PICES XIII S10-1960 Oral

Interdecadal variation of lower trophic ecosystems in the Northern Pacific between 1948 and 2002, using a 3-D physical-NEMURO coupled model

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Regime shifts, consisting of decadal-scale oscillation in atmosphere-ocean systems, have recently been the focus of many marine ecosystem studies. These "regime shifts" affect the sea surface temperature and Mixed Layer Depth (MLD), as well as overall changes the environment of marine ecosystems. We simulated changes in lower trophic marine ecosystems caused by interdecadal climate variability, using data from 1948 to 2002 using a global three-dimensional physical-biological "3D-NEMURO" coupled model.

The results were consistent with observations. Comparing before and after the late 1970s regime shift, primary production and biomass of phytoplankton increased in the North Central Pacific region but decreased in the sub tropical zone in the Western and Eastern Northern Pacific after the regime shift. This corresponds to the Pacific Decadal Oscillation index (PDO) that indicates interdecadal climate variability in the sub-tropical and tropical Pacific. The biomass in the North Central Pacific correlates positively with PDO, while that in the East and West North Pacific correlates negatively with PDO.

PICES XIII S10-1919 Invited

Intrusion of Kuroshio water onto the continental shelf in the East China Sea and its influences on the ecosystem

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A 1/18-degree nested ocean model is used to determine the location, the volume transport, and the temporal variation of Kuroshio onshore flux across the shelf break (KOF) of the East China Sea (ECS). The KOF shows a strong seasonal variation: maximum (~3 Sv) in autumn and minimum (< 0.5 Sv) in summer. The short-term (~17 day) variation due to Kuroshio meanders induces large fluctuations of the onshore fluxes but its temporal average over one year almost vanishes. The KOF has two major sources, the Kuroshio intrusion northeast of Taiwan and the Kuroshio separation southwest of Kyushu; with the former providing larger onshore flux than the latter. In addition to the KOF, the water from the Taiwan Strait is also a major source of water into the ECS. The role of the Taiwan Strait water and the KOF on material transport in the ECS is examined with passive tracer experiments. In the summer, about half of the tracer in the Tsushima Strait, the major exit of the water over the continental shelf of the ECS, originates in the Taiwan Strait, while the other half comes from the Kuroshio region. From summer to winter, the ratio changes dramatically: the contribution from the Taiwan Strait decreases to 20% and that from the Kuroshio increases to 80%. The tracer distribution shows the Kuroshio water dominates the bottom layer of the continental shelf of the ECS throughout the year. This implies that the oceanic nutrient supply from the Kuroshio region plays an important role in the ecosystem of the ECS.

PICES XIII S10-2041 Oral
Quantifying cross-shelf and vertical nutrient flux in the Gulf of Alaska with a spatially nested, coupled biophysical model

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The Coastal Gulf of Alaska (CGOA) is strongly productive, yet is subject to downwelling favorable winds over most of the year. Sources of nutrients to feed primary production in this topographically complex region are poorly known. As part of US-GLOBEC, we are utilizing a spatially nested, coupled biophysical model of the CGOA and the deep basin offshore, to explore when and where cross-shelf and vertical nutrient fluxes are most intense. The circulation model is based on the Regional Ocean Modeling System, implemented for this area with spatial nesting and one-way coupling of velocity and scalar fields. Our embedded NPZ model contains 11 state variables, chosen to simultaneously represent both coastal and oceanic ecosystems. Nutrient limitation terms include both nitrogen (which is believed to be more limiting on the shelf) and iron (which is believed to be more limiting in the open ocean). Our nested model results indicate significant "rivers" of cross-shelf nitrogen flux due to horizontal advection, as well as "fountains" of vertical transport over shallow banks due to tidal mixing. Using this output, we construct a provisional budget of nutrient transport among subregions of the Gulf of Alaska.

PICES XIII S10-1920 Poster
Assessing the quality of marine ecosystem models

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Aquatic ecosystem studies are of special interest to experts in marine biology. Basically, biologists express the knowledge about ecosystems as informal models. These models contain various numbers of trophic blocks and coupling between them as well as average values of the mass or energy flows for certain periods of time. For verification of the informal models the mathematical models are implemented and their properties studied. Well-known methods for representation of the dynamic processes in trophic chains have been used for the formal description of metabolism. Implementation of mathematical models based on known biological descriptions of ecosystems includes the following stages: a choice of the mathematical relations describing exchange processes; a definition of the concrete trophic functions and functions of mortality; and identification of parameters. It is necessary to note that usually not all values of the parameters are known. Thus, models are determined only to within several parameters. Therefore, it is required to carry out calculations under various assumptions about the unknown values.

