PICES XIV S5-2213 Oral
Life history, climate forcing, and fish stock assessment – Evaluating statistical power

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Inter-annual atmosphere-ocean climate variability in the Pacific, *e.g.* the Pacific Decadal Oscillation and the El Niño Southern Oscillation, has been well documented along with concurrent variability in both pelagic and demersal species. However, changes in population abundance of fish stocks are largely attributed to fishing impacts, rather than environmental variability. High variability around stock-recruitment curves indicate that climate, in addition to stock size, probably affects early life history survival and subsequent recruitment to fisheries. Thus, management advice that ignores inter-annual climate forcing of productivity and / or carrying capacity may cause stocks to be over- or under-harvested. The efficacy of including environmental impacts on recruitment in management models needs to be evaluated to take account of environmental considerations within the single-species stock assessment paradigm. Therefore, simulation testing is used to determine the statistical power of currently-used stock assessment methods to correctly identify whether climate is forcing either carrying capacity or stock productivity. Specifically, climate may impact productivity via the steepness of the stock-recruitment curve (h) or via the unfished average stock size. Simulation results provide guidance for including climate as a forcing function in single-species stock assessments for three generalized life history types: a short lived pelagic schooling species, a moderately long-lived flatfish, and a long-lived rockfish.

PICES XIV S5-2332 Oral
Using the model approach to understand functioning of the Okhotsk Sea ecosystem

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The study of the marine ecosystem functioning is important for describing quantitatively the processes, which occur there. Development of this theory assumes extended studies of quantitative regularities in metabolism, rations, growth, species and population production. Knowledge of organic substance production both for populations and for ecosystem/subecosystem (pelagic and bottom) has scientific and applied importance. When quantitative characteristics (biomass, production, ration, mortality) are determined it is possible to compare ecosystem states corresponding to different climate regimes.

Biologists usually implement models in the form of block-schemes of mass flows between trophic blocks. Those mass flows present average values for a certain period of time. A method for assessing informal biological models is proposed. This method includes several steps:

1. Implementation of formal models in the form of differential equations;
2. Parametric identification according to a chosen scenario and under assumptions of stability;
3. Numerical simulations and predictions for various characteristics of the system for different periods of time.

Two scenarios of the Okhotsk Sea ecosystem model are used for parameter identification. In the first scenario, the natural mortality coefficients are calculated when biomass, ration and assimilative growth coefficients of trophic blocks are known. Results suggest that the natural mortality coefficients for every trophic block (except phytoplankton block) are greater than experimental data. In the second scenario, the assimilative growth coefficients are determined when biomass, ration and natural mortality are known. The model values of the assimilative growth coefficients for every block (except non-predatory zoobenthos block) are less than those known from literature. The equilibrium points are determined during parameter estimation. Deviations of equilibrium points were analyzed and the results show the motions close to the equilibrium points.

PICES XIV S5-2346 Poster
Stock assessment of jack mackerel around Korean marine ecosystems using environmental factors

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Successful recruitment was dependent on the abundance and distribution of spawning biomass in the previous year, food availability and temperature in the major habitat of jack mackerel around Korean waters. Using a sequential data processing technique, a regime shift, or discontinuity, was tested in ocean environmental time series relative to the catch, recruitment and biomass at age of jack mackerel for 1968-2004. The spawning biomass and recruitment relationship of jack mackerel shifted in 1976 and 1987, and the estimated recruitment considering three regimes was highly significantly correlated with observed recruitment of jack mackerel ($P<0.001$). The optimal harvest rate of jack mackerel was estimated to be within the range of 30-35% of the unfished level of spawning biomass per recruit (SPR) that provides a yield near MSY for any probable spawner-recruit relationship (SRR). The SPR harvest rate required for establishing an F_{MSY} proxy for jack mackerel was also examined. Based on the optimal harvest rate, a maximum fishing mortality threshold (MFMT) was defined, which prevents overfishing while still achieving an optimal yield from the major jack mackerel fishery. For potential refinement of the present management system, a revised five tier system was developed that included an overfishing level (OFL) as well as acceptable biological catch (ABC) of jack mackerel around Korea waters.

