the Okhotsk Sea is convection. We conducted survey in the region 54°20'-54°00'N, 153°20'-154°40'E from 23 March to 14 April 1998, when winter convection process just have finished. To define vertical temperature distribution we used TR-1000-F Data Logger. The standard spectrophotometric method was used to determinate phytoplankton pigments. Samples were fixed, concentrated and than the species composition was determined by settling method.

Pigment and species composition of samples taken through 50-100 m shown very spotty character of phytoplankton distribution. Its concentration varied in 2-3 times on a distance of 250-300 m.

Spottiness in phytoplankton distribution remained when samples were averaged on a distance of 1 km. Its scale was about 10-15 miles.

Dominant species were *Gymnodinium simplex*, *Thalassiosira sp.*, *Criptophyta*, small flagillates. Concentration of chlorophyll *a* varied from 0.129 to 2.422 mkg/l.

Two different types of temperature distribution were observed in studied area. First type characterized water of the Okhotsk Sea, and another one waters of the West Kamchatka Current.

Temperature profiles for both types showed a pronounced maximum stratum at the depth of 80-120 m, what witnessed that convection process was weakened during last winter, and the depth of cooling of upper layer did not exceed 80 m. Usually this depth reaches 125 m. Remainders of cold subsurface layer formed by previous winter were observed at the depths of 120-150 m.

We suggest that two different scales of space variability in phytoplankton distribution are related to two causes: continued convection process and interaction between the West Kamchatka Current and the Okhotsk Sea waters.

7AM1998-BIOpaper01 poster

## EVIDENCE FOR A RECENT INCREASE IN JELLYFISH IN THE BERING SEA, WITH POSSIBLE LINKS TO CLIMATE CHANGE

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We examined quantitative catches of large medusae from summer bottom trawl surveys which sampled virtually the same grid station on the eastern Bering Sea shelf and used the same methodology every year from 1979 to 1997. This series shows a gradual increase in biomass of medusae from 1979 to 1989, followed by a dramatic increase in the 1990s. The median biomass increased ten-fold between the 1982-89 and the 1990-97 periods. The majority of this biomass was found within the Middle Shelf Domain, with a higher rate of increase in the Northwest shelf region. Whether this dramatic increase in biomass of gelatinous zooplankton has resulted from some anthropogenic perturbation of the Bering Sea environment or is a manifestation of natural ecosystem variability similar to that seen in other ecosystems is unclear. However, several large-scale winter/spring atmospheric and oceanographic variables in the Bering Sea exhibited concomitant changes beginning around 1990, indicating that a possible regime change occurred at this time.

7AM1998-BIOpaper02 poster

## FRONTS AND FISH: INTERANNUAL DIFFERENCES IN FRONTAL STRUCTURE AND EFFECTS ON POLLOCK AND THEIR PREY

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A tidal front exists around the Pribilof Islands in the eastern Bering Sea which separates well-mixed nearshore water from the strongly stratified middle shelf water farther offshore. Enhanced mixing of nutrients at the structural front results in high abundances of phytoplankton, zooplankton and micronekton. We examined interannual and between-habitat differences in abundance, distribution,

size composition, age, growth, and feeding habits of age-0 walleye pollock in relation to the physics and biology associated with fronts north and south of the islands during September of three (1994-96) hydrographically contrasting years. The frontal region occurred at similar locations offshore during all years, but thermocline depth varied greatly. Highest chlorophyll and small zooplankton concentrations occurred seaward of the front and were lower inshore of the front. Large zooplankton (euphausiids and cnidarians) were abundant in the stratified offshore waters. Pollock densities were the highest at the front or offshore of the front but were variable by year. The smaller and younger pollock were inshore and at the front compared with those found offshore, but the offshore fish were in significantly better condition. Pollock consumed primarily copepods and euphausiids, although other prey (pteropods, chaetognaths, other age-0 pollock) were important at times.

7AM1998-BIOpaper03 poster

## PRIMARY PRODUCTION OF *AHNFELTIA TOBUCHIENSIS* (*AHNFELTIALES, RHODOPHYTA*) POPULATION IN THE BAY OF IZMENA, KUNASHIR ISLAND

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Regularities of distribution and primary production of *Ahnfeltia tobuchiensis* (*Kanno et Matsubara*) *Mak.* population, an agar-containing red alga, were studied in the Bay of Izmena. Experiments were conducted in a flow-through system under the conditions similar to algal habitats. The population of *A.tobuchiensis* unattached to the ground may be from a few centimeters to as much as 1 m thick. It has been shown that only the upper part of a stratum 15-20 cm thick receives a sufficient amount of light to realize its production potential. While 15-20% of photosynthetically active radiation (PAR) of that falling on the water surface reaches the stratum surface, only 0,1% of PAR from that falling on the water surface penetrates through a stratum 15 cm thick. It has been shown for *A.tobuchiensis* that its photosynthetic rate curve during the daytime mainly follows the PAR intensity curve. The highest values of photosynthetic rate have been measured in the afternoon when PAR reaches its maximum. It is noted that a stratum 15-20 cm thick has peak values of net primary production (NPP) which averages 3.2 gC $m^{-2}day^{-1}$. The total area of *A.tobuchiensis* population was 23,4 $km^2$, and its biomass was 125 000 tons in this area. On average, the NPP of the *A.tobuchiensis* population made up in summer and in autumn was 46.8 and 26.0 % of its biomass, respectively.

7AM1998-BIOpaper04 oral

## THE FEEDING BY A MIXOTROPHIC THECATE DINOFLAGELLATE *FRAGILIDIUM CF. MEXICANUM* ON RED-TIDE DINOFLAGELLATES

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We investigated prey species, prey selectivity, and the growth and grazing rates of a thecate mixotrophic dinoflagellate *Fragilidium cf. mexicanum* feeding on red-tide dinoflagellates and also explored light and nutrient effects on the grazer's feeding. Among red-tide dinoflagellate prey offered, *F. cf. mexicanum* can ingest *Lingulodinium polyedrum*, *Gymnodinium sanguineum*, *Prorocentrum micans*, *P. minimum*, and *Scrippsiella trochoidea*, but it did not feed on *Amphidinium carterae* or *Cochlodinium polykrikoides*. The feeding frequency (FF), based on the percent ratio of *Fragilidium* containing one or more target prey cells to total grazers, was significantly affected by prey species. The maximum FFs of *F. cf. mexicanum* on *L. polyedrum* and *S. trochoidea* after 72 h incubation in unialgal diet were much higher than those for *P. micans*, *P. minimum*, and *G. sanguineum*. *F. cf. mexicanum* strongly selected *L. polyedrum* over *S. trochoidea* in prey mixtures. With increasing mean prey concentration, the growth and ingestion rates of *F. cf. mexicanum* feeding on *L. polyedrum* continuously increased with saturation at a mean prey concentration of approximately 500 cells $ml^{-1}$. The maximum specific growth rate of *F. cf. mexicanum* on *L. polyedrum* under a 12:12 h light-dark cycle of illumination with 20 $\mu E\ m^{-2}\ s^{-1}$ was 0.36 $d^{-1}$, while its growth rate without added prey was -0.05 $d^{-1}$. The maximum ingestion rate of *F.* cf. *mexicanum* on *L. polyedrum*, 3.9 prey eaten *Fragilidium*$^{-1}d^{-1}$, was comparable to those of co-occurring heterotrophic dinoflagellate *Protoperidinium cf. divergens* and *P. crassipes* on the same prey. The ingestion rates of *F. cf. mexicanum* on *L. polyedrum* was not significantly affected by light intensity or nutrient environments when prey was plentiful.

7AM1998-BIOpaper05 oral

## EVALUATION OF COPEPOD GRAZING AS A CONTROLLING FACTOR OF PHYTOPLANKTON IN MASAN BAY, KOREA

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The factors controlling phytoplankton populations such as nutrient, temperature, salinity, and grazing were evaluated in Masan Bay of Korea from the viewpoint of both top-down and bottom-up controls. chlorophyll *a* concentrations were higher in summer (June to August). Especially they were extremely high at the surface layer compared with bottom layer, where dinoflagellates were dominant. Copepods, the most dominant zooplankton in the study area, showed higher abundances in spring and fall, and lower in summer. Low grazing pressure in summer was evaluated to be one of the factor that caused high biomass of phytoplankton in this season. Individual grazing rates of copepods ranged from 0.0096 to 0.2856 Chl-*a*/copepod/day, and individual ingestion rates ranged from 0.432 to 12.852 C/copepod/day. Grazing rates by copepod community in 1-liter ranged from 0 to 3.750 Chl-*a*/day at the surface layer, and from 0.014 to 0.094 Chl-*a*/day at the bottom layer. Average community grazing

rates in 1-liter throughout the water column ranged between 0.007 and 1.850 Chl-*a*/day. Copepod community consumed up to 11.9% of the total phytoplankton biomass in May, and minimum was 0.2% in October.

7AM1998-BIOpaper06 poster

## NEGATIVE EFFECT OF DIATOM DIETS ON EGG PRODUCTION AND HATCHING SUCCESS IN MARINE COPEPOD *PSEUDOCALANUS NEWMANI*

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Clutch size and hatching success in marine copepod *Pseudocalanus newmani* was examined when it was fed on two diatom diets *Chaetoceros gracilis* (*CHA*) and *Phaeodactylum tricornutum* (*PHA*), and two non-diatom diets *Pavlova sp.* (*PAV*) and *Heterocapsa triquetra* (*HET*). Both clutch size and hatching success varied with food algae after the 3rd clutch. The largest clutch size was shown at *CHA*, intermediate at *HET* and *PAV*, and the smallest at *PHA*. Whereas hatching success at both the diatom diets was significantly lower than that at the two non-diatom diets. Clutch size at mixed diets of *CHA* and *PAV* was the same value as at either *CHA* or *PAV*, while the hatching success of the mixed diets was slightly lower than that at *PAV* alone but always higher than that at *CHA* alone. The feeding experiments showed that females of *P. newmani* feed on both non-diatom and diatom algae at the same rate. The eggs exposed to high concentration of the extract from *CHA* exclusively failed to hatch, but those of the same concentration from *PAV* successfully hatched at more than 80%. These results suggest that the negative effect of diatom diets on hatching success in *P. newmani* may be caused by some inhibitory compounds in the diatom cells for copepod embryogenesis. Additionally, the lack of some poly-unsaturated fatty acids in diatom cells may enhance the failure of hatching.

7AM1998-BIOpaper07 poster

## DISTRIBUTION OF *DALL'S PORPOISES* (*PHOCOENOIDES DALLI*) IN THE NORTHERN NORTH PACIFIC OCEAN AND BERING SEA BASED ON HIGH-SEAS SALMON SURVEYS

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The distribution of *Dall's porpoises* (*Phocoenoides dalli*) in the northern North Pacific Ocean and Bering Sea was analyzed using data collected during Japanese high-seas salmon surveys. The data consisted of two sets: those from sightings from 1992 to 1994 and those on incidental catch in surface gillnets from 1981 to 1993.

Among cetaceans recorded, *Dall's porpoises* were most frequently found during sightings and taken in gillnet operations. Two color morphs, dalli-type and truei-type, were found: the latter was restricted to the western North Pacific while the former widely occurred in the northern North Pacific and Bering

Sea. Incidental catch was high south of the Aleutian Islands from May to August and in the Bering Sea in June and July. The species also was often caught off southeast Hokkaido. It occurred in a wide range of sea surface temperatures from 2.8 to 17.4C.

7AM1998-BIOpaper08 oral

## THE EFFECT OF FLUCTUATIONS IN THE INPUT OF NITRATE ON PHYTOPLANKTON BIOMASS AND PRODUCTION: A MODEL ANALYSIS

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The effects of fluctuations in the input of nitrate on phytoplankton biomass and primary production in the mixed layer were examined using a simple biological model with four compartments (nitrate, phytoplankton, zooplankton and ammonium). Simulations were carried out varying the frequency and magnitude of the nitrate input. The model was run using different sets of parameter values to explore the influence of the phytoplankton growth rate and the phytoplankton-zooplankton coupling on model results. Model simulations showed that when phytoplankton growth was close to its maximum growth rate or when zooplankton was food limited, phytoplankton did not respond to variations in the input of nitrate, even when the input of nitrate to the euphotic zone was high. In contrast, the highest response was obtained when phytoplankton growth was nitrate limited and zooplankton grazing was saturated. For typical growth and grazing rates, periods of nitrate fluctuations equal or less than 4 days did not influence phytoplankton biomass and production. On longer time scales, the magnitude of the biomass increase depended on the frequency and magnitude of the input of nitrate, as well as on the zooplankton parameters.

7AM1998-BIOpaper09 poster

## THE INFLUENCE OF HIDROCHEMICAL INVIRONMENTAL FACTORS ON THE PRODUCTIVE INDICES OF *AHNFELTIA TOBUCHIENSIS* (*AHNFELTIALES, RHODOPHYTA*) POPULATION IN THE BAY OF IZMENA (KUNASHIR ISLAND)

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The distribution pattern and the degree of provision with the nutrient availability of the agariferous red alga *Ahnfeltia tobuchiensis* (*Kanno et Matsubara*) *Mak.* were studied during 1989-1990 and 1997 in the Bay of Izmena (Kunashir Island). It has been shown that the areas of maximum concentrations of dissolved oxygen ($O^2$), ammonium [$NH_4^+$] and ortophosphate [$PO_4^{3-}$] are disposed in the central and northeastern parts of the Bay, where the main stocks of *A.tobuchiensis* are concentrated. On average, the concentration of oxygen under the layer of *A. tobuchiensis* increased from 8.2 (0.09 mg $l^{-1}$ to 8.7 (0.08 mg $l^{-1}$ during the day, that testified to the intensive photosynthetic processes in the population. As a result of daily ammonium and ortophosphate assimilation in algae, the decreasing of the concentrations of these nutrients from 5.1 M $NH_4^+$ $l^{-1}$ and 0.45 M $PO_4^{3-}$ $l^{-1}$ to 3.53 M $NH_4^+$ $l^{-1}$ and 0.35 M $PO_4^{3-}$ $l^{-1}$, respectively, was observed in near-bottom water layer. According to the analysis of the molar nitrogen / phosphorus ratios in seawater (N:P ratio was 11.5 (3.3 in the morning and 10.6 (3.3 in

the evening for waters of the Bay) and in algae tissue (N:P ratio was equaled 33 for thallus of *A. tobuchiensis*), the conclusion of the sufficient supply of productive processes by the stocks of the main nutrients in the Bay of Izmena was made.

7AM1998-BIOpaper10 oral

## THE RESPONSE OF PHYTOPLANKTON AND NUTRIENT DYNAMICS TO CLIMATE VARIABILITY IN A COMPLEX COASTAL SYSTEM

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The extent to which the dynamics of marine ecosystems are predictable is of fundamental importance to understanding ecosystem functioning. The complexity of planktonic trophic interactions suggests that marine ecosystem dynamics may be non-linear, and hence that responses to changes in the environment are unpredictable. However, re-occurring seasonal dynamic patterns in nutrients and plankton functional groups, indicate a degree of predictability in whole year dynamics. We report on several years of monitoring data of physical properties, phytoplankton, nutrients, zooplankton, and mussel growth and condition, in a hydrodynamically complex coastal environment: Pelorus Sound, in the north of the South Island of New Zealand. We use this dataset to evaluate the linearity in ecosystem response to climate forcing. Inter-annual variability in phytoplankton abundance, nutrient concentrations, and mussel condition show a predictable response to variability in freshwater inflows - though the affects of water-column stability on light-limited growth of phytoplankton. Thus, despite evident shorter timescale responses of phytoplankton dynamics to changes in both the nutrient supply and zooplankton abundance, the inter-annual variability appears to be determined largely by climate variability. At these longer timescales, we argue that the phytoplankton dynamics in this system may be insensitive to trophic complexity, but highly sensitive to environmental changes which affect the supply of resources (light and nutrients), driving primary productivity.

7AM1998-BIOpaper11 oral

## PRODUCTION AND FATE OF PHYTOPLANKTON OUTSIDE ISHIKARI BAY, HOKKAIDO, JAPAN

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Primary production rates were measured outside Ishikari Bay, Hokkaio by the $^{13}C$ tracer method in February, March, April, July and September. The depth integrated primary production rate in euphotic layer was strikingly high during the spring bloom. The compositions of fatty acids in the photosynthetically produced material and suspended particles were determined by the $^{13}C$-GC/MS method. In April, there was a significant diatom bloom judging from the diatom biomass indexes (16:1/16:0, total C16/C18) and phytoplankton pigment data. Startling production of storage lipids (16:0, 16:1) was observed in the upper 10 m euphotic layer. The low polyunsaturated degree in C16

fatty acids in April was on account of nitrogen limitation in the surface 10 m water, which was made by a developed pycnocline. While a high polyunsaturated degree in C16 fatty acids in suspended particles found at 100 m water depth in April suggests that the suspended particles at 100 m were originated from the particles synthesized in the logarithmic growth period. This is also supported by relatively high Chl-*a* concentration and low fatty acids concentration ratios to Chl-*a* at that depth indicating a large proportion of phytoplankton.

7AM1998-BIOpaper12 oral

## EXPERIMENTAL STUDY OF THE RESPONSES OF MARINE PELAGIC COMMUNITY TO NUTRIENT INPUT USING A MESOCOSM. MACROZOOPLANKTON AND MICROZOOPLANKTON DYNAMICS

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The rolls of grazing by dominant zooplankters (microzooplankton and mesozooplankton) were estimated during a nutrient enrichment experiment using a mesocosms. Grazing rates of microzooplankton, copepods, and *Noctiluca scintillans* were estimated by dilution method, egg production, and apparent growth rate, respectively. The primary production estimated by 14C uptake increased about 11 times from D0 to D3, and the grazing rate by zooplankton also increased 7.4 times. The primary production exceeded the grazing rate from D0 to D5, and the grazing exceeded the primary production only D7, after that, almost balanced rates were observed. The grazing rate of *Paracalanus. parvus* did not increase much although egg production increased responding the phytoplankton blooming, which is because the biomass of the copepod was almost stationery during the experiment. The most important grazer was microzooplankton. The contribution in the grazing was largest from D0 to D7, and the response to the phytoplankton growth was fastest. The grazing by *N. scintillans* contributed a significant portion of the zooplankton grazing after D5, and became the most important grazer D9 and D11. Over all, the contribution of the microzooplankton grazing was the largest as the loss processes of phytoplankton as well as cell sinking. Their response to the phytoplankton growth was very quick, and they remove about 50 % of the primary production constantly.

7AM1998-BIOpaper13 poster

## SENSITIVITY OF SUBTIDAL *CHONDRUS CRISPUS* TO ULTRAVIOLET B RADIATION AND THE ROLE OF SYNTHESIS OF MICOSPORINE-LIKE AMINO ACIDS IN PHOTOACCLIMATION

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The induction and protective role of UV-absorbing compounds known as micosporine-like amino acids (MAAs) was examined in subtidal *Chondrus crispus Stackh.* transplanted for 2 weeks in the spring to shallow water under three irradiance conditions: PAR (photosynthetically active radiation), PAR + UVA, PAR + UVA + UVB. Subtidal thalli collected around Helgoland, North Sea, Germany from 6m below mean lowest low water contained less than 0.1 mg $g^{-1}$ dry weight total MAAs, while intertidal samples contained over 1 mg $g^{-1}$ DW. Transplantation to shallow water led to the immediate synthesis of three MAAs, in the following order: shinorine (max 334 nm), palythinol (max 332 nm), and palythine (max 320), with the shinorine peaking and then declining after exposure to 100 mols photons m-2 (2 days). Maximum total MAA content (2 mg $g^{-1}$ DW) occurred after 2 days induction, exceeding the content normally found in intertidal samples. After 2 days, the total content declined to the intertidal value. Once induction was complete, and in intertidal thalli, the major MAA was palythine. Similar data obtained for all treatments, indicating that MAA synthesis in *C. crispus* is induced by PAR and nor particularly simulated by UV radiation.

The ability of photosystem II to resist damage by UVB was tested periodically during the acclimation period by exposing samples to a defined UVB dose in the lab. Changes in chlorophyll fluorescence (Fv/Fm and effective quantum yield, (II) indicated that PSII function was inhibited during the initial stage of acclimation, gradually improving with time. No difference among screening treatments was detected except in the spring, for samples acclimating under PAR + UVA + UVB, where Fv/Fm and (II were significantly lower than the other treatments. During the first week of each experiment, growth rates were also significantly reduced by UVB. The reduction occurred despite maximum MAA content, indicating an incomplete protection of photosynthesis and growth-related processes.

7AM1998-POCtopic01 poster

## DECADAL VARIABILITY OF RAINFALL IN EAST ASIA

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Since climate system is highly nonlinear, some characteristics are not easily interpreted with linear physics. Many studies on global atmospheric and oceanic variables have pointed out a distinguished low-frequency fluctuation in the climate system.

We investigate on the climatic regime shift of precipitation data of East Asia in the point of view of the time-frequency domain. The climatic regime shift have been analyzed in the 12 years cycle from mid-1970s to mid-1980s, which is not shown in time series of precipitation data over Korean Peninsula except northeast region. Some stations showed the dominant 22 years cycle, but its phase was shifted along longitude. The trend of 3-5 years cycle in precipitation data on the time-frequency domain below

35°N was well matched with the cycle of Southern Oscillation Index (SOI). This situation seems to be occurred as one of regional scale regime shift.

In the mid-1970s, there were decadal climatic regime shift at the 500 hPa geopotential height over Tibetian and Aleutian area. In pre-1976 Tibetian High had negative anomaly and Aleutian Low had positive anomaly, which means both were weak. But the anomaly of Northern Pacific High (NPH) height was oscillated along the mean. In post-1976, Tibetian High has a positive anomaly and Aleutian Low has a negative anomaly, which means both are strong. So NPH has not oscillated like as in pre-1996, but nearly positive anomaly. The trends of NPH is associated with ENSO. The track and initiative region of major Typhoon was significantly changed since mid-1970s as a trace of climate regime shift.

7AM1998-POCtopic02 poster

## PECULIARITIES OF SEASONAL PRECIPITATION DISTRIBUTION OVER THE JAPAN AND OKHOTSK SEAS AND RESTORING OF PRECIPITATION FIELDS BY REGRESSION BETWEEN THE ECMWF MODEL OUTPUT DATA AND THE SUMS OF PRECIPITATION ON COASTAL STATIONS

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The measurement of precipitation over the sea surface is not produced at a regular basis. Nevertheless, this information is very important for the simulation of ocean dynamics to calculate a common mass balance on a sea surface and the water mass formation.

The methods of an interpolation and extrapolation of sums of precipitation at coastal and island meteorological stations are usually used to estimate the precipitation distribution over the sea. That gives approximate representation about a real picture of precipitation above the sea, especially at moving away from the coastal zone. It is important to find methods to approximate a distribution of precipitation over the sea areas.

The monthly and seasonal sums of precipitation over the Japan Sea, Okhotsk Sea and the surrounding continental areas were calculated with use of the daily prognosises of precipitation with 12-hour lead time from the ECMWF high resolution model (T213L31, about 62 km horizontal resolution, 1992-1997 years data). The fields of model sums of precipitation satisfactorily agree with observed sums of precipitation at coastal meteorological stations.

The analysis of distribution of observed at the stations and the model fields of precipitation were realized by a singular value decomposition method (SVD). It showed a high correlation and similarity of first main modes in both fields. On this basis we got the regression equations for restoring of seasonal sums of precipitation over the sea surface from the coastal stations data. Such approach gives more realistic estimates of precipitation over the seas than immediate use of an interpolation and extrapolation from the coastal stations.

The restored by regression fields of precipitation with a high degree of reliability reflect the seasonal singularities of the precipitation distribution including the influence of the orography and regional atmospheric circulation patterns. As example there are the magnification of precipitation on the windward slopes of mountain ridges and during the summer blocking of western cyclones, the winter

minima over the continental coastal zone and the western part the of Japan Sea and the magnification of precipitation above the eastern part of the Japan Sea.

7AM1998-POCtopic03 poster

## PECULIARITIES OF YEAR-TO-YEAR VARIABILITY OF AIR TEMPERATURE AND WATER TEMPERATURE IN THE NORTH-WESTERN JAPAN SEA

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Variability of the hydrometeorological regime of coastal waters of the Northwestern Sea of Japan is analyzed. Specific features of the distribution of mean monthly temperature of air and water over the period of 54-66 years were found on the basis of a series of observations from four coastal hydrometeostations (HMS), State Network of Hydrometeoservice in Peter the Great Bay (1930-1996).

Mean month-to-month variability of water temperature is most likely affected by of the Primorye Current and wind upwelling. Air masses above the investigated region have more uniform temperature. The interannual fluctuations of temperature of water and air were synchronous at all stations. The comparison between El Niño events and years of extremal water and air temperature was made.

Climatic trends were determined. Air temperature exhibited a positive trend at a 5% significance level. A significantly positive water temperature trend was recorded only at HMS of Vladivostok; whereas at Possyet and Gamov stations, situated in the southwestern Peter the Great Bay, there was no significant trend. The only exception was HMS of Nakhodka, located in the southeastern part of the bay, where a negative trend was found.

For recent year from 1983, there was a positive temperature trend at a 1% significance level at all stations.

Monthly trends of distribution of time series of water and air temperature were analyzed for the Possyet HMS. Winters and springs became warmer; summer and autumn temperatures varied in the range of mean many-year values.