An approach for assessing the quality of marine ecosystem models was developed and applied to an informal model of the Okhotsk Sea ecosystem. The aggregated three-block system was implemented and analyzed theoretically. Then it was decomposed into six-block and eleven-block models and the properties of these expanded models were numerically investigated. The dynamic processes that evolved by the deviation of equilibrium points were considered. The results obtained are an indirect confirmation that the informal representation of the Okhotsk Sea ecosystem requires detailed elaboration.

PICES XIII S10-2120 Oral

A study for interannual variability of Pacific saury using a simple 3-box model of NEMURO.FISH

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A simple 3-box model of NEMURO.FISH (saury version: Ito *et al.* 2004) was forced by observed sea surface temperature (SST) from 1950 to 2002. In the model, fish wet weight is calculated according to a fish bioenergetics equation. The observed condition factor of Pacific saury showed quite large decadal variability with relatively large year-to-year variability. In the model, wet weight of Pacific saury also showed decadal and year-to-year variability, however the amplitude of decadal variability was much smaller than the observed. It may be due to the absence of a multi-species fish formulation in the model. Fishes like sardine which have large biomass and fluctuation, have the potential to affect to the zooplankton density in the saury migration region. We also investigate differences of interannual growth variability between spawning seasons. Since Pacific saury spawns from autumn to the folllowing spring, we set three seasonal (autumn, winter and spring) spawned cohorts in the model. The amplitude of growth variability is largest for the autumn spawned cohort and smallest in the spring spawned cohort. This difference is caused by the difference of life history of each spawned cohort. The spring spawned cohort spawns only once in the life, however other cohorts spawn twice in their life. The second spawning timing changed year-to-year and it caused relatively large interannual variability in the autumn and winter spawned cohorts.

PICES XIII S10-2062 Oral

The effects of seasonal variability on copepod overwintering and population success: The match-mismatch of zooplankton and phytoplankton

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In temperate and high-latitude regions, large-bodied copepods typically enter a dormant state and descend to depth during the winter, re-ascending to the surface in the late winter/early spring in order to reproduce and take advantage of the spring bloom. Interannual variability may lead to mismatches between the timing of copepod reemergence, which is partly determined by conditions encountered by the copepods during the previous season, and the spring phytoplankton bloom. In turn, such mismatches can lead to further mismatches between copepod productivity and their availability as prey to higher trophic levels, such as small pelagic fish and first-feeding juveniles of certain species. Using an individual-based model (IBM), the effects of changing the timing of physical and biological seasonal cycles on the diapause entry and exit timing, and subsequent reproductive success of the common coastal copepod *Calanus pacificus* were investigated. The variable seasonal cycles examined included temperature, and spring bloom amplitude, timing, and magnitude. Because each individual copepod within an IBM can be "tagged" and their history recorded over their entire life, it was also possible to examine the effects of spring bloom variability on the reproductive success of the 2nd yearly generation of copepods, which are produced by females in the early spring which had just finished overwintering. Thus the ramifications of early spring copepod-phytoplankton matches or mismatches on subsequent generations were examined. The results of this model, as well as the possible implications for predators which rely on copepod blooms, will be discussed.

PICES XIII S10-2083 Poster
Modeling iterannual and decadal variability of Pacific saury

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Pacific saury, *Cololabis saira*, is mainly located in Northwest Pacific, and it is one of important commercial fisheries in Japan. Saury migrates widely in Northwest Pacific. Saury growth and stock vary widely from year to year, but the cause for these fluctuations is unclear due to paucity of data. A modeling approach is useful to investigate physical and biological processes responsible for variation of saury biomass and growth rate. This study focuses on interannual and decadal variability of physical and biological processes regulating Pacific saury growth. The saury model is linked with a 3-D lower trophic biological model consisting of multiple phytoplankton and zooplankton. The results show that the saury growth rate is higher during El Niño years, but lower in La Niña years. This is mainly due to the modeled interannual variability of zooplankton biomass in the mixed water region (Kuroshio-Oyashio interfrontal zone) and Oyashio regions where both young and adult saury feed. Also, the growth rate tends to be higher after the 1976/77 Pacific climate shift due to the modeled zooplankton biomass increase after the 1976/77 climate shift, which correlate well with the Pacific Decadal Oscillation (PDO). During the positive PDO phase, the mixed water region tends to be colder with deeper mixing during the winter and early spring. Therefore spring phytoplankton productivity is higher, which results in higher zooplankton biomass. The results show potential linkages between the physical variability and plankton dynamics with the Pacific saury growth and migration patterns.