PICES XIV S5-2480 Invited
Detecting and modeling environmental effects on recruitment: Strategies and pitfalls

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Research into the effects of environmental variability on recruitment has increased our general understanding of recruitment dynamics and has informed fisheries management decisions both qualitatively and quantitatively. However, there are few examples where environmental effects have been successfully incorporated into stock assessment or ecosystem models for predicting future recruitment. I will discuss general strategies for successfully quantifying and modeling environmental effects while minimizing the risks of identifying yet more spurious relationships. Strategies include (1) developing models based on biologically meaningful relationships (rather than inferring relationships from statistical models), (2) carefully selecting appropriate temporal and spatial scales of averaging for explanatory variables based on independent analyses, (3) accounting for effects of spawner abundance on recruitment and allowing for different environmental effects at low and high spawner abundances, and (4) modeling effects across multiple stocks of a species or across similar species. Examples from the Northeast Pacific will be provided to illustrate these strategies.

PICES XIV S5-2488 Oral
Population decline of Japanese sardine and variation of mixed layer depth in the Kuroshio Extension

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Japanese sardine, *Sardinops melanostictus*, is known to fluctuate drastically on inter-decadal time scales. There have been many previous studies about the population decline of Japanese sardine. Watanabe *et al.* (1995) attributed the cause to high larval mortality between the end of the first-feeding stage and age 1 and Noto and Yasuda (1999) reported the positive correlation between the winter sea surface temperature (SST) in the Kuroshio Extension (KE) and the sardine mortality. We found a significant negative correlation between the mortality coefficient from the postlarval stage to age 1 and March MLD in the KE. From late 1970's to 1987, March MLD was deep and the mortality coefficient was low. Since 1988 March MLD had been shallower and

the mortality was high. We use the NEMURO model to estimate interannual variation of bait-plankton. This model is forced by observed MLD, SST, short wave radiation and by monthly climatology of vertical nutrient profile. The estimated spring zooplankton biomass showed a positive correlation with March MLD. Because shallow winter MLD hastens the spring bloom in years of high mortality and shallow MLD, the plankton bloom didn't occur in spring but in winter and the spring biomass was low. Nutrients were consumed in the earlier bloom. This study suggested the following hypothesis: since the late 1980's, winter SST was high and MLD was shallow in the KE, the environmental change could lead to the decrease of spring zooplankton biomass and juvenile sardine coming into the KE couldn't survive due to the low food density.

PICES XIV S5-2369 Oral

Concepts of marine ecosystem carrying capacity, and their application to NE Pacific herring populations

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The mean level of abundance of a species in a particular area was included by Michael Sinclair (Marine Populations, 1988) as one of the four key factors in the regulation of marine populations. However, this concept has received relatively little attention in recent years in contrast to the problem of population (recruitment). Although these concepts are closely linked the mean level of abundance is a more direct reflection of the concept of "carrying capacity", *i.e.* the number of individuals in a population that can be supported by the resources of that ecosystem over the long term. The carrying capacity of a population in an area has important implications for long-term sustainable harvest as well as considerations for species viability and reference points for rebuilding strategies. We explore concepts of carrying capacity of marine ecosystems, beginning with (what have been called) long-term levels of (sustainable?) commercial catch and population productivity, and then examine the spatial and temporal variability of estimated carrying capacity in greater detail for herring populations in the NE Pacific. Our goal is to identify the carrying capacity for herring in these regions and to better understand the factors determining these levels and their variability.

PICES XIV S5-2400 Invited

Recruitment processes of jack mackerel (*Trachurus japonicus*) in the East China Sea (ECS) in relation to environmental conditions

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Jack mackerel is an important fishery resource in southern Japan, Korea, and Taiwan, but information of their recruitment processes is limited. Ichthyoplankton surveys during 2001–2004 revealed that the primary spawning ground of jack mackerel is formed in the shelf break region of the southern ECS south of 28°N during late winter to spring. By the Kuroshio and its branch currents, a large proportion of larvae and juveniles originating from the spawning ground were transported to the northern ECS, Pacific coast of Japan, and western Japan Sea to recruit into the fishing grounds off Japan. Relationships among the abundance of larvae and juveniles, and age-0 recruitment of jack mackerel suggested that (1) survival during postlarval and juvenile stages was important for determining their year-class strength and (2) the survival rate was very high in 2001 during our study period. The otolith increment analysis suggested that early growth is one of the important factors determining recruitment success of jack mackerel. We discuss the relationship between the fluctuation of survival during postlarval and juvenile stages and the environmental conditions, such as habitat temperature, currents, and prey condition during 2001–2004. The copepod egg production rate in 2001 was much higher than in 2002–2004 in our study area, corresponding well with the jack mackerel survival. Importance of scyphozoan medusae for jack mackerel survival is also discussed, since jack mackerel juveniles associate with them and annual variations in medusae abundance and jack mackerel survival corresponded well in ECS.