7AM1998-POCtopic04 invited

## DECADAL/INTERDECADAL SCALE VARIATIONS FOUND IN THE NORTH PACIFIC

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Decadal- to interdecadal time scale variations are seen in every oceans and the clarification of mechanisms which are responsible to these variations is the most important target in the climate research of the present days (e.g., CLIVAR-DecCen). In my talk, I will try to review the studies on this time scale phenomena found in the North Pacific, mainly from the view point of observational facts and will point out the key subjects to be solved in future works.

It is reported that the regime shift in the Pacific sector occurred in mid 1970s and the next regime shift took place in the late 1980s. Just after the former regime shift, the surface waters in the boundary region between the subarctic and subtropical gyres had been cooled. There are several reports described this cooled water mass was subducted and moved to the south and southwest along the general circulation pattern inferred by the ventilated thermocline theory. However, whether or not this water mass reaches the equatorial Pacific is still open question. Although the lack of data, especially salinity data makes this question so difficult, this is the key point to be solved.

In may talk, I also like to insist the importance of the data archive and rescue as well as retrospective analysis and reconstruction of time series using proxy data, in order to make deep and complete understandings on this time scale phenomena.

7AM1998-POCtopic05 oral

## INFLUENCE OF OKHOTSK SEA-ICE EXTENT ANOMALIES UPON THE ATMOSPHERIC CIRCULATION OVER THE NORTH PACIFIC: IMPLICATIONS TO THE DECADAL CLIMATE VARIABILITY

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Influence of sea-ice extent anomalies within the Sea of Okhotsk on the large-scale atmospheric circulation is investigated using a general circulation model. In response to heavy Okhotsk ice cover, an anomalous surface cold high appears over the ice-covered Okhotsk and the Aleutian low develops over the southern Bering Sea. In a simulation for light Okhotsk ice cover, the cold high over the Okhotsk weakens and the Aleutian low also weakens and is split into two cells. The opposing anomalous wind directions simulated over the Okhotsk and Bering Seas are consistent with well-known observed seesaw-like variability in sea-ice cover between the two seas. Significant response appears not only around the Sea of Okhotsk but also downstream towards North America in the form of a stationary wavetrain in the troposphere. This atmospheric remote response is regarded as a stationary Rossby wave generated thermally through the anomalous surface heat flux distribution, because wave activity flux emanates from the lowest layer over the Okhotsk upward and then to the downstream. The wavetrain appears to be reinforced thermally around Alaska by the anomalous heat fluxes through wind anomalies induced by the wavetrain itself. This study suggests that the atmospheric circulation and sea-ice distribution over the North Pacific may be significantly influenced by anomalous sea-ice cover over the Okhotsk Sea in association, for example, with decadal-scale changes observed in the late 1980's.

7AM1998-POCtopic06 oral

## DECADAL VARIABILITY OF THE ARCTIC OCEAN AND THE GULF OF ALASKA

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An analysis of ocean, ice, and atmospheric variables from the northern high latitudes demonstrates temporal variations at the decadal scale over the Arctic Ocean, the northern Gulf of Alaska, and the Bering Sea. This decadal variation couples the ocean, ice, and atmospheric signals into a single arctic oscillation of the mid- and high-latitude climate system. The present analysis builds on results from a wind-forced barotropic, coupled ice-ocean model forced from 1946 through 1997. The model Arctic Ocean surface oscillates at a ten to fifteen year period, and atmospheric pressure gradients between the north pole and the Aleutian Low are correlated with the arctic ocean oscillation. Our results show that this decadal variability extends over broad regions from the Arctic Ocean to the northern Gulf of Alaska and the Bering Sea. The Arctic Ocean oscillation and its corresponding signals in the North Pacific are a fundamental mode of northern hemisphere climate variation linking variability of the Arctic Ocean to observed river discharge from the Mackenzie and Kenai Rivers, salinity anomalies in the Gulf of Alaska, ice cover in the Bering Sea from 1979, and Alaska permafrost temperatures.

7AM1998-POCtopic07 oral

## SYNOPTIC WIND FLOW PATTERNS OFF THE WEST COAST OF NORTH AMERICA IN RELATION TO RECENT CHANGES IN PACIFIC SALMON CATCHES

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Linkages between winds and ocean circulation are well known. For example, the Bakun Index estimates upwelling from wind direction and intensity. These upwelling estimates have been linked to ocean productivity, where strong upwelling events are usually linked to increased productivity. While large-scale wind forcing on ocean circulation is well known, the persistent trends in the patterns of these large-scale winds are less known. When wind patterns are classified into standard types, there are distinct decadal-scale trends that change after periods of about 5 to 20 years. These large-scale wind patterns can be documented for the north Pacific back to 1900. Trends in southwesterly flow along the coast of North America match the general trends in flow of large rivers such as the Fraser River. Changes in wind patterns also tend to occur at the same time as changes observed for Pacific salmon populations. In the 1990s, from 1989 to 1995 the annual number of days of westerly flow was above the historic average. Beginning in 1995, the trend has been to increasing northwesterly flow, a pattern typical of the 1960s and early 1970s.

7AM1998-POCtopic08 oral

## CHANGES IN ABUNDANCE OF SALMON STOCKS IN THE CONTEXT OF CLIMATIC VARIATIONS IN THE NORTH PACIFIC REGION

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Spatial and temporal features of climatic variations in the North Pacific region over the last 40 years are analyzed, based on data available from Russian Hydrometeorological Center (sea surface temperature, surface air temperature and pressure, H500) and U.S. National Oceanographic Data Center (World Ocean Atlas 1998). Several large-scale subdomains with the coherent sea temperature anomaly fluctuations both on the surface and in the subsurface levels were defined, using a hierarchical clustering method of Ward (1963). The spatial structure of SST anomaly variations in the North Pacific area are characterized by two independent patterns: changes in the SST anomalies in the northwestern and southwestern North Pacific, and those in the eastern and central North Pacific, are out-of-phase. These two patterns are significantly correlated with the well-known atmospheric teleconnection patterns (Western Pacific and Pacific/North American ones, respectively). The combined analysis of all data sets allowed identifying several climatic regimes in the region. During the last 20 years shift from one regime to another occurred in 1976/77, in the end of the 1980s, and possibly in mid-1990s. The above regimes are the most prominent in the eastern and central North Pacific. In the Okhotsk and Bering Seas since 1993 there is a clear tendency toward the surface warming, and 1997 was the warmest year. At the same time, SST in the Northwest Pacific started to decrease. Changes in atmospheric characteristics, sea temperature, and geostrophic circulation occurred during the shift in the regimes as well as interannual variations in the rates of spring-summer warming of the surface layer in both, the Okhotsk and Bering seas are described. The correspondence between periods of high and low abundance of several Asian and American pink and sockeye salmons and observed climatic changes in the North Pacific are further analyzed. Mechanism(s) for possible climate impact on salmon stocks under consideration will be proposed.

7AM1998-POCtopic09 poster

## THE RESPONSE OF THE NORTH PACIFIC CIRCULATION MODEL TO VARYING SURFACE BOUNDARY CONDITIONS

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The 3-D finite element North Pacific Circulation Model developed in the Novosibirsk Computing Center (ICMMG) is used to study the response of the North Pacific circulation to the varying boundary conditions at the sea surface. On the first stage the diagnostic and short-range prognostic numerical experiments were carried out for studying of the climatic circulation for different seasons. The results show the remarkable seasonal variations of the circulation, mass transport and meridional heat fluxes. The next step is concerned to the spin-up prognostic experiments for studying of the sensitivity of the North Pacific hydrophysical characteristics to quazi-real variation of the SST and wind-stress distribution at the sea surface. For this purpose the different sources has been used. Monthly mean distribution of the satellite-derived SST was taken from NASA Jet Propulsion Laboratory Physical Oceanography Distributed Archive, 1992. Wind -stress was adopted from the European Centre

Medium-Range Forecast Re-analysis Sample Data and Seasonal Ensemble Simulation, 1987. The results of spin-up experiment for several-year period with the climatic initial state and varying boundary conditions at the sea surface were analyzed. The anomalies of the circulation, temperature distributions, mass transport and meridional heat fluxes are discussed in comparison with the climatic state at the diagnostic calculations. The work was supported by RFFR grant 96-05-65953.

7AM1998-POCtopic10 poster

## THE EFFECT OF THE DEVELOPMENT OF ANOXIC WATER ON BENTHIC FLUX AS MONITORED FROM AN INCUBATION EXPERIMENT

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Anoxic water has been developed by eutrophication in the Korean coasts of the Yellow Sea. Benthic fluxes of nutrients and metals were monitored during an experiment in which transition from oxic to anoxic seawater was simulated through a benthic chamber incubation. The chamber consisted of 20 cm-thick sediments underlain by 20 cm-thick oxic seawater column. The incubation, initiated with the complete enclosure of the chamber lid, generated an anoxic condition of the water in a gradual manner. The anoxic condition was maintained until 250 hr when the lid was removed to resume an oxic condition in the chamber water.

Ammonia in the water column increased at the initial 0-1 hr, then kept somewhat constant to 24 hr, and rapidly increased until 250 hr after which it began to decrease. This temporal variation in the ammonia flux appears to be tied up with both the degree of oxidation of the chamber water and the concentration gradient across the sediment-water interface.

Phosphate in the water column did not show any significant variation for most of the transition period from the oxic to anoxic conditions (0-250 hr). However, it showed a rapid increase at the resumption period after 250 hr. Adsorption of phosphate unto iron-oxide phase appears to be the most important mechanism to control the benthic Phosphate flux.

7AM1998-POCtopic11 oral

## LONG-PERIODICAL CLIMATIC WAVES IN THE WESTERN BERING SEA AND THEIR EFFECT ON BIOLOGICAL PRODUCTIVITY

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The coincidence of phases of commercial fish catches fluctuations and global physical factors' dynamics was previously considered. Thus, a conception was formed on determinative effect of large- scale atmospheric and oceanological processes on biota. Average annual and monthly values of sea level (SL), water (SST) and air (AT) temperature were analyzed from data collected at the 12 hydrometeorological stations in 1944-1994. Duration of periods with negative SST and AT values,

with SST below -1°C, with ice covering have been calculated. Spectral analysis of data series allows to find variations with periodicity of 2-3 and 6 years, and also two shifts of long-term dynamics tendencies. Maximal duration of cold periods occurred in late 1960s - early 1970s. The warm period continued up to late 1980s - early 1990. Selected long-term variations are the Bering Sea response on meteorological factors' influence and coincide to climatic waves in atmosphere. The SL data showed that the inclination angle grew across the Kamchatka Strait in 1970-1987. It suggests the water outflow increase through the Strait. The high volume was fixed in 1989 - about 7 Sv (from another sources, mean value varied from 6 to 12 Sv). Then, the water flow weakened and in 1995 outflow intensity was estimated about 3,5 Sv in layer of 0-1500 m, in 1996 - 2,4 Sv only.

Analysis of residuals of annual catch values with regard to trend line was conducted for extraction of component respective to effect of the environment conditions from the general long-term dynamic of the Russian Fisheries catch. Negative residuals occurred in relatively cold period in the western Bering Sea. Since first half of 1970s the catch value begins to grow by surpassing rates in relation to the trend line and reaches high value in 1980s.

Thus, in late 1980s - early 1990s a typical shift occurred in tendencies of global climatic and biological processes. It is characterized by consecutive changes of atmospheric circulation pattern, then, of water structure and parameters, and - of catches and indexes of abundance of fish species.

7AM1998-POCtopic12 oral

## BIDECADAL AND PENTADECADAL CLIMATIC OSCILLATIONS OVER THE NORTH PACIFIC

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Climatic variations on bidecadal (about 20 years) and pentadecadal (50–70 years) timescales are analyzed in terms of their seasonal and regional dependencies in the North Pacific and North American sector. The both bidecadal and pentadecadal variations are evident in SLP fields associated with the strength changes of the Aleutian low. The bidecadal variability is evident only in winter both in the SLP and air-temperature fields, whereas the pentadecadal signal exists from winter to spring seasons in the SLP field and only in spring in the air-temperature field. The SLP structure of the pentadecadal variability is approximately unchanged through the present century. The bidecadal variability exhibits frequency decrease (period increase) from 1930 to 1950, and simultaneously the center of the variability migrated southward. The century scale modulation of the bidecadal signal is also supported by the fact that an out-of-phase relationship between the Aleutian low strength and air-temperature holds throughout the present century for the Alaska but only after the 1930s for the West Coast of midlatitude North America.

7AM1998-POCtopic13 poster

## RECONSTRUCTION OF SEA SURFACE WIND FIELDS IN THE NORTHERN HEMISPHERE FOR THE PERIOD FROM 1899 TO 1997

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10 m height wind fields in the north of 20°N of the Northern Hemisphere are reconstructed based on historical sea level pressure (SLP) fields for the period from January 1899 to December 1997 adopting purely empirical method. The historical sea level pressure fields have been prepared by applying smooth bicubic spherical spline approximation to Trenberth's monthly mean Northern Hemisphere SLP, Japan Meteorological Agency MA)'s Northern Hemisphere SLP and JMA's global SLP. In all data sets, SLP data are filled at 5- degree grids.

The following reconstruction method is adopted. First, by comparing geostrophic wind vectors and real 10 m height wind vectors, the reduction factor and correction angle at each grid are determined. In this step, ECMWF 10 m wind fields and ECMWF mean sea level pressure fields for the 10-year period from 1988 to 1997 are used. It is found that although in the past studies, these factors have been considered to be constant over the whole basin or longitudinally, in this study, temporal and spatial variations of these factors are not negligible. Next, using determined reduction factor and correction angle, sea surface wind fields for the whole period are reconstructed. Long-term variability of sea surface wind fields detected from the data will be discussed.

7AM1998-POCtopic14 oral

## A TEMPERATURE MINIMUM IN THE GULF OF ALASKA

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Temperature versus sigma-theta curves in the subarctic North Pacific show a temperature minimum at the base of the pycnocline centered at sigma-theta = 26.85 corresponding to a depth of 200 m. The temperature minimum occurs at a density slightly denser than that of the salinity minimum associated with the North Pacific Intermediate Water (sigma-theta = 26.7). The temperature anomaly associated with the temperature minimum, ranges from sigma-theta = 26.7 to 27.0 (depth = 150 to 300 m). The lateral distribution of this water type is limited to parts of the Gulf of Alaska. The origin of this temperature minimum has been previously ascribed to vertical overturn to the base of the pycnocline. An alternate hypothesis of differential advection is presented.

7AM1998-POCtopic15 oral

## OBSERVED ASSOCIATION BETWEEN SST AND ATMOSPHERIC ANOMALIES IN THE NORTH PACIFIC DECADAL CLIMATE VARIABILITY

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Decadal/interdecadal climate events (DICEs) observed in the North Pacific over the last few decades are documented. Except in the tropics, the observed decadal sea surface temperature (SST) variability in the basin is concentrated in the subarctic and subtropical frontal zones (SAFZ and STFZ, respectively). The decadal SST anomalies in SAFZ are associated with the anomalous Aleutian Low and accompanied by the Pacific/North American (PNA) pattern aloft, whereas those in STFZ are associated with the anomalous subtropical high. The decadal SST fluctuations in STFZ exhibit strong negative simultaneous correlation with the tropical fluctuations but those in SAFZ do not. Neither cooling within SAFZ in the mid-1970's that occurred in advance of tropical warming nor SAFZ warming in the late 1980's can be attributed to the direct tropical influence via "atmospheric bridge". In fact, wave activity flux associated with the PNA anomalies is strongly divergent over SAFZ, indicating the PNA is forced there. The associated wind and air temperature anomalies are such that they act to reinforce the SST anomalies by changing heat fluxes, mechanical mixing, Ekman temperature advection and wind stress curl. It is suggested that observed DICEs in the subpolar gyre and atmospheric circulation above could be associated with internally-generated variability in that coupled atmosphere-ocean system, although the associated wind anomalies influence the subtropical gyre. Lag correlation analysis reveals that significant SST anomalies tend to appear off Japanese east coast and Kuril Islands 2 ~ 3 years before the maturity of SST nomalies in SAFZ.

7AM1998-POCtopic16 oral

## INTERANNUAL CHANGE IN RESIDENCE TIME OF THE SEA ICE IN THE EASTERN BERING SEA

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Annual residence time of the sea ice in the eastern Bering Sea was summarized from the Weekly Ice Charts from February to April in 1972-1998. There are an eventual change in residence time index from 1976 to 1979 and two peaks (1974, 1976) and three bottoms (1979, 1987, 1996) during the research period. These large fluctuations are following to ENSO events. Since 1976-1979 decline in RTI (regime shift ?), warm conditions (low RTI) continued until 1990. Then relatively high RTI (exceed standard deviation) for the research area and the 58-59°N area occurred in 1991 and 1995.

In cool years, drift ice field reaches and encloses St. Paul Is., but in warm years the ice edge stays more than 100 km away from the island. This large variability may affect on ecosystem dynamics in the eastern Bering Sea.

7AM1998-POCtopic17 oral

## INTERANNUAL VARIATIONS IN NORTH PACIFIC INTERMEDIATE WATER IN THE N. PACIFIC SUBTROPICAL GYRE

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A simple kinematic model of the mid-depth N. Pacific circulation has been constructed using historical hydrographic data and data from WOCE RAFOS floats in the western N. Pacific. Using this kinematic model, the trajectories of a large number of individual parcels of North Pacific Intermediate Water (NPIW) are traced from the NPIW formation region north of Japan into the subtropical gyre. An examination of the isopycnal and diapycnal mixing terms along these paths allows mixing mechanisms of NPIW to be studied in detail. The trajectories and the properties of NPIW in the central N. Pacific subtropical gyre are compared to the annual and interannual variability of NPIW properties at the HOTS site near Hawaii, and it is shown that the observed interannual variability is generally consistent with the many varieties of mixing observed over a large number of NPIW parcels in the model.

7AM1998-POCtopic18 oral

## NEW REGIME SHIFT IN THE NORTH PACIFIC: BACK TO THE STRONG SUBPOLAR GYRE

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As part of the International North Pacific Ocean Climate Study (INPOC) an intensive array of CTD stations was taken to monitor the western subarctic currents. The interannual dynamics of the Oyashio current system has been investigated using these detailed long-term eddy-resolving hydrographic observations. Prominent changes in the structure of Oyashio and its fresh-core eddies occured during this period. Volume transport ratio of Coastal to Offshore Oyashio changed by a factor of 10 during 1990-96. One of the main result from this project was the discovery of the regime shift, occurred in the North Pacific. Here the processes associated with this thermohaline transition are described. Initially, stratification in the region was destroyed in 1990 by the low transport of the Coastal Oyashio and Kamchatka currents, and by the increased influx of the Soya warm and salt water to the Sea of Okhotsk and Oyashio area. The transition to another mode with strong subpolar gyre occurred during 1991-1996. Thermohaline features of the major currents and large Oyashio anticyclonic eddies were choosen as indexes of this transition. Within successive mesoscale eddies off Boussole Strait their fresh-core (100-400 m) became progressively cooler y 2.5-deg. C) and fresher. Variability of this scale is among the largest observed anywhere in the global ocean. The main consequences of the regime shift are the intensification of the subpolar gyre and restratification of its water.

7AM1998-POCtopic19 poster

## WHY IS NO DEEP WATER FORMED IN THE NORTH PACIFIC: EVIDENCE FROM A REGIME SHIFT PHENOMENA

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According to climatological data low salinity of near-surface water in the northern North Pacific is due to the small regional evaporation rate. The low evaporation rate is due in turn to the relatively low surface temperature (which decreases the specific humidity of the air-sea interface). Warren (1983) explains low surface temperature "mainly by the relatively large proportion of cold upwelling water in the inflow to the surface layer". Here an alternative cooling scheme is presented in which the water of the northward flowing Subarctic Current becomes cooler and fresher in the Bering and Okhotsk seas. These marginal seas cool the bottom of the halocline, that reduces evaporation and acts as a feedback to keep the North Pacific fresh. The cooling is greater when the subpolar gyre is stronger. The cooling and freshening of the North Pacific surface layer is shown through the observation of the regime shift phenomena which occurred in the western subarctic during 1990-1996. Its main consequences are the intensification of the subpolar gyre and restratification of its water.

7AM1998-POCtopic20 poster

## WAVELET ANALYSIS OF CLIMATIC VARIABILITY IN OCEANOGRAPHIC DATA SETS IN THE JAPAN (EAST) SEA

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Recently Wavelet transform (WT) was successfully applied to climate time series analyses, such as El-Niño/ Southern Oscillation (ENSO) index, North Hemisphere Surface Temperature and solar activity recorded by sunspot groups. In this work WT was used to reveal and investigate the climatic signals of interannual and decadal scale recorded in observed Japan Sea oceanographic data, to specify its connection with known features of variability of main climate time series. The basis for this study was formed by all available for us historical Japan Sea temperature, salinity, dissolved oxygen, nitrate, silicate, phosphate data, which were robustly processed first on vertical profiles and then on certain levels and in certain time intervals.

Preliminary results agree with trends in dissolved oxygen, potential temperature, phosphate and silicate concentrations in the different layers, time intervals and regions of the Japan Sea. In frequency domain WT shows the presence and relationship of ENSO-scale and quasi-biennial oscillations (QBO). The results of the WT analysis for bidecadal variations and longer cycles may have less reliability and have to be validated by means of a proper statistical significance test and physical considerations.

The climate regime shifts in the Japan Sea are stimulated by significant change of deep convection and ventilation processes intensity, caused first of all by winter monsoon, cooling on a surface and receipt of warm waters Kuroshio variations.

7AM1998-POCtopic21 oral

## ON THE TELECONNECTION PROCESSES AROUND THE NORTH PACIFIC WITH REFERENCE TO THE DECADAL VARIATIONS IN ATMOSPHERE AND OCEAN

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Teleconnection processes around the North Pacific are studied with reference to the decadal variations in atmosphere and ocean. Decadal variations in Oyashio and ENSO phenomena divided by 1976 are prominent; anomalous southward intrusion of the Oyashio east of Japan occurred relatively frequent after 1975 and ENSO index has a tendency to show negative (positive) value after (before) 1975, which indicates relatively frequent occurrence of the tendency of El Niño after 1975. It is demonstrated from data analyses and numerical model that the anomalous southward intrusion of the Oyashio is caused by the wind stress formed by southward shift of the enhanced Aleutian Low, which is a part of Pacific/North American (PNA) Pattern formed by warm SST in central equatorial Pacific. It is also pointed out that the snow cover extent over the Eurasian Continent is small in winters with the anomalous southward Oyashio intrusion. The small snow cover extent over the Eurasian Continent induces the strong summer monsoon, which induces anti-El Niño. Because the southward shift of the enhanced Aleutian Low is formed by warm SST temperature in mature stage of El Niño, the occurrence of anti- El Niño implies the opposite tendency of the ENSO phenomena. A possible change process of the ENSO through the North Pacific is suggested.

7AM1998-POCtopic22 oral

## THE ARCTIC OSCILLATION

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The leading empirical orthogonal function of the wintertime sea-level pressure field describes a meridional seesaw in atmospheric mass between the Arctic basin and parts of the surrounding zonal ring. Although it resembles the North Atlantic Oscillation (NAO) in some respects, its primary center of action covers more of the Arctic, and it has opposing centers of action over both the North Pacific and the North Atlantic basins. Coupled to strong fluctuations at the 50-hPa level on the intraseasonal, interannual, and interdecadal time scales, this "Arctic Oscillation" (AO) can be interpreted as the surface signature of modulations in the strength of the polar vortex aloft. Zonally asymmetric surface air temperature and mid-tropospheric circulation anomalies observed in association with the AO may be secondary baroclinic features induced by the land-sea contrasts. The same modal structure described by the AO strongly resembles recent winter and springtime trends in the geopotential height and temperature fields throughout the depth of the troposphere and the lower stratosphere. These trends can be interpreted as the development of a systematic bias in one of the atmosphere's dominant, naturally occurring modes of variability.

7AM1998-POCtopic23 oral

## STABLE LOCAL WIND PATTERNS OVER THE SEA OF JAPAN AND OKHOTSK SEA, DERIVED FROM THE HIGH RESOLUTION ECMWF OPERATIONAL ANALYSIS AND FORECASTING SYSTEM

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The stable local seasonal patterns in wind distribution over the Sea of Japan and the Okhotsk Sea were analyzed using the sea surface (10 m) winds provided by the high resolution ECMWF operational analysis and forecasting system (T213L31 model; about 62 km horizontal resolution; 00,06,12 and 18 UTC analysis; October 1991- March 1998 data).

To estimate the singularities of a wind fields the vorticity and divergence of wind vector were calculated. The stability of divergence and vorticity patterns were estimated as relation of main value to the standard deviation in the same point.

The areas of wind vector convergence and divergence are placed along the coasts by wide belts, which are more expressed in winter season.

Despite of the common regional monsoon air circulation structure for the both Seas the distribution of the surface wind divergence and the surface wind vorticity have a sharply different character for the Sea of Japan and the Okhotsk Sea. It is stipulated as by local circulating, and substantially, by the orographic reasons.

In winter, along the northern coast of the Okhotsk Sea the active convergence zone is created. For the Japan Sea it is possible to note the extensive steady zone of a divergence from the coast of Russia to the central part of Japan with a maxima of intensity near the south coast of the Primorye Territory of Russia. The remaining part of the Japan Sea is characterized by the convergence of surface winds.

The surface wind vorticity is characterized by a number of alternated local areas of a different sign. The pairs of a different sign vorticity zones are stipulated by the presence of a series of local intensive and steady air streams between more weak winds. The areas to the south of Vladivostok and near the north of the Korean peninsula concern to such areas in the Sea of Japan, in the Okhotsk Sea – the Gulf of Shelikhova and the area along the northwest coast. In the summer the sign of marked above dipole patterns of the surface wind vorticity mainly changes on opposite with the simultaneous decreasing of their absolute value.