PICES XIII S10-2112 Oral
A biophysical model for walleye pollock in the Gulf of Alaska to study recruitment variability: A coupled modelling approach

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An individual-based model for young pollock in the Gulf of Alaska coupled to an hydrodynamic model output (*i.e.* salinity and u,v,w components of velocity) and a 3D NPZ (Nitrogen-Phytoplankton-Zooplankton) model that accounted for the food of the early stages of pollock up to juveniles was run. The NPZ model was used to describe the population dynamics of two zooplankton species, *Neocalanus spp*., the biomass-dominant copepod in the western coastal Gulf of Alaska and Shelikof Strait, and *Pseudocalanus spp*. Ten years of simulations of the coupled models estimating a pre-recruitment index (*i.e.* proportion of juveniles remaining from the total eggs released which reached the nursery area inshore of the Shumagin islands) were performed to examine variation in recruitment featuring years 1993-2003. To assess alternative recruitment hypotheses several factors were varied such the pre-recruitment index definition, nursery areas, spawning areas and dates of spawning.

PICES XIII S10-1978 Poster
Influence of energetic meso-scale eddies on the lower trophic levels of the ecosystem in the northeastern tropical Pacific

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A sub-domain of the global Navy Coastal Ocean Model is coupled to a medium complexity ecosystem model in order to simulate biogeophysical interactions in the northeast tropical Pacific. The model domain encompasses the Costa Rica Dome and the coast of Central America. The ecosystem model includes two size-classes of

phytoplankton and two size-classes of zooplankton. The physical model is run with real-time forcing and data assimilation from 1999 to 2002, and the results of the coupled model are validated with ocean color data from SeaWiFS. The emphasis of the study is on interactions between the coast and the offshore regions through upwelling and advection by eddies. Patterns of modeled upper-layer chlorophyll concentration correspond well with those observed by SeaWiFS, although the magnitude differs somewhat. Model runs without horizontal advection do not reproduce these patterns, indicating that a one-dimensional model would have been inadequate in this area. Horizontal advection by eddies provides a strong and perhaps unique link between the productive coastal areas and open ocean. As the eddies propagate offshore, they develop a characteristic signature, with elevated chlorophyll concentration along the rim of the eddy and lower concentration in the center. This signature can be detected more than 1000 km from the coast. Whether this phenomenon is purely advective or is associated with local upwelling in the eddy has yet to be determined.

PICES XIII S10-1796 Oral

A three-dimensional numerical study of the spirals and water exchange near the shelf front in the northern South China Sea in winter

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In recent years, the Pearl River and adjacent continental shelf areas in the northern South China Sea have become eutrophic. These regions have also seen the highest frequency of occurrence of Harmful Algal Blooms (HAB) in the coastal China Seas. The Princeton Ocean Model (POM) is used to study the water exchange of the eutrophic coastal water and oligotrophic open sea in the shelf front area. To simulate the front well, an orthogonal curvilinear grid is used in the horizontal (the grid near the front is about 2km×2km) and 15 sigma levels in the vertical. The open boundaries, including tidal elevation, temperature and salinity, are obtained from a large SCS ocean model. Surface conditions are obtained from a realistic MM5 meteorological model. First, the tidal results are validated in this paper. Next we compare the temperature, salinity and current results with *in situ* survey data in January 2004. The characters of the SST distribution agree well with the data from space imagery. Therefore, we conclude that the model can successfully reproduce the main hydrodynamic process of the front area in winter, such as front dynamics, water exchange, and some frontal instability phenomena associated with atmospheric variations. The formation of the vortex in February 2001 is also simulated in this paper. The mechanism of the eddy formation is related to inertial instability and the meso-scale climatic fluctuation.

PICES XIII S10-1798 Oral

Simulations of annual cycle of phytoplankton production and the utilization of nitrogen in the Yellow Sea

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A nutrient dynamics model coupled with a 3D physical model has been developed to study the annual cycle of phytoplankton production in the Yellow Sea. The biological model involves interactions between the inorganic nitrogen (nitrate, ammonium), phosphate and phytoplankton biomass. The model successfully reproduces the main features of phytoplankton-nutrient variation and the production dynamics. 1. The well-mixed coastal water is characterized by high primary production, as well as high new production. 2. In summer, the convergence of the tidal front is an important hydrodynamic process, which contributes to the high biomass at the frontal area. 3. The evolution of phytoplankton blooms and thermocline in the central region demonstrate that mixing is a dominant factor to the production in the Yellow Sea. In this simulation, the nitrate- and ammonium-based productions are estimated regionally and temporally. The study also reveals that phosphate is the major nutrient, limiting the

phytoplankton growth throughout the year and can be an indicator to predict the bloom magnitude. The North Yellow Sea ranks among the major regions in fixing carbon and nitrogen. The annual averaged *f*-ratio of 0.37 indicates that regenerated production prevails over the Yellow Sea. Finally, the relative roles of external nutrient sources have been evaluated, and benthic fluxes might play a significant role in compensating 54.6% of new nitrogen for the new production consumption.