7AM1998-POCtopic24 oral

## SEASONAL AND INTERANNUAL VARIABILITY OF SEA-ICE COVER IN THE ARCTIC AND SUBPOLAR REGIONS, 1900-1997: SIGNATURES OF AO, NAO AND ENSO?

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The nature of the sea-ice cover in the Arctic and subpolar regions associated with AO (Arctic Oscillation), NAO (North Atlantic Oscillation) and ENSO (El Niño/Southern Oscillation) episodes is

investigated using historical data from 1900 to 1997. A principal component analysis (or empirical orthogonal functions, EOFs) was applied to SLP, SAT, and sea-ice areas for the period of 1900-1997. The results indicate that the first EOF mode is associated with AO, while the second significant mode with NAO and the third mode is related to BH (Bearfort High), and the fourth mode with ENSO. Each EOF mode from the three variables has consistently physical explanations, with some discrepancy. The overwhelming mode is AO whose spatial and temporal patterns are consistent with the total Arctic ice anomalies.

It is worth mentioning that if the sea-ice data updated using the NASA SMMR and SSMI source is used for the EOF analysis, significant difference from the other data sources is observed, which will be further examined.

7AM1998-POCtopic25 poster

## MOVEMENT OF JAPAN SEA PROPER WATER

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The uniformly cold water named as 'Japan Sea Proper Water' occupies more than 80% of the Japan Sea water mass. This study deals with the movement of Japan Sea Proper Water based on the data obtained by the direct current measurements from October 1995 to July 1998. The measurements were made to investigate the deep water movement in the Yamato Basin by the mooring systems with self-recording current meters.
The following results are obtained:
1. In the northwestern part of the Yamato Basin, there was a stable southwest current, but a northeast current in the southeast part. This indicates that there is a counterclockwise circulation system in the Yamato Basin.
2. The Japan Sea Proper Water has a clear current with an internal period, not with tidal period.

7AM1998-POCtopic26 oral

## VARIABILITY OF THE EURASIAN PATTERN AND ITS INTERPRETATION BY WAVE ACTIVITY FLUX

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The polar vortex has intensified since 1988/89 winter both in the troposphere and stratosphere. The Eurasian (EU) pattern, which is one of the five teleconnection patterns found by Wallace and Gutzler (1981), has also changed its sign from positive to negative since then. The EU pattern extends from the North Europe to the East Asia through the Eurasian Continent and its wave-length corresponds to wavenumber 3. The variation of the polar vortex and that of the EU pattern is closely related.

The EOF analysis is performed for the wave activity flux at 500hPa to extract the dominant variation modes over Eurasia and investigate the wave-mean flow interaction. Two dominant modes associated with the EU pattern is detected. The first mode is closely linked with the height anomaly field over the

polar region and contributes to the shift in 1988/89 winter. This mode is linked with the variability of the North Atlantic sea surface temperature (SST). Over the tropical Pacific region, however, it is not linked to the SST there.

The appearance of the mode is interpreted by the meridional wave propagation of Rossby wave. It is found that the wave number 3 wave is sensitive to the change in the meridional profile of zonal wind. When the polar vortex is strong, the wave propagates equatorward, while it propagates more zonally when the polar vortex is weak.

7AM1998-POCtopic27 oral

## TWO DISTINCT INTERDECADAL MODES OF THE PACIFIC IN A COUPLED GCM

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Two distinct interdecadal modes of the coupled atmosphere-upper ocean temperature variability are found in the Pacific Ocean in a 150-year-run of a coupled atmosphere-ocean general circulation model (GCM). The modes have spatio-temporal structures coherent to the observed SST variability. The first mode which accompanies an ENSO-like spatial pattern for the SST and the surface wind behaves like a delayed oscillator in ENSO. Westward propagating trans-Pacific signal in the upper thermocline temperature in the extratropics appears to determine the delay time for the first mode. The second mode is characterized by a midlatitude-subtropical dipole pattern of the upper ocean temperature, which rotates clockwise around the North Pacific subtropical gyre. The temperature anomaly at the sea surface, which is reinforced by the atmospheric forcing around the Kuroshio Extension region, is subducted into subtropical subsurface layer along isopycnal surface, and is reinforced again in the southern branch of the North Pacific subtropical gyre in response to the associated wind forcing. Apparent negative feedback processes between atmosphere and ocean cannot be found in the second mode. It is suggested that the second mode is excited by the internal variability of the atmosphere which has no characteristic interdecadal timescale. It is proposed that the timescale of the second mode is selected by the ocean which has the interdecadal timescale associated with the clockwise rotation of the temperature anomaly around the North Pacific subtropical gyre.

7AM1998-POCtopic28 oral

## DECADAL VARIABILITY OF AEROSOL CHARACTERICS AND DEPOSITION OF CRUSTAL SUBSTANCES AND POLLUTANTS IN OCEAN AREAS NEAR CHINA

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In this paper the possible influence factors on contents of crustal and pollution elements in aerosols in ocean areas near China were discussed. Based on the statistical method the relation between the concentration of different elements in aerosols and the meteorological parameters was calculated and the formulae computing the concentration of different elements in marine aerosols in the East China Sea

were obtained applying meteorological data. Based on these data the interannual variabilities of crustal substances and pollutants in the East China Sea were calculated for the period from 1971 to 1995. The calculated results showed that there was a decreasing tendency of concentrations of these elements, but this decreasing tendency slowed down entering the nineties. In addition, the dry and wet depositions of crustal substants and pollutants in different ocean areas near China were discussed and the interannual variabilities of the depositions was calculated.

7AM1998-POCpaper01 oral

## TRANSFORMATION OF THE BRINE BOTTOM WATER IN THE GULF OF ANADYR IN SUMMER-FALL 1995

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Modification and movement of the dense bottom lens in the Gulf of Anadyr based on the data of four CTD surveys conducted in July-August 1995 is analyzed. This high salinity water formed in the Kresta Bay in winter due to brine rejection in polynyas and outflowed to the Gulf of Anadyr by a little portions even in summer during favorable wind conditions. Lens spread along izobath with speed 1-2 sm/c east southeast in the Gulf of Anadyr accelerating during dense water injection from the Kresta Bay. Weak mixing with surrounding water occurred due to strong stratification on the lens boundaries with rate 0.01-0.02 Sv. It is concluded based on the estimates of the lens speed that dense water from the Kresta Bay may reaches to the Bering Strait within 90-100 days after brine rejection and plays an important role in the formation of the cold halocline in the Chukchi Sea.

7AM1998-POCpaper02 poster

## CONSIDERATIONS ON THE EDDIES ASSOCIATED WITH SUBARCTIC FRONT OF THE NORTHWEST PACIFIC OCEAN

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In the present paper the author intends to review such synoptic eddies associated subarctic front of northwest Pacific Ocean and were found and investigated by the joint expedition carried out by the research vessel "Prof. Bogorov". The hydrological properties of the eddy differ greatly from those 42°-53°N, 159°-163°E of northwest zones of the Pacific Ocean.

In the former type there exists no significant accompanying eddy and in the latter case a large cyclonic cold eddy is always observed in its shore side.

In addition to this cold eddy, two other sorts of oceanic eddies are noteworthy to review. They are associated with the large meandered Kuril-Kamchatka flow east of 160°E. On is a cold eddy observed south of the Kuril-Kamchatka flow and it contains low salinity water, roshic. Unfortunately, the oceanographic surveys in this area are not so active to reveal the characteristics of the eddy such as life

time, scale and frequency of formation. Distinguishing feature of an icyclonic ring are common, when the wind is 4-9 m/s and seem to be associated with a modulation of the surface capillary-gravity waves by the current shear. Some small-scale features of circulation were also detected due to the surface films just after period of ice melting, which correlated with biological activity. Spatially organized vortex structures of 6-11km in diameter with sprong current shear were found at peripheral parts of the rings. However, the main areas of tidal energy dissipation seem to be stable and tightly related to the bottom topography. Spatial structure od flow and new fine details of the surface water circulation are discussed.

7AM1998-POCpaper03 poster

## NONSTANDART EDDY OF THE NORTHWEST ZONES OF THE PACIFIC OCEAN

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A new cyclonic eddy was found and investigated by the joint expedition carried out by the research vessel "Dm.Mendeleev". The hydrological properties of the eddy differ greatly from those 30°-45°N, 145°-170°E of northwest zones of the Pacific Ocean.

Analysis of the 10SDT and XBT surveys showed that the eddy moved in the northeast direction covering the distance of 180 miles during 2 months, increasing the speed from 2.3 to 7.3 miles per day.

This angle decrease from 4-5° to 1.5-2° with the propagation of the eddy TS - analysis showed that there was a high salinity "sense" in the centre of the surface cone at depths of 150-200 m formed in the south-east area of the northwest zones of the Pacific Ocean.

The eddy swirl speed structure was maintained by means of three successive series of moorings. At the beginning of the experiment, the core of the eddy was at the 200-400 m depth and swirl speed 30-35 cm/s. At the end of the investigation, the mean swirl speed increased up to 50-70 cm/s, while the lower boundary of the maximum speed layer sank to 700 m. At the same time the eddy compressed. The 500 m deep area of the 15° isotherm by 3.5 - 4 times for 2-5 months.

An attempt to study the structure of the zone between north and south subarctic fronts, cyclonic and anti-cyclonic eddies, of interaction of eddies of the free Rossby waves and non-frontal origin is made.

The report reviewed the most important field investigations of eddies in the Pacific Ocean, which play the central role in modern physical oceanography. The large-scale structure of the ocean is described as a background on which the processes of synoptic scale are evolving. Basic results of Rossby waves theory, physical mechanisms of generation of eddies in the ocean, the fundamental of statistical theory of dynamics of the eddies are considered. Various hydrodynamical models of interaction eddies and large-scale ocean circulation are reviewed. Special attention is paid to the results of experiments conducted especially for the eddies investigation, for the analysis of large-scale of special distribution of temperature and salinity, their fluctuation in a wide frequency currents and horizontal density stratification on dynamics of waterway mass.

In the present work the results analysis are on the data of temperature and salinity vertical distributions obtained with STD. It is established that the small scale and mesoscale structure formation and movement and also at intermediate depths of the frontal zone. This phenomenon is a mechanism of transformation and decay of synoptic eddies. A statistical description of revealed structure formations is presented. Their general features and differences in frontal and non-frontal eddies are shown.

Attention was also given to the dynamic of the Rossby waves on the basis of the fluctuation observation of the surface water temperature field in frontal of northwest zones of the Pacific Ocean

7AM1998-POCpaper04 poster

## CHARACTERISTICS OF ANTICYCLONIC RINGS IN THE NORTH-WESTERN JAPAN SEA

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Historical satellite and hydrographic data were examined to study physical structure and evolution of mesoscale anticyclonic eddies observed to the north of Polar front in the northwestern part of the Japan Sea. Typical parameters of the eddies (size, lifetime, trajectories, water mass composition) and their influence on hydrographic conditions in the area are discussed in the paper.

7AM1998-POCpaper05 poster

## LONG-TERM VARIABILITY OF THE BERING SEA ICE CONDITIONS

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Ice coverage of the Far-eastern seas is objective, well defined indicator of the climatic processes occurring in the region.

On a basis of historical archive (1960-1988) ten-day and monthly averaged data of ice coverage it is attempted to detect linear constituent, and to estimate a presence and input of different quasi-periodical fluctuations to evolution of ice conditions of the Bering Sea.

Statistical analysis of ice arrays did not reveal presence of noticeable linear trends. It permitted to conclude that the main climatic estimations of ice coverage of the sea remain unchanged. However it could be noted in some degree changing character of seasonal processes - increasing of intensity of ice growing (December-February).

To reveal possible quasi-periodical constituents of long-term variability of ice processes running averaging with different periods was carried out. Statistical estimations and spectral functions were analyzed.

It is shown that significant input to total ice coverage variability is supplied by high-frequency fluctuations which are random constituent and quasi-periodical components with periods up to three year. Their summary part is about 30%. After their removing it is possible to distinct statistical significant peaks on the periods about 7-8, 11-12, and 22-25 years.

Besides of it noticeable irregularity of weight distribution for some variability constituents is observed. During ice growing the processes with periods of 7-8 years, and for ice decaying period oscillations of 11-12 and over 22 years prevail.

Some parts of the Bering Sea also in more or less degree have similar features.

In conclusion estimations of long-term predictability limits for the Bering Sea are presented.

7AM1998-POCpaper06 poster

## SPACE-TIME RELATIONS OF ICE CONDITIONS IN THE BERING AND OKHOTSK SEAS

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The 39-year (1959-1998) observational data on ice cover in the Far Eastern Seas are used to analyze space-time relations between the processes forming the ice conditions in the Bering and Okhotsk Seas. In general (averaged statistical estimations for the observational period) the processes of ice conditions evolution on both basins are to be inversely related, i.e. during active growth of ice cover in one of them it should be waited weakened ice forming in another.

However against the background of pointed tendency there are cases of its violation. Their total repeatedness reaches 40%, with their number essentially increasing for the recent 10-15 years. It means that there is a change of the ice processes type in the Far Eastern basin. Along with it periods (about 7 years) of "principle of inverse phases" violation are revealed. These periods are distinguished by character of seasonal relations between ice coverage of the Bering and Okhotsk Seas. All this witnesses about possible periodicity of 14 years in ice processes occurring in the Far Eastern Seas climatic system.

7AM1998-POCpaper07 poster

## ANALYSIS OF THE WATER CIRCULATION IN THE KURIL REGION BY THE TYPES OF THE ATMOSPHERIC CIRCULATION

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Using the quasigeostrophic baroclinic model based on the principles of self-similarity of the second order and the main types of the atmospheric processes, the numerical experiments have been carried out to calculate the jet streams and vorticity structures.

The input data for calculation are real fields of the atmospheric pressure, water salinity and temperature on the sea surface. Bottom topography, coastline, water exchange at the liquid margins are also concerned. The atmospheric pressure corresponds to type of the atmospheric processes predominant for given month for three years (most cold, most warm and mean-statistical for 20 years series of observation).

The obtained schemes of the waters circulation point to the predominant vorticity of the anticyclonic character formed around the South-Kuril islands, but the predominant vorticity of the cyclonic character formed around the North islands, as well as the bilateral character of the streams in all straits. It's given the estimation of the values and the order of the variability of the water exchange through the straits according to the seasons and years.

7AM1998-POC/BIOtopic01 invited

## RADIOCARBON IN THE NORTH PACIFIC: WHAT WE HAVE LEARNED SINCE GEOSECS

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The GEOSECS program provided the first global scale description of the radiocarbon distribution during the mid-1970's. Between 1990 and 1994 another survey (U.S. WOCE) was conducted which increased the available radiocarbon database by approximately an order of magnitude. These new data provide a much improved description of the large scale radiocarbon distribution and allow investigation of the changes in the bomb-produced radiocarbon distribution over the intervening 15-20 year period. During WOCE radiocarbon was sampled using both the traditional large volume beta counting method (LV) and the new small volume accelerator mass spectrometry method (AMS). All of the LV measurements from the U.S. WOCE Pacific survey have been measured and approximately 80% of the AMS samples. Normally, the AMS technique was used to sample the upper thermocline and the LV technique to sample deep and bottom waters.

GEOSECS sampling in the Pacific was carried out less than 10 years after the peak in the atmospheric radiocarbon concentration. At that time the near surface ocean radiocarbon distribution was totally dominated by air-sea exchange processes and the maximum oceanic concentrations were at the ocean surface. Twenty years later, ocean circulation processes have had time to strongly affect the distribution and the maximum radiocarbon concentrations are generally found below the ocean surface. Examination of the change in the distribution of bomb-produced radiocarbon gives a strong indication of the primary thermocline ventilation pathways. Additionally, the data has been used to calculate thermocline ventilation rates. A new method using alkalinity, rather than silicate to differentiate bomb and natural radiocarbon significantly reduces the uncertainty of this calculation.

In deep and bottom waters the new data shows that the oldest waters in the North Pacific are located south and west of North America. This agrees with what is known about the large circulation in this region, but is in contrast to what was implied by the limited GEOSECS data. The primary bottom water inflow to the North Pacific is in a relatively narrow band near the dateline. Once across the equator, the bottom flow splits with the main flow channeling clockwise to the north and west and a lesser flow trending northeastward south of the Hawaii. The mid depth return flow can not be discerned with the North Pacific data, but from the South Pacific data, it appears occur in two bands, one near the dateline and one against South America, both at depth of approximately 2400 meters. While the existing WOCE data set has significantly improved what is known about the radiocarbon distribution, considerable improvement would be obtained by a zonal section, even with reduced sampling frequency, at mid-latitude in the North Pacific.

7AM1998-POC/BIOtopic02 poster

## EFFECTS OF BIOLOGICAL PRODUCTION AND AIR-SEA INTERACTION ON SEASONAL VARIATIONS OF CARBON DIOXIDE IN THE SUBARCTIC NORTH PACIFIC

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The Japan Meteorological Agency has been conducting semi-annual observations of carbon dioxide, $CO_2$, in the surface water and the overlying air on board the R/V *Ryofu Maru* in the western North Pacific, since 1989. Distributions of the partial pressure of carbon dioxide, $pCO_2$, total dissolved inorganic carbon, DIC, and nutrients in the surface water as well as the upper water column mainly along the 165°E in the subarctic North Pacific were investigated in spring and autumn, 1996-1997. The $pCO_2$ in the surface water showed large variability ($<$200-420 $\mu$atm on spatial scales of 10-100 km in the high latitudinal region (north of 40°N in spring. High levels of $pCO_2$ decreased and $pCO_2$ values showed relatively small spatial variability in autumn. The region north of 47°N changed from the source for the atmospheric $CO_2$ in spring to the sink in autumn, whereas, the southern region (40-45°N was the sink in both seasons. Concentrations of DIC and nutrients in the surface mixed layer were depleted significantly from spring to autumn. The C/N ratios calculated from seasonal deficits of DIC and nitrate in the surface mixed layer were different from those for biological consumption, suggesting a significant influence of the air-sea interaction on the DIC concentrations. Seasonally integrated net community production as well as the air-sea $CO_2$ flux from spring to autumn were estimated based on these observations. These analytical methodology and results will be discussed.

7AM1998-POC/BIOtopic03 poster

## SURFACE SEAWATER $pCO_2$ DISTRIBUTIONS IN SUBARCTIC WATER OF THE WESTERN NORTH PACIFIC

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We have measured surface seawater $pCO_2$ in subarctic water of the western North Pacific (nominally 140-170°E; 32-50°N) in the spring of 1996 and early winter of 1997.

In spring, the area north of 45°N acted as a source (delta $pCO_2$ = ~ 50 $\mu$atm) for atmospheric $CO_2$, while in early winter, the same area was equilibrated with atmospheric $CO_2$ (delta $pCO_2$ = ~ 0 $\mu$atm). In both seasons, distributions of surface seawater $pCO_2$ were mainly controlled by large-scale variations related to planetary-scale oceanic circulation and by small-scale variations related to existence of oceanic fronts and biological activity. Multiple linear regression analysis reveals that spatial temperature dependence of $pCO_2$ is 7-8 $\mu atmC^{-1}$ and ~ 3 $\mu atmC^{-1}$ for the spring and early winter, respectively.

A simple model calculation showed that the seasonal differences of surface seawater $pCO_2$ ($dpCO_2$) at 45°N and 50°N along the 165°E meridian were comparable to the differences due to changes of water temperature (($dpCO_2$/d T)dT) and nutrients (($dpCO_2$/dNu)dNu). However, the differences at 40°N and 35°N were not, probably implying that effect of water mixing was dominant in these latitudes.

In the spring, surface seawater $pCO_2$ in latitudes 41-45°N along the 165°E meridian was decreased by biological activity, probably by diatom, to act as a stronger sink for atmospheric $CO_2$. As a result, the local air-to-sea $CO_2$ flux decreased by 5-10 mmol $m^{-2}$ $d^{-1}$.

7AM1998-POC/BIOtopic05 oral

## VARIABILITY OF $pCO_2$ IN THE SUBARCTIC NORTH PACIFIC: A COMPARISON OF RESULTS FROM FOUR EXPEDITIONS

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Time-space variability of surface seawater $pCO_2$ is examined over the region (150°W–180°, 46°N–50°N) of the subarctic North Pacific where large meridional gradients of temperature and nutrient concentrations exist. The data were collected during four trans-Pacific expeditions in three different years (1985–1987), but within the same 30-day period of the year (August–September). Systematic measurement differences between the four data sets are estimated as $< 10$ $\mu$atm. The inter expedition comparison suggests that surface seawater $pCO_2$ in the study area is quite variable, with mean differences of up to 25 $\mu$atm, and local differences up to 60 $\mu$atm. Spatial and interannual variability of surface seawater $pCO_2$ were found to contribute significant uncertainty to estimates of the mean $pCO_2$ for the study area. Fluxes were calculated using $pCO_2$ values from the four expeditions combined with gas exchange coefficients calculated from four different wind fields giving a range of –0.94 to +4.1 mmol $CO_2$ $m^{-2}$ $d^{-1}$. The range of fluxes from the study area is scaled to a larger area of the North Pacific to address how this variability can translate into uncertainties in basin-wide carbon air-sea exchange fluxes.

7AM1998-POC/BIOtopic06 oral

## DIRECTLY OBTAINED $CO_2$ EXCHANGE RATE AT THE SEA SURFACE FROM CARBON AND ITS ISOTOPES

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In Funka Bay (area, 2270 $km^2$; mean depth, 60 m, 42.3°N and 140.6°E), the exchange of water with the open sea occurs only twice a year, in spring and autumn. We can estimate the gas exchange rate at the surface from the water column inventory change in tracer components during the stay of water inside the bay. Of course, we must correct results for other *in situ* processes such as biological production and decomposition of organic matter and small effects due to the mixing of open sea-water and the fresh water change, using nutrients and salinity, respectively. An observation station was

occupied at the center of the bay and the inventories of salinity, phosphate, nitrate, dissolved oxygen, total carbonate, C-13 were determined once a month during one and a half year.

The results show that the inventory of C-13 (strictly speaking C-13+OC-12 ratio) increased with time during winter even before making the above mentioned correction. This must be due to the gas exchange, because the decomposition of organic matter reduces the inventory of C-13 and the gas exchange enriches C-13 in the being cooled surface water. We have obtained an unbelievably large gas exchange rate for C-13 in winter, while it is not large in summer, and found that the estimated rate decreases in the order of those from C-13, total carbonate and oxygen, indicating the effect of bubbles.

7AM1998-POC/BIOtopic07 oral

## SEASONAL AND SPATIAL CHARACTERISTICS OF $fCO_2$ IN THE NORTHERN NORTH PACIFIC MONITORED BY A SHIP-OF-OPPORTUNITY

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The use of ships-of-opportunity is an effective way to obtain $CO_2$ fugacity ($fCO_2$) data with complete seasonal coverage along a fixed transects of the ocean. In March 1995, we started monitoring of $fCO_2$ in the northern North Pacific using a cargo ship, M/S Skaugran (owned by Seaboard, Canada). Then, measurements of 27 round trip cruises have already been carried out with on board personnel.

The data sets of difference in $CO_2$ fugacity (delta $fCO_2$) between seawater and atmosphere were mathematically analyzed for modeling seasonal and spatial variation of delta $fCO_2$ over the whole area in the North Pacific. A seasonal and spatial delta $fCO_2$ function was applied to each ocean grid in the North Pacific. The seasonally resolved delta $fCO_2$ maps for the North Pacific were then produced from the grid functions. Seasonality having winter maximum and summer minimum in delta $fCO_2$ was clearly observed in the western subarctic North Pacific. Seasonality in the central North Pacific of 40-45°N zone showed maximum in spring-summer and minimum in autumn-winter. The seasonal amplitude of delta $fCO_2$ in the Gulf of Alaska was smallest. The results indicated annual net efflux of $CO_2$ from the western subarctic North Pacific and from the Bering Sea. The middle latitude North Pacific was annually net $CO_2$ sink. Grid functions of salinity and nutrients also indicate clear seasonal variation. The variation of $fCO_2$ and nutrients were parallel in the western sub arctic North Pacific, indicating the biological production in spring-summer and water mixing in autumn-winter.

7AM1998-POC/BIOtopic08 oral

## CARBONATE SYSTEM OF THE SEA OF OKHOTSK CONTROLLED BY SEA ICE FORMATION

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At the formation of sea ice, chemical substances dissolved in the surface water should be transported to the deeper layers by the deep convection and brine formation. In the Sea of Okhotsk, the area covered

with sea ice and its thickness vary widely from year to year. This may influence the amount of $CO_2$ carried into the intermediate and deep layers. To estimate this amount, we collected the Okhotsk sea-water (0-1000 m) in the region off Hokkaido and southern Skharin in 1996 and 1997 summer, and analysis measured pH and total-alkalinity. The total dissolved inorganic carbon concentration was calculated from them.

In 1997, the subsurface water (50-200 m) was cooler by about 2°C and deep water salinity higher by about 0.05-0.1 psu than in 1996. This water was also rich in normalized total-alkalinity and inorganic carbon content in 1997. According to the direct observation of sea ice in winter, the sea ice was thicker and the surface mixed layer was also thicker in 1997 than those in 1996. At around 200 m depth, the C to nutrient ratio in the increments between 1996 and 1997 agreed approximatery with the so-called Redfield ratio, the ratio at depths below 500 m was larger than the Redfield ratio (i.e. C increased more in 1997). The latter can be understood if the deeper water in 1997 was formed from surface water enriched in dissolved inorganic carbon within the Okhotsk Sea at the time of sea ice formation.

7AM1998-POC/BIOtopic09 poster

## ON CARBONATE SYSTEM OF THE CHUKCHI SEA AND BERING STRAIT

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The continental shelf of the Bering and Chukchi Seas is a controlling area for the flux of Northern Pacific waters, fresh waters (entered by riverine input), nutrients, and carbon into the Arctic. Waters originating in the North Pacific Ocean enter the Arctic after a long transit through the Bering and Chukchi Seas to submerge under the permanent sea ice cover and form a distinct layer in the Arctic halocline. Previous studies show that the Pacific water plume causes basin-wide differences in biogeochemical cycles and thus contributes to significant differences between the Canadian and Eurasian basins of the Arctic Ocean. Here we present the first reliable carbonate data system for the transitional North Pacific-Arctic region, because all previous data were obtained southward from the Bering Strait. In the fall of 1996, about 700 samples were analyzed in the Bering Strait-Chukchi Sea east of 170°E to map $pCO_2$ values from surface to bottom. Pumping of $TCO_2$ from surface to bottom of the Chukchi Sea was evaluated, and new results for the carbonate chemistry of the North Atlantic water inflow along Barrow Canyon were obtained.

7AM1998-POC/BIOtopic10 oral

## CARBON CYCLE STUDIED WITH SETTLING BIOGENIC PARTICLE IN THE WESTERN NORTH PACIFIC

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To study biogeochemical cycle of carbon in the western North Pacific, settling particles were collected and analyzed for both major biogenic components (organic carbon, biogenic opal, calcium carbonate) and fatty acids as biomarkers. Time series sediment traps were deployed at 1000 m and 4200 m water depths from 21 October 1994 to 28 May 1996 at the central part of northern Japan Trench. The vertical fluxes of major biogenic particles varied temporally indicating significant annual change in the primary production. Fatty acid fluxes at 1000 m indicated positive correlation with those of biogenic opal and organic carbon. In addition, the composition of fatty acids also varied seasonally. The polyunsaturated fatty acids (PUFAs) content to total fatty acids increased strikingly during spring bloom. The PUFAs content (%) at 1000 m showed a good correlation with the depth-integrated chlorophyll *a* concentration in the 0-50 m surface water, which was observed 7 times during the deployment period. These results strongly suggest that primary production is directly related to the downward fluxes of biogenic particles at 1000 m water depth. The biogenic matter fluxes including organic carbon, opal, and fatty acids were 3 times larger than those at 1000 m. This indicates that a significant part of settling particles are transported laterally at 4200 m. However, the multivariable analysis using fatty acids data shows that the laterally transported particles do not change the composition of settling fatty acids at deeper water in the Trench.

7AM1998-POC/BIOtopic11 oral

## CARBON DIOXIDE AND DISSOLVED OXYGEN IN THE JAPAN SEA: ESTIMATION OF BIOLOGICAL AND THERMAL EFFECTS

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The partial pressure of carbon dioxide ($pCO_2$) and the apparent oxygen utilization (AOU) in seawater are regulated by two major mechanisms: photosynthesis or organic matter decomposition (the biological pump) and heating or cooling of seawater (the physical pump). A method for estimating the biological and thermal term contribution in $pCO_2$ and AOU distribution was proposed and used to process data collected aboard the R/V *Akademik Lavrentjev* in November-December, 1995, during the survey along a line crossing two climatic regions of the Japan Sea: warm southeastern area of subtropical waters and cold northwestern area of transformed waters. It was found that in both zones, even in late autumn, photosynthesis surpasses the oxygen demand for respiration and oxidation of organic matter. As a result of that and cooling of surface water, the Japan Sea is a strong $CO_2$ sink at this time.

7AM1998-POC/BIOtopic12 oral

## ROLE OF THE NORTHWEST PACIFIC IN THE ABSORPTION OF ATMOSPHERIC $CO_2$, SPECIFICALLY "CONTINENTAL SHELF PUMP" WORKING IN THE EAST CHINA SEA

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We have defined the potential sink capacity of water for absorbing atmospheric $CO_2$. The Pacific Deep Water has a larger potential sink capacity by 170 mmol/kg than the Atlantic Deep Water. This is due to the gas exchange without consuming nutrients in the winter Antarctic Ocean (50 mmol/kg), the dissolution of $CaCO_3$ in the deep Pacific (60 mmol/kg), and the atmospheric $CO_2$ change after it was formed (60 mmol/kg). If the flow rate of the Deep Water is 15 Sv, the Deep Water can absorb $CO_2$ by 1.0 Gt C/yr more than the newly formed Atlantic Deep water, when the water comes up to the surface and its nutrients are completely consumed.

We have pointed out four processes making the potential sink capacity actual. They are (1) the process of Intermediate Water forming in the North Pacific down to about 1000 m with a residence time of a few tens to one hundred years, (2) that occurring in the continental shelf, referring to Continental Shelf Pump (the pump accounts for the net oceanic uptake of $CO_2$ of 1 Gt C/yr, if the world shelf zone absorbs $CO_2$ at the rate observed in the East China Sea), (3) the gas exchange process in the high-latitudes especially in winter, where bubbles formed under heavy storms are taken into the subsurface, and (4) the biological process in water enriched in silica in the western North Pacific, producing many large particles sinking quickly into the abyss with larger organic-C/carbonate-C ratios. These seem to be overlooked or underestimated by the present modelers giving smaller values for the oceanic uptake of $CO_2$.

7AM1998-POC/BIOtopic13 oral

## CARBON DIOXIDE AND RELATED PARAMETERS IN THE EAST CHINA SEA

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A low temperature, low salinity water mass lying on the bottom of the shelf area in the northern area of the East China Sea (ECS) in summertime is regarded as remnant winter water. Carbonate and related parameters suggest that it may originate from the Yellow Sea Cold Water which is formed farther north.

There are no apparent annual variations in the carbonate parameters in the Kuroshio east of the shelf break. The partial pressure of $CO_2$ calculated from the pH, TA or $TCO_2$ data in this study show that the surface water in the shelf area is undersaturated with $CO_2$ in spring and summer. When combined with other data collected in different seasons, the results show that the shelf area of the ECS is indeed a net sink for atmospheric $CO_2$. It may absorb 0.015-0.029 Gt C per year. The carbonate data also suggest that the Tsushima Warm Current is a branch of the Kuroshio.

7AM1998-POC/BIOtopic14 oral

## CARBON FLUX IN THE SUBARCTIC NORTHEAST PACIFIC

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The subarctic Northeast Pacific Ocean has productivity as high as the equatorial Pacific (Wong et al., 1995). It is a high nutrient-low chlorophyll *a* (HNLC) regime, with large export production that correlates well with change in production in the upper ocean. The Climate Chemistry Laboratory has been conducting both time-series measurements of particle fluxes in coastal and open-ocean waters using moored sequential sediment traps for long-term study and free-drifting sediment traps for short-term deployments. We review results of particle fluxes of organic carbon, carbonate, nitrogen and opal in time-series records at Station P and coastal stations, including La Perouse. We also present formula describing the change of these fluxes with depth, implication for the remineralization rate in the organic carbon cycle and effect of El Niño on productivity from the detritus time-series records.

7AM1998-MEQtopic01 oral

## ECOLOGICAL IMPACTS OF MOLLUSCAN SHELLFISH CULTURE

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Extensive estuarine areas on the North American West Coast are currently used for commercial cultivation of oysters (*Crassostrea gigas* and others), Manila clams (*Tapes philippinarum*), mussels (*Mytilus spp.*), and geoduck clams (*Panopea abrupta*). Oysters are cultivated using a variety of methods including ground or bottom culture as well as suspended culture techniques. Manila clams are cultured on the bottom in open or bag-culture systems, or in suspended culture. Mussels are cultivated almost exclusively with suspended (raft or floating long-line) systems. Geoduck clams are new to commercial culture and are grown in net-protected plastic tubes or under plastic netting in the intertidal zone. Cultivation of these species accounts for a large fraction of the West Coast U.S., Canadian and Mexican shellfish production.

Research is now underway to assess and quantify the ecological impacts of shellfish culture on benthic habitats, positive and negative effects on associated flora and fauna, and the role of suspension-feeding bivalves with respect to water quality and clarity in West Coast estuaries. This research is prompted by changing regulatory policies of the US Army Corps of Engineers and other federal agencies, state and local habitat regulations and guidelines, and environmental management standards such as Endangered Species Act, ISO 14000 and UNFAO Code of Conduct (Article 9, Aquaculture Development), all of which increasingly play a role in the siting of shellfish farms as well as culture and harvest practices.

This presentation includes video photography to illustrate beneficial and adverse impacts of shellfish farming on juvenile salmonids, and other selected marine fauna and flora, and to examine selected farming practices and management protocols that protect and/or enhance those resources. A model case-specific environmental management plan is presented. This plan suggests a suite of managerial, operational, and structural measures which may be applied during the culture of farmed shellfish with a goal of maintaining and enhancing water quality and fish and wildlife habitat in shellfish growing areas.

7AM1998-MEQtopic02 oral

## THE ENDANGERED SPECIES ACT AND THE CHANGING ROLE OF ARTIFICIAL PROPAGATION

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Hatcheries figure prominently in the management of Pacific Northwest salmon. For the most part, hatcheries have been successful in producing fish for the fishery. Unfortunately, hatcheries have frequently been used as an all-too-easy excuse for habitat loss, and this philosophy has often worked to the detriment of wild stocks. The traditional production-oriented hatchery is not compatible with the goals of the Endangered Species Act to restore threatened and endangered species to their habitat. A new generation of conservation hatcheries must be developed to supplement and recover listed species . Conservation hatcheries should apply combinations of captive broodstocks, rearing container structures and feeding strategies that mimic natural conditions, behavioral conditioning, and optimal release strategies for restoration efforts. Artificially propagated juveniles should be similar in growth, development, and behavior to their wild cohorts.

7AM1998-MEQtopic03 poster

## THE DEVELOPMENT OF ANOXIC WATER IN LAKE SHIWHA

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An anoxic condition is developed in Lake Shiwha, a man-made enclosure of the coastal embayment by dike construction of the Ansan and Shiheung coasts, Yellow Sea, Korea. The hydrography of the lake is characterized by high-salinity deep water of Yellow Sea origin underlying low-salinity surface water of land origin. Strong depth gradients of nutrients develop across the anoxic interface between the oxygenated surface water and the hydrogen sulfide rich deep water. Enrichments of ammonia and phosphate below the anoxic interface are so enormous that they are higher than those of the neighboring Yellow Sea, the deep lake water's immediate origin, by the factors of 100 and 30 at maximum, respectively. Stoichiometric mass balance on ammonia suggests that a certain portion of the ammonia enrichment below the anoxic interface is supported by nitrate reduction in suboxic condition which appears to be superimposed on the interface.

7AM1998-MEQtopic04 oral

## GLOBAL FEED REQUIREMENTS TO SUSTAIN EXPANSION OF AQUACULTURE PRODUCTION

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Global seafood demand is currently met in part by fish produced through aquaculture. In 1997, aquaculture supplied 22% of total seafood production, and for some species, e.g., salmon, aquaculture supplied over 2/3 of fresh and frozen products. Given the fact that capture fisheries landings have decreased every year since 1989, aquaculture production must continue to increase to meet expect seafood demand in the foreseeable future. Most of the increase in global aquaculture production in recent years has been achieved through expansion of intensively raised species, e.g. salmon, shrimp, sea bass, and especially pond fish in China. Freshwater production of farmed fish in China increased by over 1,000,000 mt in 1996, an amount greater than all aquaculture production from North and South America. This increase was achieved by converting freshwater production from extensive to semi-intensive systems by using pelleted feeds. Further increases of this magnitude will tax world supplies of two key ingredients used in fish feeds, fish meal and fish oil. World production of fish meal and oil has averaged 6,000,000 and 1,300,000 mt in recent years, and aquaculture feeds now use over 20% of world supplies, up from 12% a few years ago. As world demand for fish feeds increases, aquaculture feeds may command a higher proportion of world fish meal and oil supplies, at the expense of other users and at a higher cost. Alternative sources of protein and lipid for fish feeds are grain and oilseed by-products, rendered products, and seafood processing waste, including by-catch. Global fisheries by-catch is nearly 90% of world landings of fish used to produce fish meal. Thus, utilization of by-catch to produce fish meal and oil for animal and fish feeds has tremendous potential to alleviate future shortages of fish meal and oil. Further, by-catch protein complements the amino acid profiles of protein sources of plant and rendering origin, thereby offering the potential of supporting higher aquaculture production and lower metabolic excretion of nitrogen and phosphorus, nutrients that can degrade local aquatic environments near farms.

7AM1998-MEQtopic05 oral

## PERCEPTIONS, ATTITUDES AND BIOLOGICAL REALITIES ASSOCIATED WITH WILD FISH AND FISH HELD IN ARTIFICIAL CULTURE FACILITIES

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The decline of Northwest salmon stocks has resulted in many recent listings under the United States Endangered Species Act (ESA). Opponents of fish culture often attribute population declines and disease outbreaks to public hatcheries and private fish farms. Many consider these facilities to be reservoirs of infection responsible for epizootics in wild fish. There is substantial documentation that parasites and infectious diseases have been transferred between free-ranging wild fish to fish in culture facilities. Fish pathogens evolved and adapted with the various host species, and many biologists believe that indigenous parasites and diseases play an essential role in maintaining the stability of marine and freshwater ecosystems. However, stress and adverse environmental conditions can

predispose both wild and cultured fish to diseases and opportunistic infections. Fish health issues and other aspects of wild and cultured fish interactions will be examined.

7AM1998-MEQtopic06 oral

## STUDIES ON BIODEPOSITION IN KELP MARICULTURE

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Its well known that up to 25-40 % of gross production of Laminariales algae turn in to particulate and dissolved organic matter. This matter is commonly accepted as detritus. The general characteristics of biodeposition in kelp mariculture are reviewed. The vertical flux of particulate mater at kelp farm is characterized by 1) The great absolutely meaning (up to 148.2 gm. per square meter per day); 2) The great dependence from rough sea; 3) The fast sedimentation rates of dissolved organic mater which produced by kelp (*Table*).

*Table: The vertical fluxes of particulate matter and organic carbon at kelp farm and nearest bays (by Shulkin, 1987).*

| Region | Depth, m | Deposition rate as gm. per square meter per day | Organic carbon rate as gm. per square meter per day |
|---|---|---|---|
| kelp farm | 5/25* | 2.20/10.72** | 0.043 / 0.217** |
| - " - | 7,5/25 | 1.06 / 86.23 | 0.177 / 4.000 |
| - " - | 10/25 | 10.00 / 148.23 | 0.630 / 11.128 |
| Nearest bay | 10/12 | 7.5 | 0.206 |
| - " - | 18/20 | 8.39 | 0.231 |
| - " - | 32/40 | 1.51 | 0.175 |

* The numerator gives samples depth; enumerator gives total depth.
** The numerator gives measure under calm; enumerator gives measure under strong rough sea. Our data suggested that cultivated kelp be exposed to great influence of sedimentation process. Its greatly stimulated an initial fouling phase. Under certain conditions (fouler's larvae and spore presence) it may induce settlement of cultivated kelp by various epiphytic organisms.

7AM1998-MEQtopic07 poster

## EFFECTS OF RESTORE FEEDING BASE ON GROWTH AND REPRODUCTION OF THE SEA URCHIN STRONGYLOCENTROTUS INTERMEDIUS

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Sea urchins is important commercial object. Gonads of the sea urchin have a great dietetic meaning. Quality of gonads, degree of its development, color and taste depends on the type of its feeding. As a

result of observation digestive tract of sea urchins in April - May 1998 twelve species of alga inhabiting coastal area of Primorye were discovered.

Urchin continuously fed Laminaria japonica, especially sporeling with size from 0,5 up to 5 cm, had a significantly greater gonad index (25-30 %) than urchins, fed Lithotamnion, Lithophyllum, Bosiella (0,5-5 %). This results became a reason for composing of cadastre of bottom landscape of the coast of Primorya with the description of sea urchin feeding base. Four types of landscapes including the waste substratum which feel the need of meliorative operations, to restore Kelp were extinguished. Experiment with sowing of waste stony bottom were conducted. The sporeling of Laminaria was born in April, when sea urchin was coming from the deep to shallow area for active feeding and reproduction. In the result of this feeding gonads of the sea urchin had increased in its size and had improved its guality.

7AM1998-MEQtopic08 oral

## A PRELIMINARY EXAMINATION OF THE TRANSFER OF OXYTETRACYCLINE (OTC) FROM FARM FISH TO FAUNA ADJACENT TO A NET-PEN OPERATION IN BRITISH COLUMBIA

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The objective of this preliminary study was to examine the possible transfer of oxytetracycline (OTC) from a small marine salmon farm operation in the Strait of Georgia to adjacent natural fauna. OTC residues were not detectable in clams (*Saxidomus giganteus*) or mussels (*Mytilus spp*) located within 75 m of the farm. Residues were also not found in deeper water organisms such as lemon sole (*Parophrys vetulus*) or shrimp (*Pandalus danae*) trawled near the farm. There was evidence of OTC accumulation in a sample of crab (*Cancer productus*) taken directly beneath the net pens. Statistical evaluation of the crab data indicate no significant difference in OTC levels in samples from the farm site and a reference site. Results are discussed in the context of the amount of OTC used at the particular farm, ecological risk considerations, oceanographic features of the study area, and biodegradation.

7AM1998-MEQtopic09 oral

## THE STATUS OF AQUACULTURE IN NORTH PACIFIC RIM NATIONS-WAS PETER LARKIN RIGHT?

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In 1982, Peter Larkin, the renowned Canadian biologist, preferred a pessimistic view of the potential for the development of aquaculture in Pacific North America and other Pacific Rim nations. Larkin stated that "if it is indeed true that much of aquaculture as presently practiced, is simple, then it surely

has a bright future..... why isn't there more aquaculture than there is today?" Larkin listed four major constraints to aquaculture development in the region: the short growing season in temperate/arctic regions; aquaculture, as practiced in the 1970's was a small-scale, artisanal endeavor, with few economies in scale; lack of national aquaculture policies, particularly in North America; and the harvest from wild fisheries was more than adequate to supply national demand for seafoods. He concluded that "now (1982) is not the time for extensive aquaculture of the traditional variety in North America". How prophetic was Larkin in predicting the role of aquaculture in Pacific rim nations? How has development proceeded through the 1980's and 90's? Has aquaculture been constrained by the reasons given by Larkin and are there other extant constraints to the development of viable aquaculture systems?

7AM1998-MEQtopic10 poster

## CULTURE OF CRABS ON MARICULTURE INSTALLATIONS IN AN OPEN WATER AREA

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The natural ability of populations to reproduce is reduced in conditions of their exploitation. At the coast of the Primorsky region, Sakhalin and Kuril Islands (Russia) annual catch of a King crab has decreased more than 20 times. A 20-year prohibition of fishery for King crab at the coast of Alaska and Primorye has not resulted to the restoration of its commercial stocks. The artificial reproduction of commercial important crabs should ensure steady development of fishery.

The cultivation technique consists of the collection of naturally occurring crab larvae on to mollusk mariculture installations and rearing to the viable size. Here an artificial ecological niche is created for larvae settlement and development and growth young crustaceans. The structure of food items of larvae and young crustaceans coincides with the species structure of fouling community of mariculture installations. In addition, mariculture installations provide shelter from predators. On installations young crustaceans grow to the viable size and are then released into the natural environment.

The costs of the construction and operation of mariculture installations are covered at the expense of realization of mollusk mariculture produce. The operation of mariculture installations on open shelf creates zones protected from the influence of trawl fishery, which will allow formation of a "reserve" for pasturing of young crab stocks.

7AM1998-MEQtopic11 oral

## POTENTIAL EFFECTS OF FARMED SALMON ON WILD SALMON STOCKS IN THE PACIFIC NORTHWEST

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Global farm salmon production has skyrocketed since the mid-1980s and in 1997 preliminary estimates indicate farm salmon production surpassed that of salmon capture fisheries for the first time. In

contrast to the rapid expansion of salmon farming in Norway, Chile and the United Kingdom, farming in Washington and British Columbia, which represents less than 5% of total production, has been nearly constant in recent years. Farming is banned in Alaska and a moratorium on new farms in British Columbia has been in place since 1995. Salmon farming operations in British Columbia and Washington, which produce mostly Atlantic salmon (70% overall), underwent extensive environmental reviews during the past two years. Reported escapes of farmed salmon in British Columbia declined substantially from 392,000 salmon in 1989 (mostly chinook, all sizes) to approximately 44,500 fish (mostly Atlantic salmon) per year since 1991. In Washington, escapes were relatively small (21,000 per year) until the large escapes in 1996 (127,000 Atlantic salmon) and 1997 (370,000 Atlantic salmon). Key factors causing the escapes include net pen operation errors, vandalism, and weather. Recoveries of Atlantic salmon in marine waters vary with escape levels and proximity of fisheries to the escape location and period. Total recoveries have been <5,000 fish per year, including up to 135 recoveries in Alaska during 1996. Escaped salmon consumed less prey than wild Pacific and Atlantic salmon based on stomach analyses. Recoveries of farmed Atlantic salmon in freshwater varied with survey effort and water conditions and up to 312 farmed fish (1996) were observed in British Columbia and Washington streams per year; sitings of Atlantic salmon in freshwater typically represent <1% of total observed adult salmon during snorkel surveys. No Atlantic salmon spawning has been observed in Northwest streams, although a few ripe individuals have been observed. No juveniles produced by Atlantic salmon in Northwest streams have been observed. Numerous attempts to introduce and establish self-sustaining runs of anadromous Atlantic salmon outside their native range, including British Columbia and Washington, have failed. Juvenile Atlantic salmon appear to be less competitive in streams compared to Pacific salmon. Although farmed salmon are competitively inferior to wild conspecific salmon on the spawning grounds, farmed salmon may reduce reproductive success of wild salmon, depending on their abundance, timing and distribution on spawning areas. Genetic composition of native Pacific salmon may be altered by interbreeding with farmed Pacific salmon, but production of Pacific salmon has declined in recent years. Laboratory studies indicated exceptionally low survival of Pacific/Atlantic salmon hybrids. Predation by farmed salmon on Pacific salmon is not likely to be significant. The risk of disease transfer, which was addressed by other scientists in the review process, was judged to be low but not nil. Although the two recent large escapes in Washington State were high and unacceptable, the overall risk of salmon farming to wild salmon was judged to be low by the review team in British Columbia. Nevertheless, numerous recommendations were made to improve farm management. Two key recommendations were to 1) produce all-female Atlantic salmon in order to further minimize the potential for colonization, and 2) limit production of Pacific salmon in order to minimize potential genetic impacts to wild stocks.

7AM1998-MEQtopic12 oral

## THE EXPERIMENTAL CULTIVATION OF UNATTACHED FORM OF GRACILARIA VERRUCOSA IN LAGOONS OF THE SEA OF JAPAN (RUSSIA)

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The method of plantation cultivation of agaroproducing macroalga at the plantations in the lagoons of South Primorye (Sea of Japan, Russia) was worked during 1993-1997. Gracilaria grew in capron nets and on ropes. The planting material was placed inside the nets or interwoven in the ropes. The nets and ropes were horizontal fastened to cables, attached to the anchors.

Growth rate of Gracilaria at the sites was on the average 3-8 % per day during whole vegetation period. Maximal growth rate was observed in July of 1993 (11 % per day). The biomass of Gracilaria on ropes and in nets reached on the average 600-800 g fresh weight per 1 meter of substrate (1600 g/m maximally). The harvest of Gracilaria in lagoon usually reached 5 ton of dry weight per 1 hectare within vegetation season (April - October).

The worked out method of cultivation of the unattached Gracilaria verrucosa at the plantation in lagoons is harmless for ecology, because it excepts the use any hydrobiotechnical construction (dams, sluice, artificial ponds). The location of plantations in lagoons caused the reduction of the intensity of water change around the sites, but it did not significantly modify natural community in lagoon (the community of Zostera japonica). Contrary, plantations enriched the fauna of the Zostera community by crustaceans and mollusks species.

7AM1998-MEQpaper01 oral

## AN ASSESSMENT OF ANTHROPOGENIC CONTAMINATION OF SEDIMENTS IN SUBTROPICAL LA PAZ LAGOON, SOUTHERN BAJA CALIFORNIA

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94 samples of sediments of the La Paz Lagoon and 16 samples of the material of dry streams were analyzed by the method of neutron activation analysis to establish the contents of trace metals and the state of anthropogenic contamination of this area. Obtained data reveal the existence of specific patterns of the distribution of concentrations of elements in sediments inside of the lagoon. Sc, Co, Th, Rb, Cr and Cs are accumulating mainly in the deep part where predominates fine clay material with high content of Fe and organic carbon. Zn show accumulation between the deep zone and the Punta Comitan. Ni has an elevated content in front of dry streams in northwestern part of the lagoon. As reveals the enrichment in sediments of the northern part near the Estero Zacatecas and El Mogote. Concentrations of trace metals Zn, Cr, Ni and Co in sediments and their enrichment factors correspond to natural levels. High values of enrichment factors registered for Se, As and Sb probably are caused by the input of products of the erosion of volcanic rocks of the drainage basin.

7AM1998-MEQpaper02 oral

## BIOCHEMICAL MONITORING OF COASTAL ZONES USING OYSTER BIOMARKERS

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In our previous work it was found that some subcellular biochemical parameters such as DNA content, lysosomal activity, esterase activity and biomembrane microviskosity of oyster cells may indicate the pollutant-induced cell injury and damage and can be used for biochemical monitoring of environmental contamination (1).

Six sampling sites in Chonsoo Bay (west coast of Korea) and three sites in Masan Bay (South coast of Korea) were inspected during June-October of 1997. The specimens of Crassostrea gigas employed in our study were obtained from these places every two months, hemocytes were isolated from oyster hemolymph and activity of listed intracell biomarkers were detected using certain fluorescent probes.

Determination of seasonal variations of biomarker activity in each site and comparative study of biomarkers from oysters collected in different places were investigated. The general differences in physiological status of oysters from inspected sites were determined. It was found that the main tendency of seasonal fluctuation of biomarker activity in the given period has a V-evocative character with clear minimum of activity in August and increased in June and October. Relationships between biomarkers activity and climate, physiological changes in animals and effects of pollutant are discussed.

7AM1998-MEQpaper03 oral

## SEA URCHIN EMBRYOS AS A MODEL FOR ECOTOXICOLOGICAL MONITORING OF MARINE POLLUTION

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Echinoderms constitute an ideal material for marine ecotoxicological tests and sperm, eggs, embryos and larvae of sea urchins are more preferable and already used as a test organisms in some laboratories. These cells can easily be reared in experimental cultures, their embryology is well-known and abnormalities are easily visible thanks to the transparency of the eggs. In the marine environment these eggs and larvae are planktonic for some weeks and float quite near the water surface. They can therefore be considered as relevant test organisms for marine toxicology testes with pollutant solved or dispersed in water because the early life stages of these marine organisms are particularly sensitive to pollution.

Our bioassays were conducted with *Anthocidaris crassispina* sea urchin sperm, eggs and embryos to determinate the toxicity of some chemical compounds (organotins) and extracts from bottom sediments collected in different parts of Korean coast waters. A summarized data of the toxicity (ED50 and threshold concentration) of the various organotins and their specific effects on sea urchins cells are given. Comparative investigation of relationship between different organotins structures and their activities was made. Differences in sensitivity between developmental stages used are underlined. The

toxicity of sediment extracts was estimated and compared with calculated concentrations of total organotins from corresponded sediment samples, regression analysis was made and general trends are drawn.

7AM1998-MEQpaper04 oral

## POLYCULTURE AS A POSSIBLE TECHNIQUE TO CLEAR THE POLLUTED WATERS AND TO INCREASE A PRODUCTIVITY OF COASTAL COMMUNITIES

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The effectiveness of mono- and polyculture has been evaluated in the controlled conditions. It was determined that due to different trophic levels of the used hydrobionts (echinoderms, bivalves and algae) the cultured objects utilized the additional food resources, their productivity was heightened and the polluted water has been cleared. So the coastal polyculture is a very perspective branch of fishery industry.

7AM1998-MEQpaper05 oral

## THE CHANCHING OF Cu AND Zn SPECIATION UNDER INTERACTION RIVER WATERS WITH SEAWATERS (THERMODINAMICS ANALISYS)

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Copper and zinc are very toxic chemical elements. The toxic of chemical elements in the environment dependents from speciation elements in the water solutions. It is known then more element has possibility to form the different complexes (associations, ion pairs) it is less toxic. So it is clear that determination of forms migration and transformation chemical pollutants in nature and pollution waters is very important ecological problem. We think also that quality of environment depends from physico-chemical conditions in it. One of the way to understand this problem is to carry out thermodynamic analysis of natural systems. To solute this task authors used method of physico-chemical modeling by computer (method of minimize of Gibbs energy). This method gives possibility to determine the speciation Cu and Zn in the model solutions of very complicate composition. It was inserted 157 chemical water species, 8 gases in the model. During solution of this task by computer the seawater was added to river water drop by drop. In the process of modeling we could watch how the speciation of Cu and Zn had been changing. It was found the organic species of these elements play insignificant role in the river water and seawater, but the tendency of Cu to form complexes is higher then Zn.

7AM1998-MEQpaper05 oral

## A GEOCHEMICAL BUDGET OF RADIOACTIVE PU IN THE EAST SEA (JAPAN SEA)

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Radioactive plutonium (Pu) isotopes, a nuclear fission product, is an environmental tracer for pollution and geochemical cycles of elements. In the present study, radioactive Pu isotopes, $^{239,240}$Pu, were determined in the atmosphere, soil and the East Sea, a marginal sea in the northwestern Pacific.

$^{239,240}$Pu concentrations in rain varied from 0 (< detection limit) to $131^{+4}$ μBqkg$^{-1}$ with higher concentrations during the dry season than during the heavy rainfall season. $^{239,240}$Pu concentrations in falling dust particles varied from 0.012-0.300 Bqkg$^{-1}$ and dust depositional flux varied from 1.40 to 14.8 gm$^{-2}$month$^{-1}$, with an annual mean of 56.6~88.4 gm$^{-2}$yr$^{-1}$. Total atmospheric deposition of $^{239,240}$Pu varied from 0.03 to 2.20 mBqm$^{-2}$month$^{-1}$ with an annual mean of 4.46-8.88 mBqìm$^{2}$yr$^{-1}$. The annual fallout of $^{239,240}$Pu showed continuous decrease since 1958 and the primary source of fallout of $^{239,240}$Pu in the Korean coasts appears to be originated from resuspended continental soil-dust transported by the westerly wind. The total inventory of $^{239,240}$Pu in soil was 81 MBqkm$^{2}$.

$^{239,240}$Pu concentrations in surface seawaters varied from 3.36 to 10.1 μBqkg$^{-1}$, with a broad maximum between 750 to 1000 m. Particulate $^{239,240}$Pu concentrations were in the range of 0.17 to 1.00 μBqkg$^{-1}$. $^{239,240}$Pu concentrations in surface sediments ranged from 0.098 to 2.580 Bqkg$^{-1}$, with a mean of 1.760 Bqkg$^{-1}$. The total Pu inventory of seawater and sediment was estimated to be 80.60 Bqm$^{2}$. $^{239,240}$Pu contents in sinking particles at St. KD from 2.39 to 3.68 Bqkg$^{-1}$ with its fluxes of 770¡-1060 μBqm$^{-2}$d$^{-1}$. Residence times of Pu in the water column of the East Sea were 55~146 year, which were two or three times shorter than those of the Atlantic and the Pacific Ocean. The contents of Pu in zooplankton ranged from 0.010 to 1.14 Bqkg$^{-1}$, with a mean of 0.18 Bqkg$^{-1}$.

The geochemical budget of $^{239,240}$Pu in the East Sea was estimated on the basis of these Pu concentrations in various reservoirs.

7AM1998-MEQpaper06 oral

## AN EFFECT OF NATURAL HYDROCARBON POLLUTION ON A WINTER MICROALGAE "BLOOMING" IN NOVGORODSKAYA BAY OF PETER THE GREAT BAY (JAPAN SEA / EAST SEA)

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Increased concentrations of methane (2000-3000 nl/l), heavy hydrocarbons (50-100 nl/l) coming up from the interior, perhaps, from oil-gas deposit have been found in the bottom water layer of Novgorodskaya Bay. In response to the region geological activity taking place in the last ten years fracture permeability has increased, and consequently, natural gas migration is likely to be more intensive. Just this process is assumed to be responsible for the methane increase 3-5 times (300-500 nl/l) against the background. At the individual stations methane concentrations exceed the background

20-30 times. As a result, currently an influence of hydrocarbons on the bay ecology has strengthened. Thus, in the zones with heightened hydrocarbon concentrations seaweed thickets have got thin appreciably, a range of species and biomass of hydrobionts have decreased as well.

The zones of increased hydrocarbon gas concentrations represent strips about 750 m wide. In summer oxygen concentrations containing in the water of these zones decrease to 43% at average saturation 65%. In winter an average oxygen saturation of the water is 80%, but in the indicated zones it raises noticeably (up to 94% - in the bottom layer, 106% - in the surface one).

It is well known that oxygen oversaturation of the water is a result of phytoplankton "blooming". In Peter the Great Bay phytoplankton represents predominantly diatoms, 70-90% of them are Thalassiosira nordenskioldii.

In the bay hydrocarbon zones are characterized by heightened transmittancy, to judge from mercury concentrations that increase of 25% (28 ng/g of dry mass) regarding to its mean amount. Due to a high mobility, mercury is a good indicator of rock penetrability, and areas of mercury anomalies are normally characterized by a heightened heat flux.

The data presented in this work point to the fact that in winter hydrocarbon zones produce favorable conditions for phytoplankton development. It is promoted by biogenic elements incoming into the surface water layer in the course of microbiological activity and hydrodynamic processes caused by raised temperature.

7AM1998-MEQpaper07 oral

## CHARACTERISTICS OF COMMUNITIES: NEW INDICES INCORPORATING DATA OF ABUNDANCE AND BIOMASS

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As known well, if communities had naturally or artificially induced environmental impacts, a variety of species-abundance relationships and probably species-biomass relationships have been recognized depending on strength of the impacts. I devised new indices describing characteristics of communities based on both of species diversity and species-abundance (biomass) etc. These indices, similar to ABC method developed by Warwick and his colleagues but indicating several merits different from ABC method, incorporate data of abundance and biomass.

7AM1998-MEQpaper08 oral

## LEAD-210 CHRONOLOGY OF TRACE ELEMENT ACCUMULATION IN SEDIMENT CORE FROM THE UPPER GULF OF CALIFORNIA

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Fine sediments in estuaries and marginal seas keep often valuable information related to recent environmental changes. Sediment core from the Upper Gulf of California has been used to decipher the history of the influence of the Colorado River input on the accumulation of trace elements on the floor of the adjacent marine environment. Results of both $^{210}$Pb-dating of this core and of the determination of elements by neutron activation analysis in core sub-samples have elucidated following important facts: a) the absence of notable contamination of the area by environmentally important trace elements Cr, Zn, Co, Ni, Sb and As; b) almost 2-hold decrease of contents of Fe, Sc, Cr, Co and U in upper horizons corresponding to last 40 years caused probably by the artificial regulation and almost full disappearance of the freshwater discharge of the Colorado River; c) the existence of one horizon with strong enrichment in Ca and of two horizons enriched in Sr reflecting episodic strong planktonic blooms in past times.

7AM1998-MEQpaper09 oral

## DISTRIBUTION AND PERSISTENCE OF ORGANOPHOSPHORUS PESTICIDES IN SOME ESTUARINE ENVIRONMENTS OF KOREA

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To study the distribution of organophosphorus pesticides which are extensively used in Korean agriculture, surface sea water samples taken from 4 coastal areas in May and August, 1997 and sediment samples taken from two coastal areas were analyzed using Gas Chromatography/Nitrogen Phosphorus Detector (GC/NPD). In August most abundant organophosphorus pesticides in Kunsan area were IBP (m=432.5 ng $l^{-1}$) and EDDP (m=37.4 ng $l^{-1}$) largely used between June and September to prevent rice blast disease. In Danghang Bay dry fields located near the mouth of the estuary seemed to affect the contents of certain organophosphorus pesticides. Since organophosphorus pesticides applied in the watershed are rapidly decomposed while being transported along freshwater streams, watershed size of rivers is not proportional to the contents of these pesticides in the coastal waters. Pesticides values measured in August were compared with those in May. IBP contents in coastal waters were about an order of magnitude higher in August than in May. In Kunsan area contents of ethoprophos which is used for vegetables and fruits was higher in May than in August. Temporal and geographical distribution of individual organophosphorus pesticide seems to be largely affected by types of agricultural practices and patterns of pesticide use in the watershed. Chloropyrifos was the most

important compound of organophosphorus pesticides in sediments because of its persistent nature and high affinity to particulates.

7AM1998-MEQ/BIOtopic01 oral

## ORGANOCHLORINE LEVELS AND IMMUNE SYSTEM FUNCTION IN NORTHERN FUR SEALS (*CALLORHINUS URSINUS*) FROM ST. GEORGE ISLAND, ALASKA

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The northern fur seal (*Callorhinus ursinus*) population that breeds on St. George Island, AK in the Bering Sea has been declining at approximately 6% per year from 1973 to the mid 1990s, even though commercial harvest of the fur seals for pelts ceased in 1984. Previous studies have found no exact cause of this population decline but have found lower than expected return rates of pups after initial post-weaning migrations. A decline in pup population may be due to poor juvenile survival during the first migration at sea. A potential cause may be related to contaminant-linked immunosuppression. Organochlorines (OCs) are widespread, persistent environmental contaminants that are highly lipophilic and can bioaccumulate in top level predators of the marine food chain, including marine mammals. OC exposure in marine mammals has been linked to reproductive impairment, premature births, neoplasia and morphological lesions in various tissues. These compounds have also been shown to cause immune suppression and disease in experimental animals. To determine if northern fur seal pups are suffering from immune suppression or poor health status related to OC exposure, northern fur seal pups were captured and blood samples collected during the 1996 breeding season. Additionally, blood and milk samples were collected from matched dams. Using a rapid high-performance liquid chromatography coupled with photodiode array method, dioxin-like polychlorinated biphenyls (PCBs) and other selected organochlorines (OCs) were measured in the blood of northern fur seal pups and blood and milk of their dams. From these data, concentrations of total PCBs, total DDTs and dioxin toxic equivalents of dioxin-like PCBs (TCDD TEQs) were calculated. Furthermore, various immune functions (e.g., blastogenesis assays) and health parameters (e.g., retinol and thyroxine levels) were measured and compared to the OC levels in the fur seal pups. OCs were measured in all the fur seal samples analyzed, with higher OC concentrations determined in the pups blood compared to the dams blood. In addition, the OC levels measured in the pups of young dams were higher than those measured in the pups of old dams. Furthermore, pups that contained higher OC levels had lower retinol and thyroxine levels as well as poorer cellular immune responses compared to pups with lower OC concentrations.

7AM1998-MEQ/BIOtopic02 oral

## CONTAMINANTS AND HEALTH ASSESSMENT RESEARCH IN ARCTIC ALASKA WILDLIFE: BIOLOGISTS, VETERINARIANS, AND SUBSISTENCE HUNTERS TAKE ON THE CHALLENGE

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The Department of Wildlife Management (DWM) has ongoing and recently funded (Office of Naval Research (ONR), Cooperative Institute For Arctic Research (CIFAR) and NOAA) projects addressing contaminants and adverse effects in marine mammals, and contaminants exposure of people consuming these tissues. Progress has been made, but logistic constraints and a lack of basic biologic and health data compromises the assessment. Current assessments begin with gross examination by collecting vital morphologic, body condition, parasite burden, suspect lesion, hunt-related and other data. The benefits of collecting a suite of samples for microscopic examination, ageing, disease monitoring etc. will be discussed. Many studies in arctic species report little data with regards to the animals health and condition. Observations of the hunters on animal condition and the population should be integrated. Lesions, "normality" or suspect changes can be falsely associated with contaminants if other factors are not considered; and how does one show "no effect" conclusively? We stress the importance of establishing in arctic marine mammals what is now considered "basic data" in most domestic and some wildlife species. Evaluation of basic histology and tissue and subcellular distributions of metals (autometallography), and intensive examination for metal induced changes is underway to help fill this gap. Recent studies evaluate bowhead whale health and the arctic marine food chain (trophic transfer and "who's eating whom!"). This unique situation combines traditional knowledge and subsistence activities, with biologists and biomedical professionals (this case veterinarians) to form a local co-operative program to collect data and samples.

7AM1998-MEQ/BIOtopic03 oral

## CHEMICAL CONTAMINANT EXPOSURE AND ASSOCIATED BIOLOGICAL EFFECTS IN PUGET SOUND FISHES

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Puget Sound serves as the habitat for a number of recreationally and commercially important fish species. Over the past 100 years there has been substantial urban and industrial development within this region, resulting in heavy inputs of chemical contaminants at selected sites. Ongoing monitoring studies indicated that there was significant uptake of aromatic hydrocarbons (AHs) in fish from industrialized bays of Puget Sound, based on fluorescent aromatic compound (FAC) concentrations in bile. For English sole, average biliary FAC concentrations were 600 ng BaP equivalents/g bile at urban sites, compared to 100 ng BaP equivalents/g bile at non-urban sites; for demersal rockfish, exposure in urban areas was somewhat lower (400 BaP equivalents ng/g bile). More detailed studies showed that English sole from urban sites in Puget Sound experienced a range of biological effects in association with AH exposure, including toxicopathic disease and reproductive dysfunction. Threshold FAC levels for these conditions in sole were about 300 ng BaP equivalents/g bile, suggesting that AH exposure could be a potential health risk for some urban rockfish. Polychlorinated biphenyls (PCBs)

accumulated in muscle tissue of all fish species we monitored, with the highest average PCB concentrations occurring in rockfishes and flatfish sampled from bays with PCB contaminated sediments (158 ppb and 87 ppb). Although pelagic species like chinook and coho salmon migrate large distances and are not closely associated with PCB contaminated sediments, because of diet, they accumulated higher PCB concentrations (52 ppb and 26 ppb) than rockfish and English sole from non-urban bays. Muscle PCB concentrations in the more contaminated fish were equivalent to those associated with reproductive and developmental abnormalities or other conditions in fish, indicating that PCBs may pose a health risk to some Puget Sound fishes.

7AM1998-MEQ/BIOtopic04 invited

## PERSISTENT ORGANIC POLLUTANTS IN ARCTIC MARINE MAMMALS

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Contamination of ringed seal and polar bear in the Arctic marine environment with PCBs and DDT has been known since the late 1960s. Virtually every major global persistent organohalogen pollutant (POP) has now been found in high trophic level Arctic biota, primarily hexachlorocyclohexanes (HCHs), chlorobenzenes, chlordanes, toxaphenes, DDTs and PCBs. It is important to realize that the level of contamination of more volatile contaminants such as HCHs, toxaphene and chlordanes in water, air and lower trophic levels may be similar to that at mid latitudes. However, levels of the less volatile contaminants such as PCBs and DDTs are lower than at mid-latitudes. Nevertheless, marine mammals have such a large capacity to bioaccumulate these compounds, that concentrations may still reach levels of concern. This is particularly true for species such as the polar bear, which consumes mainly ringed seal, and arctic fox, which may scavenge polar bear kills. Beluga and narwhal, due to their low capacity to break down many of these compounds, also accumulate high levels and a wider range of POPs. Recent studies we have conducted have shown that persistent metabolites of PCBs bioaccumulate from ringed seal to polar bear. The toxic consequences of these exposures is only beginning to be understood. We know that liver enzymes are induced in some species. Immunotoxic effects in polar bear are possible at the concentrations found in some areas. We have also demonstrated that another class of PCB metabolites accumulates in blood, and may affect thyroid hormone and vitamin A functions. There is some indication of decreased cub survival in the Svalbard area. Much more research remains to be done.

7AM1998-MEQ/BIOtopic05 oral

## MARINE MAMMALS AT THE TOP OF THE FOOD CHAIN: ECOLOGICAL SENTINELS

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Many marine mammals occupy high trophic levels in the marine environment, and can therefore accumulate high levels of persistent, fat-soluble contaminants from their diet. While few conclusive studies have been carried out, earlier work reported reproductive impairment, immunotoxicity and

endocrine disruption in captive harbour seals fed fish from contaminated waters. Epidemiological observations of impaired reproduction, skeletal malformations and apparently increased incidence of infectious diseases in populations of marine mammals inhabiting contaminated areas appear to extend and validate the captive study results to an ecological setting. Carrying out mechanistic studies in free-ranging marine mammal populations is fraught with logistical challenges, and attempts have met with limited success. However, a basic understanding of age- and sex- related contaminant levels in marine mammals inhabiting different areas can provide a basis for comparison to captive studies. Biological (eg blood) samples from similar-aged animals (eg four-week old seal pups; one-year old cetaceans) can subsequently be used for correlative approaches for marine mammal toxicology in the field. The collection and analysis of such samples from a selection of species can provide scientists and decision makers with contaminant information which is ecologically relevant. In particular, the harbour seal has proven to be a useful sentinel species for contaminants in the environment. This pinniped has been widely studied in the fields of toxicology, endocrinology, immunology and virology, and is widely distributed along the coasts of the northern hemisphere. Further studies on the effects of contaminants on free-ranging marine mammals are needed, and will require the development of creative sample collection strategies.

7AM1998-MEQ/BIOtopic06 oral

## RESEARCH AND MONITORING IN THE WAKE OF THE *EXXON VALDEZ* OIL SPILL: THE LONG-TERM DIVIDENDS

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The *Exxon Valdez* oil spill in March 1989 had an immediate toll on resources in the northern Gulf of Alaska-killing thousands of sea otters, about 250,000 seabirds and oiling 1500 kilometers of shoreline. There is evidence for longer-term impacts on pink salmon, Pacific herring and intertidal fish, as well as other components of the intertidal and subtidal communities. While lack of baseline data, inherent imprecision of census techniques and subsequent fluctuations in the natural environment have made it difficult to assess the final injury toll, and made the timing and course of recovery controversial, there is no doubt that the studies undertaken by the EVOS Trustee Council have greatly increased our knowledge of the marine ecosystem in the northern Gulf of Alaska. Of particular value are the three large ecosystem projects, APEX, NVP and SEA, that have provided insight into the ecology of important species and the ecosystem which supports them. The current bibliography includes more than 160 peer reviewed publications. Examples of basic contributions include: a demonstrated linkage between forage fish availability and sea bird reproductive success, a 3-d general circulation model of PWS, a predictive model of plankton dynamics, characterization of a large shift in the pelagic ecosystem of the northern Gulf of Alaska in the mid to late 1970s and use of fatty acid profiles to characterize diets of harbor seals. Plans for long-term monitoring and research in order to describe and understand the causes of intra-annual, inter-annual and multi-decadal changes in the northern Gulf of Alaska are under consideration.

7AM1998-MEQ/BIOtopic07 oral

## ESTUARINE POLLUTION AND JUVENILE SALMON HEALTH

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The marked declines in several Pacific Northwest salmon stocks is attributed to the cumulative effects of natural and anthropogenic factors. The relative contributions of individual factors to changes in salmon stocks; however, is not well understood. Human impacts on habitat processes have clearly contributed significantly to stock declines. In urban estuaries, pollution is one anthropogenic factor that may influence survival of juvenile salmon. Accumulation of chemical contaminants in juvenile fall chinook salmon during their relatively short residence in several estuarine environments along the North American west coast has been demonstrated. Moreover, our recent surveys of coastal estuaries show that pathogens are present in juvenile salmon from all systems examined. Our field and laboratory studies reveal that juvenile salmon from contaminated estuaries exhibit physiological alterations ranging from subcellular effects to changes in immune function and growth, and studies by others suggest alterations in behaviour. These physiological effects have been linked to increased susceptibility to disease and to predation, processes suspected of contributing to the mortality of juvenile salmon. The findings from these studies suggest a linkage between the presence of elevated levels of complex mixtures of chemical contaminants in polluted estuaries and effects on health and survival of juvenile chinook salmon.

7AM1998-MEQ/BIOtopic08 oral

## EFFECTS OF CLIMATE CHANGE ON THE TRANSPORT, PATHWAYS, AND AVAILABILITY OF CONTAMINANTS

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Changes in atmospheric and oceanic circulation can affect the global transport and ultimate fate of pollutants and contaminants. It is important to consider how predicted climatic change will alter the long-range transport and availability of contaminants entering marine ecosystems. General circulation models (GCMs) predict a polar amplification of greenhouse gas-induced warming due to complex temperature-albedo and temperature-water vapor feedbacks resulting from the retreat of sea ice and snow. Over the Arctic and northern seas, surface air temperatures are predicted to warm by 4-5 C and substantial decreases in sea ice are expected by the middle of the next century. As a consequence, the Northwest Passage of the Canadian Arctic and the Northern Sea Route of Russia will likely be open for routine shipping. The potential increase in anthropogenic activities (industry and commerce) may increase pollution in polar and subpolar seas. Changes in latitudinal meteorological gradients (such as temperature) should alter global wind fields and also alter patterns of pollution transport. Global warming is also predicted to enhance the hydrologic cycle and increase precipitation in high latitudes in winter. Such large change in the hydrologic cycle has important implications for the pathways and load of pollutants entrained in marine ecosystems from rain, fog, ice, snow, and rivers. How is climate change altering the environmental half-lives of contaminants in marine systems? How will the sources, pathways, distributions, and persistence and behavior of pollutants be altered in a warmer world? Addressing these questions should assist in the conservation and management of fish, seabirds, and marine mammals.

7AM1998FISCCCCtopic01 oral

## UPWELLING CURRENTS AROUND A SHELF-BREAK CANYON AND INFLUENCES ON ZOOPLANKTON

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Barkley Canyon (off the West Coast of Vancouver Island) was surveyed extensively in the summer of 1997. Moorings were deployed inside the canyon at several depths from April to October and during a cruise in July, CTD casts and zooplankton tows were performed. The observations generally support recent theoretical and numerical studies of upwelling flow around canyons. In particular the changing strength of the shelf-break canyon, rather than the wind, is responsible for upwelling within the canyon. Barkley canyon shows a similar upwelling pattern as other shelf-break canyons but with a stronger water property signature in the mixed layer. Upwelling is enhanced within the canyon compared to the surrounding shelf-break. Results from the zooplankton tows show canyon currents particularly affect species with strong diel migrations such as *Euphausia pacifica*.

7AM1998FISCCCCtopic02 oral

## PACIFIC SALMON CARRYING CAPACITY, ECOSYSTEM STRUCTURE, AND DENSITY DEPENDENT PREDATOR-PREY INTERACTIONS ON THE HIGH SEAS

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The inverse correlation between population size and individual body weight of many stocks of Pacific Salmon (*Oncorhynchus spp.*) is well known, and has led to speculation that the amount of food available for salmon growth on the high seas is limited. Yet no study has found direct evidence of food limitations at sea during periods of high salmon abundance. In addition, no assessment has been made of the effect of recent high salmon production on other species in the ocean ecosystem. In this paper, multivariate analyses of data on phytoplankton, zooplankton, secondary carnivores (squid) and salmon from research cruises in the Gulf of Alaska and High Seas Salmon Project databases are used to show: (1) levels of variation in ecosystem structure on local, interannual, and interdecadal time scales, (2) the relative importance of prey availability, salmon population size, seawater temperature, and other oceanographic conditions on salmon distribution and feeding potential, and (3) the effects of salmon and salmon variation on ecosystem trophic dynamics over the last four decades.

7AM1998FISCCCCtopic03 oral

## THE IMPACTS OF DECADAL SCALE CHANGES IN CLIMATE ON THE STRAIT OF GEORGIA ECOSYSTEM

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Changes in climate in 1976/77 and 1989/90 affected the dynamics of the ecosystem in the Strait of Georgia. The regimes were characterized by increasing temperature after 1976 and decreasing Fraser River flows. After 1989 temperatures continued to increase, as well as early spring flows from the Fraser River and an abrupt increase in sea level. The shifts in trends of Fraser River flows are important because the oceanography of the Strait is affected by an esturine circulation. Biologically the changes in the Strait of Georgia ecosystem were seen as an increase in Pacific hake and Pacific herring abundance, a decline in chinook salmon and coho salmon abundance and an increase in the residency of juvenile chum salmon. The 1989/90 change also affected the movements of coho salmon out of the Strait resulting in the collapse of the recreational fishery. The link between physical oceanographic changes and increased production of hake and herring appears to be an earlier movement of *Neocalanus minutus* into the surface waters. This improves the survival of hake and herring. We propose that the more abundant hake and herring resulted in reduced food availability for chinook and coho salmon, reduced summer growth rates and higher winter mortalities according to the critical size-critical period hypothesis proposed by Beamish and Mahnken.

7AM1998FISCCCCtopic04 oral

## RETROSPECTIVE DATA ANALYSIS IN THE U.S. GLOBEC NORTHEAST PACIFIC (NEP) PROGRAM

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In late 1997, the U.S. GLOBEC program of the National Science Foundation and NOAA's Coastal Ocean Program, funded 13 projects to begin studies in the Northeast Pacific. Of these, eight concern the assembly and analysis of existing data sets--i.e., Retrospective Data Analysis (RDA). The NEP is an ideal coastal location to examine biophysical interactions because it 1) has strong physical forcing with several dominant temporal scales (ENSO's, regime shifts), and 2) there are several physical and biological data sets that are long enough to evaluate the effects of the forcing. The NEP program focuses on the response of salmon and zooplankton populations (the target species) to climate variability and climate change, but the RDA projects cover a wide range of physical processes, spatial scales, trophic levels and geographic regions. Ted Strub and coworkers are examining meso- and large-scale physical forcing and structure using satellite based sensors (AVHRR, altimetry, SeaWiFS, SAR). Frank Schwing and colleagues are examining decadal and interannual variability in atmospheric and oceanic fields and processes at the basin scale using archived surface and subsurface datasets. Suzanne Strom is using microzooplankton samples collected from winter and spring during 1987-88 and 1993-97 along Line P to evaluate mechanisms by which climate-driven physical changes in the subarctic Pacific

alter food web structure and function. Mark Ohman and David Checkley are examining taxon-specific zooplankton responses to decadal scale changes in climate, ENSO and other interannual variations, and regional differences in coastal upwelling and offshore transport using the ca. 50 years of CalCOFI zooplankton sampling. Ric Brodeur and coinvestigators are analyzing ichthyoplankton samples from the NEP from 1981-1996, with a goal of characterizing spatial-temporal distributions and spawning strategies of many of the dominant fishes and their response to changing environmental conditions. Bruce Finney is using stable isotopes in layered sediments of freshwater lakes to reconstruct and compare historic trends in salmon abundance in the CCS and GOA and examine relationships between climate change and abundance over the past 500-2000 years. Steve Berkeley and Dudley Chelton are comparing otolith-derived growth rates of long-lived sablefish from the CCS and GOA, evaluating the correspondence between juvenile growth and subsequent recruitment, and comparing time-series of sablefish growth with time-series of environmental conditions. Finally, Beth Sinclair and coworkers are investigating the effects of the 1976-77 regime shift on the trophic positions, productivity and growth of top predators (fish, birds, marine mammals) in the GOA. Preliminary findings of these retrospective projects will be presented.

7AM1998FISCCCCtopic05 oral

## MODELLING THE RESPONSE OF THE PLANKTONIC FOODWEB TO CLIMATE VARIABILITY IN THE SUBARCTIC PACIFIC

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Existing observations are inadequate to identify and to understand the processes by which oceanic and atmospheric variability affect the marine foodweb at climate scales. To aid in the identification and study of important processes, we employ a one-dimensional coupled mixed layer / planktonic ecosystem (Nutrient-Phytoplankton-Zooplankton-Detritus) model of the subarctic Pacific Ocean. Under the assumption that the availability of iron might vary as the climate varies, we test the response of our model to a simple formulation of iron limitation. Simulations with and without iron limitation of primary production by phytoplankton yield a difference of about a factor of two in the standing stock of zooplankton during the productive season, although changes in phytoplankton biomass are small. We compare this result with sensitivity studies where we add temperature dependence to metabolic processes in the model and perform simulations with a warming (or cooling) characteristic of expected natural and forced changes in climate over the next few decades. We present initial results for an isopycnal ocean general circulation model of the North Pacific Ocean with an embedded NPZD ecosystem model.

7AM1998FISCCCCtopic06 oral

## LONG-TERM VARIABILITY IN SOCKEYE SALMON ABUNDANCE IN THE GULF OF ALASKA AND CALIFORNIA CURRENT SYSTEMS

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The main goals of this US GLOBEC project are to reconstruct trends in sockeye salmon abundance in the California Current and Northern Gulf of Alaska systems over the past 500 to 2000 years, to compare trends in abundance between the systems, and to determine relationships between climate change and salmon abundance. This project is using newly developed techniques to reconstruct salmon abundance trends from stable isotopic analysis of lake sediment cores. Several sites are being studied in each of the California Current and Northern Gulf of Alaska systems to compare trends within and between regions. Fieldwork has been completed and core analysis is in progress. Initial results are available for several Gulf of Alaska sites. Similar patterns in reconstructed salmon abundance are evident during the past 500 years, with major cycles occurring over timescales of 50 to 100 years. Though the common patterns suggest forcing by large scale ocean-climate changes, relationships between reconstructed salmon abundance and paleoclimatic records, determined from tree rings studies, are complex. Major long-term changes in sockeye abundance in the Gulf of Alaska appear to have occurred over the past 2000 years. Work is in progress to assess the regional similarity of these changes, and relationships to paleoenvironmental changes over this interval.

7AM1998FISCCCCtopic07 oral

## THE HIGH RESOLUTION PALEOCEANOGRAPHY OF THE FAR NORTHWESTERN PACIFIC, OKHOTSK AND BERING SEA DURING LAST 45 THOUSAND YEARS

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The Far NW Pacific and its marginal sea sediment cores with high sedimentation rate were studied by means of planktonic and benthic foraminifera (pf, bf) d18O and d13C method, lithology, carbonate and organic content in sediment diatom and pollen analysis. The age model of these cores was based on 14C AMS datum, oxygen isotope stages (MIS) boundaries, carbonate and opal content variation.

Reconstructed regional surface water condition, productivity and surrounded land climate have demonstrated millennial cycles variability during Holocene and isotope stages (MIS) 2 and 3 similar Interstadial (IS) events and Bond cycles in the North Atlantic (Dansgaard et al.,1993; Bond et al., 1993). Diatom and pollen results allow to make the progress in separation of surface water salinity and temperature affects in the studied d18Opf records during deglaciation and Holocene, and determination of the regional IS events during MIS 2 and 3.

There are strong changes of the ice rafted debris content in the regional sediments coevaled with d18O variations of the planktonic foraminifera indicating on variability of marine ice cover and surrounded glacier extension. Intensity of the ice rafted lithic input in the FNW Pacific and South Bering Sea bottom differs from that of observed in the Okhotsk Sea during MIS 2 and 3.

Geochemical, micropaleontological and lithological results have demonstrated sufficient and abrupt paleoenvironmental changes in FNW Pacific and marginal seas during Holocene.

7AM1998FISCCCCtopic08 oral

## SOUTHEAST BERING SEA CARRYING CAPACITY (SEBSCC): ECOSYSTEM DYNAMICS RESEARCH IN A MARGINAL SEA

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SEBSCC is a NOAA Coastal Ocean Program Regional Ecosystem Study. It is a 6-yr. cooperative program between NOAA and academic scientists, and is jointly administered by the University of Alaska and NOAA's Alaska Fisheries Science Center and Pacific Marine Environmental Laboratory. SEBSCC's goal is to increase understanding of the southeastern Bering Sea ecosystem. Specifically, the program seeks to document the role of juvenile walleye pollock (*Theragra chalcogramma*), a nodal species, in that ecosystem. Our objectives are to learn which biophysical factors affect pollock survival, and to develop and test annual indices of pre-recruit (age-1) pollock abundance. To accomplish this, research is organized under 5 categories: retrospective, modeling, monitoring, lower trophic levels, and upper trophic level studies. Our presentation will address monitoring and trophic investigations during SEBSCC's first two years.

During summer and fall 1997, SEBSCC investigators observed one of the largest ecosystem perturbations ever recorded for a high latitude marginal sea. Anomalous summer conditions (warm surface temperatures [14°C], clear, sunny days, and a shallow mixed layer [5 m]) were similar to those previously predicted for a climate change scenario. Concomitant with the anomalous conditions were: a large (2.1 x 105 $km^2$), prolonged bloom of coccolithophores; water column depletion of macro-nutrients over the middle shelf; marine mammals in new summer habitat; relatively high mortality of Short-tailed shearwaters; economically crippling return of Bristol Bay sockeye salmon. Spring and early summer conditions in 1998 were completely different - the winter/spring storm transition occurred later than usual, delaying establishment of stratification and the onset of seasonal pelagic production.

7AM1998FISCCCCtopic09 poster

## SPAWNING BIOMASS AND MATURATION OF WALLEYE POLLOCK IN THE PACIFIC COAST OF EASTERN HOKKAIDO

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Previous study indicated a presence of some spawning grounds in the Pacific coast of Hokkaido. It was reported that the adjacent waters of Funka Bay was a major pollock spawning ground in the Pacific coast of Hokkaido, and another spawning grounds were small.

We examined the changes in the adult stock abundance and gonadal maturity of walleye pollock in the Pacific coast of eastern Hokkaido, from September 1990 to May 1994. The adult stock abundance decreased from September through December, and increased in February and March. Most of adults were maturing from September through December, and spawning and spent in February and March. We thought that most of adult pollocks distributed in this area in autumn had migrated to the adjacent waters of Funka Bay. Spawning season of pollock in the Pacific coast of eastern Hokkaido continued from January through May, because some female adults were observed in the stage of transparent oocytes. The abundance indices of pollock spawned in the Pacific coast of eastern Hokkaido showed the level in high in 1991 and 1994, and in low in 1992 and 1993. The spawning biomass in this area might change annually.

The body sizes of maturation were varied in individuals. The minimum lengths of primary maturation were 32 cm in females and 29 cm in males. And, averaged lengths of maturation were 40 cm in females and 36 cm in males. Annual changes were not observed in the body sizes of maturation.

7AM1998FISCCCCtopic10 invited

## GLOBEC AND GLOBEC - LIKE RESEARCH PROGRAMS IN THE ATLANTIC

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The First GLOBEC Open Science Meeting, held in Paris in March this year, provided a forum to present a draft of the GLOBEC Implementation Plan to the international science community and provided an opportunity for discussion, and feedback. A final draft of the Implementation Plan has now been completed and has been sent to National and Regional Programs for comments prior to submission to the co-sponsors of GLOBEC, IGBP, SCOR and IOC.

Major components of the Implementation Plan are the four GLOBEC Regional Programs. In addition to the PICES-GLOBEC Climate Change and Carrying Capacity Program, there are also the GLOBEC Southern Ocean Program, Small Pelagic Fishes and Climate Change and the ICES - GLOBEC Cod and Climate Change Program (CCC). All address how climate change may affect ecosystem structure and productivity of key biological species.

Current activities of the latter two programs in the Atlantic will be reviewed focussing on modelling, observational programs and process oriented research. Examples will highlight the recent results of the Continuous Plankton Recorder Survey, the Trans-Atlantic Study of *Calanus finmarchicus* (TASC), and the ICES Cod and Climate Change Program in the North Atlantic, and the BENEFIT program off Southwest Africa.

7AM1998FISCCCCtopic11 oral

## OCEAN CARRYING CAPACITY PROGRAM

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During the past 20 years, body size has decreased and the age at maturity has increased in many stocks of salmon in both North America and Asia. These changes are associated with large increases in salmonid production that coincide with major changes in ocean climate in the North Pacific Ocean that began about 1976. The inverse relation between body size and abundance of salmon in the ocean suggests that there may be limits to the carrying capacity of the North Pacific Ocean for salmonid production. In response to this evidence, the North Pacific Anadromous Fish Commission (NPAFC) called for research on the critical issue of the impact of change in the productivity of the North Pacific Ocean on Pacific salmon by studying factors affecting: (1) current trends in ocean productivity and their effects on salmonid carrying capacity, and (2) changes in the growth, size at maturity, oceanic distribution, survival, and abundance of Pacific salmon.

The Ocean Carrying Capacity Program (OCC) was formed in 1995 as the first U.S. effort specifically designed to address the NPAFC concerns. The OCC research strategy has four major components: 1) Research on salmon and associated species in the North Pacific Ocean and Bering Sea; 2) immature and maturing salmonids in offshore waters; 3) retrospective studies; and 4) monitoring studies. Results of OCC research in 1996, 1997, and preliminary results of research in 1998 will be discussed.

7AM1998FISCCCCtopic12 oral

## MODELING ACTIVITIES WITHIN THE U.S. GLOBEC NORTHEAST PACIFIC PROGRAM

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In keeping with the U.S. GLOBEC philosophy of "Modeling first!", the National Science Foundation and National Oceanic and Atmospheric Administration's Coastal Ocean Program funded five modeling projects in the first solicitation for proposals to investigate the coastal ecosystems of the Northeast Pacific. Four of these were funded specifically by U.S. GLOBEC, while a fifth was funded by NSF earlier and subsequently merged into the U.S. GLOBEC program. This talk provides an overview of the research goals and approaches of these five modeling projects and more specific details about one of them. Two of the projects are specific to the California Current (CCS) limb of the circulation in the NEP, one is specific to the Alaska Stream-Alaska Current limb (CGOA), one is examining forcing and responses at the largest basin scales, and one is developing inverse techniques to estimate plankton population dynamics and is applicable to either ecosystem. Tom Powell and Dale Haidvogel are developing coupled biophysical models of the CCS, specifically to examine how upwelling and offshore transport in filaments impact the distribution and demography of several copepods and euphausiids. This work will couple individual based models (IBM) of the target crustacea with appropriate NPZ+ models embedded in realistic 3D circulation fields. A specific goal is to investigate how species having different vertical migration patterns are differentially impacted by mesoscale features in the CCS. Loo Botsford and several colleagues are developing models of salmon and dungeness crab populations, with the goal of linking different scales of population and environmental variability and levels of ecological organization, so that the effects of changes in the physical environment on these populations can be

projected. Dale Haidvogel, Al Hermann, Sarah Hinckley and colleagues are implementing a set of linked circulation models, coupled with a lower trophic level NPZ biological model and an IBM of salmon, for the coastal Gulf of Alaska region. Forcing for the circulation models will include wind, river runoff and tides. The NPZ model will be used to provide prey fields for salmon feeding within the salmon IBM. Mark Huntley and Meng Zhou are developing a practical zooplankton model based on biomass spectrum theory. Testing and initial application of the method will use eddy-resolving CTD-optical plankton counter (OPC) data collected previously in the CCS, but later applications will be directed toward interpretation of data generated by the U.S. GLOBEC program in the CCS and CGOA. The model describes the size-structured zooplankton distribution and productivity of mixed plankton assemblages, and will directly provide 1) estimates of population dynamics rates from field observations of size distributions, 2) interactions between size classes, and 3) improved understanding of the spatial and temporal variation in size structured populations and production. The final modeling project (Frank Schwing and his coworkers) also has a large retrospective component; modeling will focus on simulating open ocean and coastal circulation and thermohaline structure of the North Pacific on interannual to decadal scales, using relatively sparse historical observations. Physical modeling objectives of the Haidvogel et al. project include the development of a regional model for the coastal Gulf of Alaska which explicitly captures both tidal and subtidal circulation. This allows a more realistic assessment of the effects of tidal mixing on the biological dynamics. A global circulation model is being developed to provide both tidal and subtidal boundary conditions for the CGOA region (and for other regional models within GLOBEC and Southeast Bering Sea Carrying Capacity programs). Numerical methods have been designed to smoothly and simultaneously pass both tidal and subtidal information from the global model (finest resolution ~12km) to the regional CGOA model (finest resolution ~4km).

7AM1998FISCCCCtopic13 oral

## EFFECTS OF HYDROGRAPHIC CONDITIONS ON THE FORMATION OF SPAWNING GROUNDS FOR SARDINE, *SARDINOPS MELANOSTICTUS*, IN THE JAPAN SEA

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The purpose of this study is to evaluate the effect of hydrographic conditions on the formation of spawning grounds for sardine, *Sardinops melanostictus*, in the Japan Sea in relation to the stock fluctuation. Vertical/ oblique towing with LNP, 80-ring net and hydrographic observations were carried out in May from 1989 to 1997 around Noto Peninsula, one of the most important spawning grounds for sardine in the southern Japan Sea, recently.

From the observation results, sardine eggs were abundant in 1992 and 1993, conversely less abundant in 1989, 1996 and 1997. Properties of waters in the spawning grounds ranged 11-16°C, 33.8-34.7 PSU at 50 m depth, but main spawning grounds were formed in the coastal branch of the Tsushima current. Strong cold water regions did not exist in the coastal waters in years when abundant eggs were collected. Moreover, we compared between egg abundance form March to May and distribution of cold water regions in March from 1979 to 1994. These results showed that the stronger cold water regions existed, the less abundant sardine eggs were collected in the Japan Sea. These facts suggest that spawning migration of sardine is affected by the distribution of the Tsushima current water in coastal areas. The long-term fluctuation of cold water regions in spring from 1964 to 1997 corresponds with air

temperature and SST fluctuations in winter with decadal signals. It is suggested that migration patterns of sardine fluctuate in relation with that of large scale air-sea reciprocal actions.

7AM1998FISCCCCtopic14 oral

## PACIFIC BASIN CLIMATE VARIABILITY AND PATTERNS OF NORTHEAST PACIFIC MARINE FISH PRODUCTION

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Review of oceanographic and climate data from the North Pacific and Bering Sea revealed climate events that occur on two principal time scales: a) 2-7 years (i.e. El Niño Southern Oscillation and interannual variation), and b) inter-decadal (i.e. Pacific Decadal Oscillation, PDO). The timing of ENSO events and of related oceanic changes at higher latitudes was examined. The frequency of ENSO was high in the 1980s. Evidence of ENSO forcing on ocean conditions in the North Pacific (Niño North conditions) were more frequently observed along the West Coast than in the western GOA and eastern Bering Sea. Recruitment data for 23 groundfish and 5 non-salmonid pelagic species from three large geographic regions were examined for evidence of Pure Temporal Variability (PTV) caused by large scale forcing at one or more of the time scales noted in oceanographic and climate data. Most salmonids and some flat fish stocks exhibited high autocorrelation in recruitment coupled with a significant step in recruitment in 1977 suggesting a relationship between PDO forcing and recruitment success. Six of the dominant groundfish stocks (Atka mackerel, Pacific cod, Pacific hake and walleye pollock) exhibited low autocorrelation in recruitment. Pacific hake and GOA walleye pollock exhibited a higher incidence of strong year classes in years associated with Niño North conditions. These findings suggest that PTV may play an important role in governing year class strength of Northeast Pacific marine fish stocks.

7AM1998FISCCCCtopic15 oral

## CARRYING CAPACITY CHANGE OF OYASHIO SHELF ECOSYSTEM WITH DISAPPEARANCE OF JAPANESE SARDINE

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The changes in Oyashio Shelf Ecosystem with disappearance of Japanese Sardine was examined using Trophodynamic Model. Among the components of model, i.e. Diatoms, Copepods, Euphausiids, Sardine and Pollock, the biomass of components except Copepods (and Sarcine) increased. The Carrying Capacity of the ecosystem for each component was examined by response of P/B ratio with perturbation of biomass.

7AM1998FISCCCCtopic16 poster

## CARBON AND NITROGEN ISOTOPIC COMPOSITION OF PRINCE WILLIAM SOUND PELAGIC BIOTA SHIFT ON ANNUAL TIME SCALES: A TOOL FOR MONITORING CHANGES IN OCEANOGRAPHIC FORCING

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Changes in the physical environment that are known to affect phytoplankton and zooplankton production were linked to fish production through carbon and nitrogen stable isotope natural abundance measurements. Stable isotopic analyses of herbivorous copepods and juvenile fishes from Prince William Sound (PWS) and the northern Gulf of Alaska (GOA) were conducted as part of the Sound Ecosystem Assessment (SEA) project, a comprehensive multi-disciplinary ecosystem study. The advective regime connecting the GOA with PWS was postulated by SEA to effect recruitment and nutritional processes in juvenile fishes. Herbivorous zooplankton, a proxy for pelagic production sources, had distinctive carbon isotope signatures when sampled in the GOA compared to those from PWS. PWS carbon had consistent carbon isotopic signatures during 1994-6 while GOA carbon varied. Nevertheless, PWS carbon was always distinctive from GOA carbon. This variation suggested that inter-annual fluctuations occurring at the food chain base are driven by processes in the Gulf.

Analyses of nitrogen isotope ratios and C/N ratios of juvenile fishes were used to make their carbon isotope ratios comparable, enabling determination of their relative affinity for GOA or PWS carbon. The data suggest a large affinity range, changing on annual time scales, consistent with observed oceanographic phenomena. For example, there was a shift to a greater dependency on GOA carbon in 1995 compared with 1994 and 1996. A parallel shift to increased GOA-originating copepods undergoing diapause (resting phase) in 1995 suggesting an influx of GOA zooplankton, provided a second line of evidence. Thus herring and other fishes partially dependent on GOA carbon are subject to vagaries of carbon flow that fall under the domain of physical oceanographic processes connecting the GOA with PWS as well as processes occurring on the GOA continental shelf adjacent to PWS.

7AM1998FISCCCCtopic17 oral

## CHANGES IN YEAR-CLASS STRENGTH OF POLLOCK STOCK IN THE RUSSIAN EEZ OF THE BERING SEA IN RELATION TO CLIMATIC VARIATIONS IN THE NORTH PACIFIC

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Changes in the year-class strength of pollock stock in the Russian EEZ waters in the Bering Sea for the 1969-1995 period are analyzed in the context of climatic variations in the North Pacific region and Bering Sea. This study is a part of interdisciplinary research conducted by VNIRO scientists with the purpose to understand how climate affects the ecosystem structure in the Russian EEZ and the productivity of the considered fish stock which is one of the key commercial species for Russia. To characterize climatic variations in the North Pacific and the Bering Sea, data on sea level presure, geopotential heights on the 700 hPa surface, water temperature and salinity at different depths, and geostrophic currents are used. The research is focused on identifying those climatic patterns which are favorable or unfavorable for formation of strong year classes of species under consideration.

7AM1998FISCCCCtopic18 oral

## SEASON, SIZE AND DEPTH PARTITIONING OF COPEPOD PRODUCTION IN THE SUBARCTIC PACIFIC

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Large copepods of the genus *Neocalanus* dominate the mesozooplankton community biomass and secondary production throughout the subarctic Pacific. Quantitative information about the fate of their large annual secondary production (what predator species consume how much, and when) is critical to questions about subarctic Pacific carrying capacity. Time and space correlations between copepod and predator abundance are open to multiple and conflicting interpretations, and direct measurements of predator consumption rate are sparse. However, much good information is available on seasonal development, growth and mortality schedules of *Neocalanus spp.* I have used this information to model the season, size and depth partitioning of predation on *Neocalanus plumchrus*. This in turn provides information about which predators are likely to be most important. Total annual production and predation mortality (about 10 billion tonnes wet weight) divides into three roughly equal categories:

1) spring season predation in the upper 100 m on nauplii and small early copepodites, probably mostly by other zooplankton.

2) spring-early summer predation in the upper 100 m on large late copepodites by pelagic fish, zooplankton and migratory micronekton.

3) late summer-winter predation below 400m on diapause copepodites and pre-spawning adults, probably mostly by midwater micronekton.

7AM1998FISCCCCtopic19 oral

## APPLICATION OF FUZZY LOGIC TO FORECASTING ALASKA WALLEYE POLLOCK RECRUITMENT

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Management of exploited marine fish stocks often relies on the use of models that project into the future the estimated impacts of implementing exploitation strategies or making assumptions about trends in future recruitment patterns. Results of these exercises are very sensitive to the recruitment assumption; a situation that underscores the critical need for reliable and accurate recruitment forecasts. Unfortunately, the complexity of the renewal problem in fisheries science makes successful recruitment forecasting an illusive goal.

In this paper, a fuzzy knowledge-based inference system for the prediction of year class strength is described and applied to Alaska walleye pollock (*Theragra chalcogramma*). The forecast model employs fuzzy logic to handle inexact reasoning and vague or incomplete knowledge regarding the factors that control or strongly influence recruitment success. Fuzzy sets are also used to address uncertain or imprecise data. Membership functions that relate information sources to recruitment success are described as fuzzy sets and calibrated to existing data. A mixture of quantitative and qualitative information as well as subjective expert knowledge are combined and processed with the knowledge-based system. Forecast and observed recruitment data are compared.

Compared to traditional modeling paradigms, fuzzy knowledge-based systems provide a robust and valuable tool which offers several significant advantages: they are well adapted to handling non-linear problems of arbitrary complexity, they do not require an a priori functional structure, they are tolerant of imprecise data and vague knowledge, and they can accommodate a wide range of information sources. First results, which show much promise, indicate that fuzzy theory seems well suited to the problem of recruitment forecasting.

7AM1998FISCCCCtopic20 oral

## LONG TERM FLUCTUATIONS OF THE BIOMASS AND SIZE COMPOSITION OF COPEPODS IN THE KUROSHIO AND THE JAPANESE SLOPE WATER IN RELATION TO CLIMATE CHANGE

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Fluctuations of biomass density and size composition of copepods and gut contents of the adult females of the major species in early spring were examined in the Kuroshio and the slope water off the south coast of the central Japan from 1971 to 1989. In both regions, biomass densities of small copepods (prosomal length < 1mm) were low around 1980, while large copepods (prosomal length >= 1mm) tended to decrease during the study period. Stepwise multiple linear regressions between the three years' running mean of the biomass densities and environmental factors revealed that (1) biomass density of the small copepods were negatively related with the percentage of possible sunshine and positively related with the wind speed; (2) the Kuroshio path affected the biomass density of the small and the large copepods in the Kuroshio. During the study period, nano-size foods other than diatoms in the gut of the major species increased in both regions, whereas diatoms in the gut decreased especially in the Kuroshio. In the Kuroshio, the biomass density of the large copepods increased with diatoms in the gut of the large species, which were positively related to environmental factors possibly enhancing the new production such as wind speed. Thus, climate change appeared to affect size composition of copepods through the effects on the composition of foods for the copepods.

7AM1998FISCCCCtopic21 oral

## ON THE EXPLANATION OF RELATIONS BETWEEN CLIMATE CHANGE AND POPULATION DYNAMICS

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The values of external (physical and chemical) and internal (biological) parameters influencing population state in the ocean are defined by many processes, which consist of a great number of randomly interacting spatio-temporal cycles. It means, following the probability theory, that no one of the separately taken global external parameters can have high correlations with the specific biological parameters in the specific region. Nevertheless many results are published (Beamish and Boullion, 1993; Klyashtorin and Sidirenkov, 1996 - among the latest), which show high correlations between

global climate and different populations' characteristics, even though the local environmental conditions for the populations can differ considerably. Here we propose and develop an approach, explaining the observed correlations as the result of independent, but simultaneous influence of the specific solar and cosmic radiation variations on climate and population characteristics. The approach is based on the experiments and theory of coherent oscillations in biological systems, excited by extremly weak electromagnetic signals. Electric vibrations in the 100 to 1000 billion Hz region, associated with a very high depole moment in biological membranes, lead to specific (oscillatory) biochemical reactions (e.g. enzyme-substrate interactions) and to macroscopic oscillations in the 10 to 100 Hz region. The dependence of such reactions on light spectral structure was shown earlier (Zvalinsky, 1993). In addition, variations of the Earth's electromagnetic fields due to primary and secondary cosmic rays should be taken into account. Analysis of the corresponding data and their comparing with published results of population dynamics gives rather interesting explanation to many facts of population large-scale variability.

7AM1998FISCCCCtopic22 oral

## ALTIMETER OBSERVATIONS OF THE MESOSCALE EDDY-FIELD ALONG THE SHELFBREAK IN THE CENTRAL BERING SEA

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Four years of TOPEX altimeter data (late 1992 through 1996) are analyzed to describe the mesoscale eddy-field along the shelfbreak in the central Bering Sea. Eddy activity is observed to occur during the entire period of the data record. The temporal and spatial scales of eddy-field variability are identified by spectral and least squares methods. Characteristic time scales of variability range from tens of days to hundreds of days whereas the characteristic (longshore) length scale is of order one hundred kilometers. Shorter period eddy activity typically occurs nearer the shelf-break than does longer period activity. Seasonal modulation of the eddy field is evident with greatest amplitudes occurring in the spring or summer months.

7AM1998FISCCCCtopic23 oral

## ENVIRONMENTAL CHANGE IN THE NORTH ATLANTIC REGION AND THE HEALTH OF TERRESTRIAL AND MARINE BIOTIC RESOURCES

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Interdecadal climate variability in the North Atlantic may be an important factor influencing the health of terrestrial and marine biota. Although a number of researchers have addressed this temporal scale for various areas, very few studies were concerned with the regional pattern of environmental change. Those are usually based on short time series or limited number of variables. Here we attempted a basin wide study employing extended time series on air temperature, atmospheric pressure, ice conditions,

water temperature and salinity with the major purpose to understand the spatial and temporal patterns of interdecadal environment variability in the region. We further analyze recruitment series for Atlantic cod (*Gadus morhua*) and tree ring records from coastal regions to determine the influence of climate change on the health of terrestrial and marine biotic communities.

Analysis of individual time series and a statistical generalization based on the empirical orthogonal functions analysis show that a strong opposition in environmental situation exists between the northwestern sector on one hand and the northeastern and southwestern areas on the other. Two periods of the seesaw are especially prominent. The 1960's where marked by anomalously benign environment for the northwestern sector while conditions in the northeast and southwest substantially deteriorated. This is coincident with increased recruitment rates and accelerated forest development in the northwest. Concurrently, there was a substantial decrease in fish presence in the northeast. Tree ring records indicate slow growth in both northeastern and southwestern sectors.

A notable cooling in the northwest during the late 1980's-early 1990's was accompanied by milder climates for the northeastern and southwestern areas. In the northwest, this interval was marked by a notable decline in cod recruitment, deforestation of the coast and tree line retreat. This coincides with an increase in availability of fish in the northeast and rapid tree growth along the northeastern and southwestern coast.

Both natural environmental trend and anthropogenic pressure seem to control the regional biotic resources. Their combined influence can be demonstrated for the northwestern sector. There, the warm environment of the 60's resulted in increased recruitment of ground fish and was able, during a short interval, to sustain extreme rates of exploitation. With the carrying capacity of environment greatly reduced, continued heavy harvest efficiently eliminated the northwestern cod in the beginning of the 90's. Therefore, understanding regional environmental trends and timely adjusting the effort to rapidly changing environmental conditions are extremely important for sustainable development. This, in turn, can be achieved through detailed environmental monitoring and wise management of natural resources.

7AM1998FISCCCCtopic24 oral

## PROGRESS REPORT ON THE DEVELOPMENT OF A BIOPHYSICAL MODEL FOR THE WEST COAST OF VANCOUVER ISLAND

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The three-dimensional, prognostic, finite element model QUODDY is used to calculate the tidal, buoyancy driven and wind-driven circulation off the west coast of Vancouver Island. The region is interesting oceanographically due to the presence of tidally-generated diurnal shelf waves, semi-diurnal internal tides, summer upwelling, a buoyancy-driven coastal current and a classical estuarine flow in Juan de Fuca Strait that arises from Fraser River discharge. The accuracy of the model is assessed through comparisons with historical observations, and its application to GLOBEC Canada will be discussed.

In particular, Lagrangian particle tracking techniques have been used to investigate horizontal transport resulting from the interaction between diel vertical migration (DVM) and numerically generated tidal and buoyancy currents. Diurnal constituents are important in producing regions of convergence and divergence, and on and off-shelf transport along the continental shelf, which repeat annually. The

inclusion of typical summer buoyancy flows dominate horizontal transport over the northern continental shelf, however on the highly biologically productive southern shelf region, DVM-tidal interactions are still important. The biological significance of the process is discussed.

7AM1998FISCCCCtopic25 oral

## GLOBEC 1998: PRELIMINARY MONITORING DATA FROM THE GULF OF ALASKA

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The Gulf of Alaska (GOA) shelf sustains a number of commercially significant fisheries. Despite dramatic changes in many of these fisheries in the late 1970's, little is known regarding the factors linking fish populations to the physical and climatic environment. Zooplankton data imply that cross-shelf transport is an important mechanism. Very little data are available, however, on nutrient distributions and primary productivity. In an attempt to document seasonal and inter-annual variability of cross-shelf transport, we have occupied a transect from the mouth of Resurrection Bay to the outer edge of the shelf break. Physical properties, nutrient concentrations, dissolved oxygen, chlorophyll concentrations, primary production rates, and zooplankton populations have been collected. A preliminary analysis of first year data will be discussed.

7AM1998FISCCCCtopic26 oral

## MEASURING THE STABLE CARBON ISOTOPE RATIO OF INDIVIDUAL FATTY ACIDS, A NOVEL TRACER IN MARINE FOODWEB STUDIES?

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Spatial variation in the stable carbon isotope composition of phytoplankton can be caused by differences in hydrographic properties, species composition, temperature, growth rate and $pCO_2$. An example of a geographical divergence in the stable carbon isotope signal of the Particulate Organic Matter (POM) can be found off the west coast of Vancouver Island. Perry *et al.* (submitted) showed that the bulk carbon isotope ratio ($\delta^{13}C$) of POM from the off-shelf environment was markedly lower than that of POM from the on-shelf region. This difference was found to be preserved higher up in the foodwebs of both regions.

The objective of current research is to develop a new tracer for marine food webs which can be used to determine food web pathways, fish movement and their influence on the dynamics of fish populations. We are using Continuous Flow Isotope Ratio Mass Spectrometry (CF-IRMS), which can determine the $\delta^{13}C$ of individual compounds. The approach is to measure the $\delta^{13}C$ of essential fatty acids in various marine trophic levels. Essential fatty acids are important structural "building blocks" for fish and in the marine foodwebs they are almost exclusively produced by phytoplankton. Therefore, a direct transfer from phytoplankton (and POM) to eventually fish, without isotopic alteration, is expected for

these fatty acids. Hence, given the spatial variance of the $\delta^{13}C$ of POM, it should be possible to link, for example, fish stocks to their former feeding ground.

The presentation will present results from samples of POM, zooplankton and several life-stages of fish, taken on multiple on-shelf to off-shelf transects off the West coast of Vancouver Island, in April 1997 as well as May 1998. Wide occurrence of Dungeness Crab megalopae were found on the latter survey and offer another good trophically horizontal control of our technique in progress.

7AM1998FISCCCCtopic27 oral

## THE GULF OF ALASKA GLOBEC LONG TERM OBSERVATION PROGRAM (LTOP)

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The Gulf of Alaska GLOBEC LTOP is an inter-disciplinary field effort directed at elucidating the temporal (seasonal and interannual) and cross-shelf variations in the physical, chemical, and biological components of this productive ecosystem. The over-arching program goal of the Northeast Pacific GLOBEC is to develop a mechanistic understanding of how climate variability affects ecological processes including higher trophic levels (as primarily represented by young-of-the-year salmon). The LTOP data are being used to quantify scales of physical and biological variability, in on-going retrospective studies, and in support of ecosystem models as boundary conditions and data sets for comparison with the models. A related goal is to devlop a cost-effective ecosystem monitoring strategy for this shelf.

Physical conditions on the Gulf of Alaska shelf are structured primarily by the wind field and the enormous freshwater discharge that enters the shelf as a coastal line source. Both winds and discharge vary strongly throughout the year leading to comparably large changes in shelf transport and thermohaline conditions. However, the winds promote coastal downwelling and the freshwater discharge has low nutrient concentrations. Thus a central focus of this program is to determine what sustains biological productivity on this shelf. These forcing variations also profoundly affect the distribution and abundance of phytoplankton, zooplankton, and salmon.

The LTOP program is a three-year effort which began in October 1997. The talk will describe the sampling design, illustrate features of the spatial, seasonal, and interannual variability in the physical and biological fields, and suggest processes causing the variability and responsible for supporting biological production.

7AM1998FISCCCCtopic28 oral

## ON RELATIONSHIPS BETWEEN CANNIBALISM, CLIMATE VARIABILITY, PHYSICAL TRANSPORT AND RECRUITMENT SUCCESS OF BERING SEA WALLEYE

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Walleye pollock (*Theragra chalcogramma*) is the single most abundant fish species in the Bering Sea and comprises the bulk of the commercial catch. Juvenile pollock are an important forage fish for pollock, other fish, marine mammals and birds. This paper examines the interaction between cannibalistic predation of adult pollock on juvenile pollock, climate variability, and related patterns in physical transport. Our analysis of adult and juvenile pollock abundance and distribution time series, ocean current modeling studies, and information on climate variability indicate that pollock cannibalism is a major determinant of interannual recruitment variability. In turn, the intensity of pollock cannibalism appears to be dependent on the degree of spatial separation of adults and juveniles. Simultaneous consideration of these important biotic and abiotic factors suggests a possible underlying mechanism. Strong year-classes occur when juvenile pollock are transported inshore and away from adults by northerly currents in spring - conditions typical of warm years. In cold years, northerly transport is reduced and juvenile utilization of inshore regions is more limited. Co-occurring distributional patterns of adults and juveniles resulting from these conditions lead to increased cannibalism and subsequent weak year-classes.

We used neural networks to examine the relative importance of physical and biological variables on year-class strength Bering Sea walleye pollock and to predict future recruitment. Both prediction and classification schemes were investigated

7AM1998FISCCCCtopic29 oral

## TEMPORAL VARIABILITY OF FOOD-WEB STRUCTURE IN THE OYASHIO-KUROSHIO TRANSITION REGION

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The area off Pacific coast of northern mainland of Japan is characterized by a complicated oceanographic structure. So the area exhibits substantial physical variabilities in various temporal scales. In this paper, the response of food-web structure to the physical variability in the transition area is presented.

A biannual trawl survey was conducted for 4 years off Sendai Bay at 100-500 m depths of water. Catches of a total of 256 bottom trawls and stomach samples were stratified based on year, month and depths. Fish diets were analyzed for each subset using over 8,000 fish stomach specimens. As a relative importance of a trophic linkage, an index considering diet and dominance of predator was calculated.

The study area showed seasonal physical variability. The bottom temperature was in a range of 2-8°C during May due to Oyashio water, whereas the sea bottom of continental shelf (¾200 m) was covered

with warm (>10°C) Kuroshio water during November. Interannual variability was also apparent especially during May.

Distinct seasonal differences were found both in predator composition and major prey of fish assemblages. These differences result from annual life cycles and responses of demersal fishes to the seasonal replacement of water mass. Interannual variability was also apparent. For instance, during May 1990 when Kuroshio water mass was prevalent, both fish and prey normally abundant in the shallow strata extended to the deep strata. Environmental variabilities thus have the potential to alter food web structure by changing abundances of both predator and prey.

7AM1998FISCCCCtopic30 oral

## THE IMPACTS OF CLIMATE CHANGES ON THE MARINE FISHERIES RESOURCES IN KOREA

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A number of changes in the marine ecosystem and fisheries resources were observed in Korean waters in 1976 and in 1988. The year 1976 was recognized as an abnormally warm year in Korea, when the mean SST of the East Sea was higher than normal and the thermal front was shifted to the northern part. Since 1976 sea anomaly indices below 50 m depth have become positive and mixed layer depths (MLD) have become deeper. The abundances of phytoplanktons and zooplanktons have decreased at the same period. In the catches of fisheries resources in Korean waters, the species composition and catch amounts began altering in 1976. For example, the catches of walleye pollock, sardine, corvenias and mackerel increased, while those of saury and herring decreased. This phenomenon indicates that the changes in species composition occurred, that is, saury population was replaced by sardine and then by mackerel in turn in warm water areas, and herring by pollock in cold waters. The changes of the marine ecosystem in Korean waters such as sea temperature below 50 m depth, MLD, abundances of phyto- and zooplanktons were observed in 1988. Considerable changes of annual catches of some important species were also observed from 1988.

7AM1998-FISpaper01 oral

## FISHING GROUND FORMATION OF SMALL PELAGIC FISHES AND MARINE ENVIRONMENT IN THE EAST CHINA SEA

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Catch condition of pelagic fishes by month and by area in the East China Sea was investigated by analyzing the catch and CPUE data in 1975-1997 from Japanese large-and-medium scale surrounding net fishery which were divided into 30'Lat. 30'Long. meshes. We got ocean color data from the observation satellites "NIMBUS" and "ADEOS". Those data were related to the distribution of chlorophyll and the dynamics of food organisms. To integrate the information from fishery and the environmental condition data and to analyze them, a GIS (Geographical Information System)

application was used. Putting catch, CPUE and other environmental factors onto the GIS layers respectively, the characteristics of fishing ground formation for each fish stock have been extracted by combining layers arbitrary. We could find some aspects of fishing ground formation which we have not detected before by analyses of water temperature profiles only. The details will be reported at the meeting.

7AM1998-FISpaper02 poster

## MIGRATION COURSE OF SMALL CETACEANS BY SATELLITE TRACKING

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Satellite transmitters were attached to two bottlenose dolphins, *Trusiops truncatus*, and eight striped dolphins, *Stenella coeruleoalba*, caught alive by drive fishery at Taiji (33°36'N, 135°56'E), Kii Peninsula in 1994-96. Migration courses of these dolphins were tracked by Argos system for 46-66 days. Total migration distances were 1,637 km and 2,200 km, and the average migration speeds were 1.4 km/h and 1.5 km/h. Both bottlenose dolphins migrated to the near shore off Kii Peninsula in February, offshore area from Suruga Bay to Boso Peninsula in March and offshore area from Izu archipelago and Enshu-nada in April. The striped dolphins were tracked for 4-18 days in the middle of January. A total migration distance ranged from 78 km to 436 km, and the average migration speed ranged from 0.8 km/h to 3.8 km/h. Both striped dolphins migrated to the near shore of Izu Archipelago. Migration course of both species coincided with the direction of Kuroshio current indicating that they utilized the ocean current.

7AM1998-FISpaper03 poster

## CONCEPTION OF PERSPECTIVE FORECAST OF PELAGIC COMMUNITY IN THE KUROSHIO REGION

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Perspective object of forecasting of fishery resources can be spectrum species the exploitating part of fish community. Characteristics of community include diversity and density. This kind of forecast differ from the annual forecast of catches, because prospective period vary independence from continuation of life cycle and continuation of period of maturing pubescence. But some features are common. This is constant number of new generations what must create exploitable stocks in the future. Characteristics of 5 - 10 generations forecast very often.

Algorithm of perspective forecast include two main steps. First step is forecast of dominant species in the early stage of community (ichtyoplankton). For this purpose we use species composition ichtyoplankton data. Every year we add to retrospective data new data of species composition. Then

rows (number) have approximated by functions but without analyze of population characteristics (size - age composition). And we can form trend of species density.

Next stage is extrapolation of this trend with giving forest alling and with including of conformities of recruitment (main population characteristics).

Second step is forecast of density of dominant species of community in its adult (fishery) phase.

This forecast look like annual forecast where is forecast of total abundance of generations and control processes of their formation (dynamic of generations and population growth).

Let ri - congestion i - th exploitaited species in the ichtyoplankton in the Kuroshio region and ri = ni / n; [ r ] = [abundence] / [v], where ni , n - total abundence i - th species in the samples of ichtyoplankton its total abundence of fishery species in the samples during one year; v - unit volume. (Suggest, that ni / n = Ni / N, where Ni É N according hypotetic calculated abundence of ichtyoplanktron i - th and all exploited species in the pelagial of Kuroshio region.)

Let { ri }1m - of many years row of congestions i - th species with period of m years. This row approximates by composition of periodic functions and pick out the trend. We can install current phase of trend and make forecast. Accordingly we forecast of congestions of ichtyoplankton of i -th species: ri,j+ p = æ(ri,j), there j - year of forecast, Ò -period forecastelling of forecast.

Therefore we can forecast exploitaited fishes occurred in the ichtyoplankton. This forecast gives dominant species for future years. After forecast of dominant species in ichtyoplankton we can really make perspective forecast of generations and calculate stock abundance with using usual remaince.

7AM1998-FISpaper04 oral

## MIGRATION ROUTES AND DISTRIBUTION OF JAPAN MACKEREL (*SCOMBER JAPONICUS*) IN THE NORTH WESTERN PACIFIC

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Japan mackerel has wide distribution in the northwest Pacific. Sometimes it reach Kamchatka Peninsula (North direction) and Emperor Sea Mountains (East direction). TINRO-Centre researched distribution of mackerel in the Kuroshio region from 1974 to 1996 in the different seasons and in the different regions.

Daily and month distance of migrations during wintering and spawning seasons are usual small. But after spawning and wintering speed of movement of fishes became very high.

In 1977 from late April, mackerel stocks began migrate to the open ocean. During May it went 200 miles, during June 120 miles, during July 400 miles, during August 160 miles, during September only 90 miles (north, northeast direction). Its stocks reached 158°00 E in this year. Next year (1978) migrations of mackerel had another speed and a little another direction. Speed of movements was higher than previous year. Mackerel stocks reached 164°00 E in that year.

South migrations is going more quickly. Migration distance from feeding grounds to spawning grounds in October-November (1978) was near 420 miles.

We can say that north, northeast migrations are slower than south, southwest migrations.

Speed, direction and distance of migrations have monthly seasonal, annual variations. These characteristics are directly connected with four main factors:

1. Abundance of populations;
2. Size composition of stocks;
3. Position of productivity regions;
4. Position of currents and eddies.

7AM1998-FISpaper05 oral

## BIOLOGICAL-PHYSICAL COUPLING IN THE FEEDING ECOLOGY OF LARVAL FISH

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Larval fish are generally believed to be selective feeders. Explanations of such selectivity usually invoke active behavioural choice by the larvae. We used a predator-prey encounter-rate model to see whether it is necessary to invoke choice by the fish to explain the selectivity patterns reported in the literature. We first determined the probability of larvae of different sizes encountering two or more prey at once. We find that, due to their limited visual and swimming abilities, and the low prey concentrations characteristic of most coastal environments, larval fish rarely encounter multiple prey. In contrast, juvenile fish greater than 30 mm standard length commonly encounter multiple prey. Next, we used prey-size spectra from a variety marine environments (including the NE Pacific), to explore whether size-biases in encounter and capture rates were sufficient to reproduce the sorts of selectivity patterns reported in the literature. Our results suggest that it is not necessary to invoke behavioural choice by larval fish to explain selectivity. Simply put, our model implies that larval diets may be under some degree of direct physical control. One consequence of this finding is that the feeding success of larval fish is more likely to be directly affected by environmental variation than is that of juveniles.

7AM1998-FISpaper06 oral

## INFLUENCE OF NATURAL-ANTROPOGENEOUS FACTORS ON A CONDITION OF LAMINARIA DEEP

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The zone type of distribution faces is characteristic of coast Prymorye, is this connection the sea vegetation will form faltering were over. They will form that narrow reef were over, which are pulled along coastal steep deep of coast and differ by rather high efficiency and relating to a rocky ground; that zone were over on a strip coarse stone of ground of width 100-800 m. Further, with increase of depth, the change of a stony ground mobile facies (sand is observed, shingle), which will not form stable substratum for an attachment of seaweed.

On shoal, in breakers to a zone, the degree of moving and wipe up of shingle in rather high, that does this zone unsuitable for moving macrophyts. The displacement pebbly of a material on depth under influence ground against current by washing away of shingle by drifting ice is observed also. With increase of depth the oscillatory movement of shingle decreases and on depths more than 15 m the movement of a superficial layer is observed only. On such sites can be settled macrophytes, capable to fasten mobile soels, forming stable substratum.

Densely acezete rhizoid in such thicket will form as though one enormous sole holding shingle. However, as a result of trade pressing there is a negative change ground substratum. The thallus of Laminaria come off together with a ground, that results in infringement of integrity substratum, for which keep rhizoid. It, in turn, results in reduction of the area, suitable for development of seaweed. Grows natural elimination thallus. As a result of influence of storm waves the displacement of a superficial layer of shingle is observed. In this connection the field Laminaria together with mobile substratum can be displaced from an initial place growth. Such migrations result in emission on a coast, and sometimes, getting in lull of a place, Laminaria the growth continues or perishs. On a rarefied craft sites, as a rule, negative influence phytophagy amplifies.

Thus, the sense of natural-antropogeneous influence on fields deep Laminaria consists that on a background of natural displacement mobile soil trade pressing causes acceleration of process of destruction ground substratum. The range of ecological changes as a result of such influence is wide: from short-term infringments in biocenosis or ecosystem as a mhole, which can be restored by a natural way before utter annihilation of all types ecosystem, connected biogenosociology by communications.

7AM1998-FISpaper07 poster

## INVESTIGATION OF CHUM SALMON HABITATS IN THE NORTH PACIFIC BY MEASUREMENTS OF STABLE ISOTOPE IN OTOLITHS

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Stable isotope technique in marine science is becoming powerful tool to reveal the environmental changes surrounding organisms during their past life histories. To investigate the geographical distribution of chum salmon (*Oncorhynchus keta*) habitats in the North Pacific, the stable isotope $\delta^{13}C$ and $\delta^{18}O$ of otoliths were measured. Salmon otoliths were collected from four hatcheries in the eastern (Canada and USA) and western (Japan and Korea) North Pacific. Cluster analysis showed well separation for two groups. Rank order for stable isotope $\delta^{18}O$ values in otoliths by hatchery location, from the highest, follows Japan, Korea, USA, and Canada, and that for $\delta^{13}C$ is reverse way. Averages of stable isotope $\delta^{13}C$ range from -5.16 to -4.31 and those of $\delta^{18}O$ from 0.34 to 1.12. In general, the variances of $\delta^{13}C$ value were relatively stable except those released from Korea. Stable isotope $\delta^{18}O$ values of Japan salmon illustrate the widest range, which implies that salmons released from Japan inhabit broad areas/environments, especially wide temperature regimes. This result is well matched by the fact that chum salmon released from Japan occupy the whole North Pacific including the Bering Sea, while salmon from Canada and USA reside mostly in the Gulf of Alaska. Especially, $\delta^{18}O$ values of Korea salmon show a very narrow range (0.39 to 0.96). It is plausible that salmon from Korea and Japan may have the different habitats each other, and some portion of Korea salmon could be confined to stay at the East Sea/Sea of Japan during their whole life. Studies using stable isotopes will help to elucidate the migratory pattern and habitat location of chum salmon.

Kalish (199?) reported that oxygen and carbon isotopes might be the most useful chemical data that can be obtained from otoliths. These data were used estimation of migratory patterns and habitat location.

7AM1998-FISpaper08 poster

## LIFE HISTORY PARAMETERS OF RISSO'S DOLPHINS OFF THE PACIFIC COAST OF JAPAN

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Life history parameters for Risso's dolphins (*Grampus griseus*) off the Pacific coast of Japan were examined using materials collected through catches (241 individuals) taken by the small-type whaling, hand harpoon fishery and drive fishery in 1991 to 1994. Based on the deposition of cemental and dentinal growth layers in the lower jaw teeth, maximum age was estimated at 37 and 36 years olds in males and females respectively. Both sexes cease growing at around 10 years olds. The average age and body length at sexual maturity were 11.2 years (se=0.46) and 265.1cm (se=0.85) in males and 8.0 years (se=0.57) and 258.4cm (se=1.44) in females, respectively. Age dependent decline in ovulation rate was not clear while the annual ovulation rate was estimated to be 0.527 (se=0.045). Body length at birth (127cm), gestation length (13.5 months) and fetal growth rate at the linear part of the growth (0.35cm/day) were tentatively inferred by using existing interspecific relationships established among the *Odontoceti* species. The sexual differences in longevity, age and body length at sexual maturity and the lack of the reproductive senescence in females suggest that the life history of Risso's dolphins is similar to those of the small sized delphinid species such as the striped and pantropical spotted dolphins than large sized or socialized delphinid species such as the short-finned pilot whales and false killer whales.

7AM1998-FISpaper09 poster

## A NEW DATA ON BIOLOGY OF SHORTRAKER ROCKFISH, *SEBASTES BOREALIS* (*SCORPAENIDAE, TELEOSTEI*) IN THE NORTH PACIFIC OCEAN

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On the basis of research cruises aboard Japanese trawlers made during 1992-1996 in the Pacific waters off the northern Kuril Islands and southeastern Kamchatka, and during 1995-1997 in the western Bering Sea a some biological features of shortraker rockfish, *Sebastes borealis*, including preliminary age determinations, migrations, and diet are considered.

The analyses of size composition data, records of mature fishes and juveniles with length less than 15 cm showed that the parturition of species considered may be occurred mainly in areas off the Oregon, Washington, British Columbia, Gulf of Alaska, Bering Sea, Northern Aleutians and western Kamchatka. Then pelagic larvae are transferred from above areas by currents to feeding areas, which are located off the southern Aleutians, Kuril Islands and probably southwestern Sea of Okhotsk. The

standard length at transformation accompanied by the transition from pelagic to benthic life pattern is about 10 cm and age about 2 years.

Species considered are predatory fish. The size composition of long-line catches and diet analysis indicate that shortraker rockfish becomes predator predominantly with length larger than 30 cm and age over 7 years. Small fishes feed on crustaceans such as mysids, amphipods and shrimps. With increasing in size, squids (mainly red squid, *Berryteuthis magister*) and fishes (mostly mesopelagic myctophids) are eaten more frequently.

7AM1998-FISpaper10 oral

## CETACEAN DISTRIBUTION AND ABUNDANCE IN THE NORTH PACIFIC, RESULTS FROM THE JAPANESE SIGHTINGS SURVEYS 1982-1996

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National Research Institute of Far Seas Fisheries has conducted systematic whale sighting surveys in the North Pacific from 1982. During a total research distance of 344 thousands nautical miles from 1982 to 1996, seven rorqual whales (blue, fin, sei, Bryde's, minke, humpback and northern right), three sperm whales (sperm, pygmy sperm and dwarf sperm), four beaked whales (Cuvier's, Baird's, Hubbs' and Stejneger's), 16 dolphins (killer, short-finned pilot, false killer, pygmy killer, melon-headed, Risso's, long-finned common, short-finned common, striped, spinner, pantropical spotted, bottlenose, Pacific white-sided, northern right whale dolphin, rough-toothed and Fraser's) and three true porpoises (Dall's, harbor and finless) were positively identified. And unidentified bottlenose whales were found in the tropical and sub-tropical waters. The distribution pattern of these species was analyzed relating to the environmental conditions. The relative abundance of these species was compared and the absolute abundance of some species was estimated using line transect method.

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## IMPACT OF SOME ARTIFICIAL FOODS ON SEA URCHINS *STRONGYLOCENTROTUS INTERMEDIUS* GONADS DEVELOPMENT AND THEIR ROE QUALITY

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The adult sea urchins, reared in the recirculation aquarium system at 10 centigrads, were fed some artificial foods on the base of immobilizator - calcium alginate.

In the first experiment (April - May) three foods (N 1-3) included additionally: the crushed natural brown alga *Laminaria japonica* and carrotinoids (Car); extract of biologically active substances (Ebas) of L. japonica and Car, a pigments complex and cellulose of the mentioned alga accordingly.

For the second experiment (October - November) foods (N 4-6) included other components: fish staffing (FS) and the dried powder of *L. japonica*, FS and Car, FS and Ebas.

The foods before use were stored in a frozen state (- 18 centigrads). The control animals consumed the crushed fresh - chillet talloms of *L. japonica*. All foods were given ad libitum daily.

It was stated that foods N 2, 3 hadn't the pronounced effect, a food N 1 caused a small growth of gonadal - somatic index. Its values increased by 3.6, 3.2 and 2.4 times when the foods N 1-3 were used. As usually the gonads of experimental animals had the orangeyellow color.

The worked out receptures and foods technologies will be tested in the natural conditions.

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## STOCKS OF REGULAR SEA URCHINS AT THE NORTHERN-WEST COAST OF SEA OF JAPAN CAN BE ENHANCED

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Many local populations of the common littoral sea urchin *Strongylocentrotus intermedius* and brown algae forests have been already exhausted by surplus fishing in Primorje Region. As the young (diameter size < 45 mm) and adult (45-70 mm) sea urchins numbers are decreasing a proportion of senile (> 70 mm) individuals changes in the opposite direction. At the same time food shortage leads to the stunted bogy growth and gonads low quality. The stocks of the black urchin *S.nudus* in danger also. The used measures to improve the situation, namely quoting, lower body and gonads sizes limitation, fishing prohibition during spawning period had no pronounced effect. So, to restore brood and exploited populations it's necessary to use some additional methods, first of all seed production and its further raising in cages or on the bottom lots, transition of sea urchins from the bare grounds to beds with sufficient food resources and cultured algae supply to the undernourished animals. A choice of either method depends on its economical feasibility. Due to preliminary experiments it seems that above mentioned transition is the most preferable method.

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## GROWTH AND MORTALITY OF SOUTHERN ROUGH SHRIMP, *TRACHYPENAEUS CURVIROSTRIS* IN THE WEST COAST OF KOREA

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Growth and mortality of southern rough shrimp were studied based on the fishery statistics and biological data collected from the winged stow nets on anchor in the west coast of Korea from April 1994 to November 1996. The relationship between carapace length (CL;) and body weight (BW; g) was expressed as: $BW=0.003CL^{2.5406}$ for females and $BW=0.003CL^{2.5487}$ for males. The growth in carapace length (CL) showed a seasonal pattern, and estimated seasonal growth equations were:

$CL_t=21.80(1-e^{-\{3.175(t-0.047)+(5.700/2\pi)\sin 2\pi (t-0.057)\}})$ for females,

$CL_t=17.00(1-e^{-\{2.237(t+0.199)+(3.864/2\pi)\sin 2\pi (t-0.069)\}})$ for males,

$CLt=20.50(1-e^{-\{2.059(t+0.151)+(3.622/2\pi)\ \sin 2\pi\ (t-0.071)\}})$ for sexes combined, where CLt indicates the carapace length in mm and t age in years. The growth of the southern rough shrimps was comparatively faster in their younger ages from August to November, however, the shrimps stopped their growth in winter from December to March after six months from hatching. The growth rate of females was much higher than that of males. The maximum ages of females and males were presumed to be 1.17 and 1.08, respectively. The instantaneous coefficient of natural mortality (M) was determined to be 1.46 $year^{-1}$. The recent instantaneous coefficient of fishing mortality (F) was estimated larger than M as 3.07 $year^{-1}$. The ages at the entrance to fishing ground were determined to be 0.08 year old, and that at first capture 0.13 year old, which were much younger than the age at 50% maturity, 0.3 year old.

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## DO MALE TANNER CRAB (*CHIONOECETES BAIRDI*) UNDERGO A TERMINAL MOLT AT MORPHOMETRICAL MATURITY?

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We fitted a length-based model to trawl survey estimates of male Tanner *crab (Chionoecetes bairdi)* abundance in Bristol Bay, Alaska, from 1990 to 1997 by shell condition (newshell and oldshell) and maturity status (morphometrically mature and immature). We estimated abundance, recruitment, and molting probability by a non-linear least squares approach. The model fitted observed abundances well, and the fit was best made without assuming a terminal molt at morphometrical maturity. Molting probability of male Tanner crab declines sharply once morphometric maturity (large claw size) is achieved: from 93% to 15% during 1990-1993 and from 61% to 0 during 1995-1996. Although the terminal molt hypothesis appears valid in 1995 and 1996, a significant percentage of morphometrically mature males appear to have molted in 1990-1993, contrary to the hypothesis. The percentage may have been much higher in previous years. Proportions of oldshell sublegal male crab during1990-1997 are about 2.5 times as high as those during 1975-1989, suggesting much higher molting probabilities prior to 1990. However, data were not collected on claw size that would have allowed us to confirm that morphometrically mature crab molted with probabilities $>15\%$ during the 1970s and 1980s. An examination of the proportions of oldshell sublegal male Tanner crab from five major Alaska stocks implies that molting probabilities vary widely by time and area. We speculate that the occurrence of terminal molt at morphometrical maturity for male Tanner crab may be stock specific and influenced by recruitment strength and environmental conditions.

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# RUSSIAN FISHERY OF FAR-EAST SARDINE IN THE PACIFIC WATERS AND OKHOTSK SEA IN 1974-1993 YEARS (START AND FINISH)

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Significant cyclic fluctuations abundance are peculiar to Far-East sardine (*Sardinops melanostictus*). Last century is well documentary two large-scale flares of abundance confirmed the fishery statistics: first from the end 20s to beginning of the 40s; second from the beginning of 70s to present time. The present flare abundance of the sardine finished practically now, and the stocks of the sardine are in depressive condition. In current of the last flare abundance of sardine occupied one of conducting places in the Russian fishery on the Far East. And the basic part of catch (50-80 % in various years) was received in pacific waters and in the Okhotsk Sea. In the pacific waters the fishery of sardine by the Russian fishermen was conducted from 1974 to 1993. The basic regions of fishery grounds it is 200-mile zone of Japan, South-Kuril region, Okhotsk Sea and in the separate periods fishery went to the open ocean outside economic zones of Russia and Japan. General catch of the sardine by Russian fleet for all examined period has made 5757 thousand tons. In 200-mile zone of Japan was extracted 1910 thousand ton, in the South-Kuril region - 2940 thousand tons, in the Okhotsk Sea - 845 thousand tons, and in the open ocean it was total 62 thousand tons. Catch of the sardine was conducted in basic purse seiner net, which was extracted 97.9% from general catch. Specialized trawl catch was insignificant, as a rule by trawls sardine was caught on fishery of the common mackerel, therefore total catch by trawl made only 2.2% from general catch for examined period. In this connection the characteristics of purse seine fishery sardine in the pacific waters was examined only. Russian fishery of the sardine in the pacific waters began to develop since 1974 (3 thousand ton). Catch has exceeded 100 thousand ton in 1976, in 1978-1979 it made 230-330 thousand tons. After decrease of catch in 1980-1981 (194 and 138 thousand ton accordingly), the maximum catch was marked in 1984-1989 years - more than 400 thousand ton, with peak - 570 thousand ton in 1988. After 1989 catch was sharply reduced, making on years (in thousand tons): 1990 - 360, 1991 - 390, 1992 - 100, 1993 - 4.5, and since 1994 the Russian fishery of sardine in the pacific waters was stopped. Together with changes of common intensity of fishery changed and character of distribution of intensity of the fishery in current year and common duration of fishery. In initial period of organization of the sardine fishery (1974-1975) the most productive was the winter-spring period, in summer period sardine dispersed on the large area and fishery was ineffective. The similar situation developed and in 1980-1981 years. During the large-scale fishery the intensity of it increased with beginning of northern migrations in April - May, reached maximum in the feeding period in July - September, when fishery grounds in basic passed to the Russian economic zone, and sharply was reduced after October, reaching minimum in March, which is the coldest period. At high abundance of the sardine stocks (1977-1987 years) the Russian fishery was possible during whole year, with sharp decrease of intensity, down to complete its discontinuance on short time, in winter period. At decrease of abundance stock the period of running of fishery has became to be reduced. Because sardine absents in region accessible for Russian fleet. Since 1989 fishery began develop only from April and completely stopped in August - September, and in 1993 it proceeded in general few more month. The maximum of intensity of fishery in the last years was displaced for June - July. Russian fishery of the sardine in Okhotsk Sea finished in 1991 and in the Pacific Ocean in 1994 years.

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## FORAGE FISHES IN THE BERING SEA: DISTRIBUTION, SPECIES ASSOCIATIONS, AND BIOMASS TRENDS

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Relatively little is known about distribution patterns and species associations of forage fishes in the Bering Sea, despite their importance as major prey of many higher trophic level organisms, such as seabirds, marine mammals, and predatory fishes. In this study, we examined survey data on some dominant pelagic forage fishes (herring *Clupea pallasi*, capelin *Mallotus villosus*, and eulachon *Thaleichthyes pacificus*) and the juvenile stages of major commercial groundfish species (walleye pollock *Theragra chalcogramma* and Pacific cod *Gadus macrocephalus*). We analyzed two main data sets: 1) a 1987 Russian survey that covered most of the Bering Sea, and 2) National Marine Fisheries Service (NMFS) summer surveys (1982-95) in the eastern Bering Sea which sampled the same grid of stations each year. In the Russian survey, age-0 pollock had the highest biomass and were the most widely distributed forage fish, although jellyfish and age-2+ pollock dominated the biomass overall. Several geographically distinct assemblages were recognized in both the eastern and western Bering Sea. Age-0 pollock were associated with warmer bottom temperatures and capelin with colder bottom temperatures compared with other species. Distributions of all species from the NMFS surveys during a cold year (1986) were more widespread and overlap among species was greater than during a warm year (1987). Pacific herring showed the most dramatic fluctuations in their biomass index over 14 years of NMFS trawl surveys and was the dominant forage fish caught in most years, although when their biomass index was low, they were exceeded by age-1 pollock, eulachon, and capelin.

7AM1998-REXworkshop02

## CHANGES IN THE TIMING AND DISTRIBUTION OF HERRING SPAWN IN BRITISH COLUMBIA: AN IMPACT OF CLIMATE CHANGE?

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Records of the timing and distribution of herring spawn in British Columbia have been collected since 1930. Major changes in the distribution and timing of spawning have occurred in the last two decades. We examined these spatial and temporal changes relative to climate change and other potential impacts such as fisheries. In all locations the total amount of spawn has fluctuated during the last 65 years, but is relatively high in recent years (1990's). In many areas, however, the distribution of spawning sites has changed. Spawning has stopped in some locations and started in others. Also, the duration of the spawning season has decreased in all areas since 1970. The first spawns are later and the last spawns are earlier, although the mean time has not changed. In general, present spawning areas are more spatially concentrated, with fewer but larger spawning sites, especially in the Strait of Georgia and the West Coast of Vancouver Island. Many of the most distinct spatial changes seem to coincide with change in sea-surface temperatures, and therefore may be evidence of a climatic effect. On the other hand, there could be other explanations, particularly those associated with the fisheries. The present

fisheries for herring roe began in the early 1970's, so it is difficult to distinguish potential impacts of fishing, or other potential causes, from those related to climate.

7AM1998-REXworkshop03

## BIOLOGICAL PRODUCTION, VARIABILITY, AND STANDARDS FOR SUSTAINABLE YIELD IN THE GREAT SARDINE AND ANCHOVY STOCKS

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A simple approach to estimating surplus biological production in anchovy and sardine stocks around the world gives valuable information about the range and variability of biological production and fishery yield in small pelagic stocks. Production rates in consecutive years are positively correlated for long lived sardines and uncorrelated or negatively correlated for shorter lived (mostly anchovy) species. Thus, biological effects of favorable and unfavorable conditions last longer in sardines and effects of effects of environmental variation appear to be mediated by longevity. Minimum and maximum production rates were more extreme for five anchovy stocks than for nine sardine stocks although mean production rates for the two groups were similar. Average annual production per unit spawning area ranged from 1.2-16. mt/km^2 for four anchovy and six sardine stocks and the median was 3.8 mt/km^2.

7AM1998-REXworkshop04

## RELATIONSHIP BETWEEN MACKEREL, *Scomber japonicus*, POPULATION BIOMASS AND ENVIRONMENTAL FACTORS IN THE KOREAN WATERS

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Yearly and monthly variations in recruit and adult populations of Mackerel, *Scomber japonicus*, off Korea and their environmental factors in the wintering and spawning grounds were studied, based on commercial catch statistics and length frequency distributions by Korean large purse seine fishery during 1980-1996.

Mackerel adult population was aggregated densely in the frontal area of westsouthern waters off Korea during winter season of 1991 and 1992 and strong recruitment followed from August in 1991 to Febrary in 1994. Significant positive correlations between adult and recruit population biomasses during year n and n+1 and zooplankton biomasses and copepodes numbers of the 2-year running means (year n-1 and n) during February and April showed in the westsouthern and southern waters respectively.

These results suggested that mackerel recruit and adult populations may be affected by the feeding conditions in the wintering and spawning grounds off Korea.

7AM1998-REXworkshop05

## EFFECT OF SHORT-TERM FLUCTUATION OF WATER TEMPERATURE ON FISH-CATCH BY SET-NET FISHING AROUND AWA-SHIMA ISLAND, THE SEA OF JAPAN

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In Awa-shima Island, which locates at the eastern part of the Sea of Japan and is influenced by Tsushima Warm Current, there exists a large coastal set-net fishery. The analysis was made for the data on fish-landing by the set-net twice a day in the morning and evening and water temperature measured at the mouth of set-net at 1-hour interval from May to July in three successive years, 1995-1997. Every year, the water temperature continued to rise from 11-12 to 18-20 degrees centigrade until end of July, and its daily fluctuation was small at the beginning, then increased about 3 degrees centigrade at the end of May, and again became less. Among various fishes landed, the landing records of tuna, yellowtail, jack mackerel and sea bream at a marketable size were compared with the fluctuation of water temperature. The results indicate that 1) occasional catch of tuna and constant landing of yellowtail start after water temperature becomes above 14 degrees centigrade, 2) good catches of yellowtail over 1000 individuals per day are observed when daily fluctuation of water temperature becomes 2-3 degrees centigrade, 3) catches of spawning adults of both jack mackerel and sea bream do not correspond to daily change of water temperature, and therefore their movement or migration was considered to rely on their spawning behavior rather than short-term fluctuation of water temperature.

7AM1998-REXworkshop06

## ACOUSTIC ESTIMATION OF BIOMASS OF THE SMALL PELAGIC FISHES IN THE EAST CHINA SEA

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The small pelagic fishes, such as the sardine, anchovy, jack mackerel, mackerel and other species, are distributed in the East China Sea, and the annual catch of these species is very high in the East China Sea. This study was aimed to assess the small pelagic fishes biomass using an acoustical method. A quantitative echo sounder (FQ-70; 50kHz or EK505; 38kHZ) was used in this study. The acoustic surveys were conducted in summer and winter from 1989 to 1998 in the waters off western of Japan (East China Sea). In order to identify the fish species, the midwater trawls were executed, and also the IKMT hawls were done for sampling the small plankton in the deep scattering layers (DSL). In early 1990's, the biomass of the sardine was very high in the winter season, but the biomass of all pelagic fishes was low level in the winter season since middle 1990's. In the summer season, the biomass of the anchovy and jack mackerel were higher than the other species, and these species distributed in the neritic area. The myctophidae fishes distributed at 200 depth layers in the daytime. The DSL was consisted of the myctophidae fishes, fish larvae, cephalopod larvae, krill, copepods, sagittas and other species. These small plankton were fed by the small pelagic fishes, and the biomass of the plankton could be estimated by the acoustical method.

7AM1998-REXworkshop07

## SCALE AND CAUSES OF GROWTH OF THE PACIFIC HERRING ABUNDANCE IN THE WESTERN BERING SEA IN THE 1990'S

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The Korf-Karaginsky population is a basic element of herring stock structure in the western Bering Sea. Several small groupings (so called "lake herrings") dwell the northwestern region. During summer some herring migrates there from the eastern Bering Sea.

In early 1990s drastic decrease of walleye pollock biomass and growth of herring population took place in the western Bering Sea in conditions of regime shift. The Korf-Karaginsky herring exploitable biomass increased twice at 1996 (up to 420 thousand tons) versus estimations of 1986-1987. This stock has further perspectives to grow due to high-yielded 1993 and 1994 generations. The high-yielded herring generations has been fixed at under-yearlings stage. Since it, survival rates have likely increased for herring early stages.

Herring distribution during feeding migrations, in particular terms of eastward migration behind the Olyutorsky Cape depend from water circulation pattern features and intensity of water inflow on shelf. Eastward from the Olyutorsky Cape herring mostly aggregated near the Central Bering Sea Current (CBSC) divergence. In 1990s the area suitable for herring feeding route was expanded due to north-eastern shift of the CBSC divergence zone.

Environment changes occurred favorable as for survival of early stages as for feeding route of adult herring in the western Bering Sea. Opposite trends of herring and walleye pollock stock dynamics are

determined by distinctions in ecology and feeding habits of these species. Decline of zooplankton biomass in the offshore waters effects herring in less degree since this fish mostly feed upon plankton concentrations on water fronts.

7AM1998-REXworkshop08

## WHICH IS RESPONSIBLE FOR FLUCTUATING SQUID CATCH RATES - FISHING OR CLIMATE CHANGE?

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[2] *Oshima-Seibu Fisheries Expansion Office, Matsumae, Hokkaido 049-1500, Japan*

Most exploited squid species have a very short life span (annual or sub-annual); thus the only manners in which catch levels and the reproductive success effected by environmental conditions at the spawning grounds in one year affect the abundance the following year is through the stock-recruitment relationship. We will present some examples of recent stock fluctuations for two Japanese squids, the ommastrephid *Todarodes pacificus* and the loliginid *Loligo bleekeri*, in relation with climate regime shifts in waters around Japan after the 1980s.

*Todarodes pacificus* catch rates have fluctuated during the 20th century. It has been suggested that the stock reduction that occurred during the 1970s and 1980s was caused by both changing environmental conditions and fishing pressure. However, annual catch rates have gradually increased since 1987, despite the lack of catch regulations. In addition, paralarval catch rates since 1989 have been higher than during the late 1970s and the mid-1980s. On the other hand, *Loligo bleekeri* catch rates in northern Japan have fluctuated annually, with a large drop from 1984 to 1988 and a gradual increase since 1989. The recent stock increases of both species appear to be related to a regime shift to warmer temperatures around Japan that occurred in the late 1980s. Both squids recruitment were related mainly to the area of their spawning grounds. Recruitment in both species may have increased due to a warming and resulting expansion of the spawning grounds.

7AM1998-REXworkshop09

## JAPANESE SARDINE RECRUITMENT PROJECT: INVESTIGATION OF POPULATION STRUCTURE AND RECRUITMENT IN THE JAPANESE SARDINE

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The population of the Japanese sardine (*Sardinops melanostictus*) has been declining since 1989 in the northwestern Pacific. A ten year research project on the population dynamics of the Japanese sardine was started in 1989, with the aim of understanding the recruitment processes in the Japanese sardine. The critical stage in the determination of year class strength has been analyzed and the amount of recruitment demonstrated to be determined by processes after the larval stage. Field surveys have established that the sardine larvae metamorphose to juveniles while entrained in the Kuroshio current. Juveniles swim northwards along the streamers separated from the Kuroshio current and there appears

to be a significant relationship between the mortality rate from larvae to one year old fish and the sea surface temperature in winter in the Kuroshio Extension area. Growth rates of adult fishes have increased with the decreasing size of the population. At the same time, the age at first spawning has lowered from three to one year olds. The spawning grounds, which expanded to outside the Kuroshio current at the peak of the population, have reduced in area and are limited to areas inside the Kuroshio current and to coastal areas. These changes in the spawning behavior have resulted from changes in the female age composition and other biological factors. Our project is now generating information that is being used in forecasting future population fluctuations in the Japanese sardine.