PICES XIV S5-2500 Oral
Incorporating environmental effects in the assessment of sablefish (*Anoplopoma fimbria*) off the continental U.S. Pacific coast

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The status of the sablefish (*Anoplopoma fimbria*) resource off the continental U.S. west coast was assessed by explicitly accounting for variation is recruitment due to changes in environmental conditions along the coast. We modeled annual recruitment deviations by integrating a sea level time series into a more traditional stock-recruitment function within a statistical catch-at-age model. In this way, the standard deviation term of the stock-recruitment function, the term which allows recruitments estimates to depart from the curve, was partitioned into two sources of variation: the variation accountable for by environmental effects, and "other" variation due to unknown sources of error. The effect of accounting for environmental variation was examined by comparing the statistical catch-at-age model fits both with and without consideration of the environmental data time series. The model with explicit accounting of environmental effects resulted in a log likelihood that was sufficiently less than the model without environmental effects so as to conclude that the additional parameter significantly improved the fit. Consequently, annual recruitment deviations were found to be significantly related to annual changes in sea level during critical times during the life cycle of larval sablefish. Furthermore, the consideration of the environmental effects made it possible to hind-cast recruitment deviations and additional fifty years as well as forecast deviations for the year of the assessment.

PICES XIV S5-2490 Poster
Modeling transport of eggs and larvae of jack mackerel in the East China Sea

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Recent larval sampling and drifter buoy observations indicate that eggs of jack mackerel (*Trachurus japonicus*) are spawned primarily around Taiwan in the southern East China Sea (ECS) and transported through survival/growth processes into three regions: the Pacific, the Japan Sea and the coastal region off Kyushu, Japan. However, the reason for annual variation in their recruitment is unclear, partly due to the complex current system in ECS, where the Kuroshio flows on the shelf break and partly separates northward linking up the Taiwan Warm Current on the continental shelf. To clarify the transport mechanism of eggs and larvae of jack mackerel, we conducted tracer experiments under realistic forcing, using an eddy-resolving OGCM assimilating satellite SSH/SST based on the adjoint ocean primitive equation model, C-HOPE, developed by the Max-Planck-Institute. The model accurately reproduced transport of the drifter buoys after additional modifications: eliminating tidal noise in SSH-assimilation on the shelf and superimposing wind/wind-wave drift on currents. Pseudo-particles were released at 20m depth around the Taiwan in February from 2000 to 2004 and transported for 90 days, incorporating survival functions parameterized by modeled temperature and SeaWiFS chlorophyll concentration. Most of the particles, released northeast off Taiwan, were transported to the Pacific along the Kuroshio, however, those that survived were more abundant in the Japan Sea. These were originally detached from the Kuroshio and transported northward on the shelf to the Japan Sea. These experiments provided good estimates of the annual change of 0-age catches, clarifying the sensitivity of particle recruitment to temporal-spatial variations of oceanic conditions.

PICES XIV S5-2448 Oral
In situ experiments to investigate the japanese anchovy eggs development

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Egg development of japanese anchovy was investigated on several one-day or two-day surveys of stations in Peter the Great Bay (Japan Sea) in June-July of 2000 and 2004. The samples were collected using an

ichthyoplankton net in the sea surface layer every 4 hours. Dead eggs dominated in the samples (averaging 90.5%). Any significant trend in the total number of eggs was not evident within a day, but large fluctuations were observed, apparently the result of patchiness in the egg spatial distribution.

The egg development was partitioned into 5 stages. Abundance of the early stages (0-I) increased towards midnight suggesting this as the time of mass spawning. Later the proportion of the early stage eggs decreased gradually as the eggs matured. The total quantity of living eggs also had a tendency to decrease after the midnight maximum. The rate of mortality depended on the stage and was higher for the early stages (2-20% per hour) than for the late (II-IV) stages (0-14% per hour).

To determine the total duration of egg development and relative length of the early stages, the "age" distribution of eggs was approximated by a Gaussian curve. In this case, the proportion of any stage could be calculated by a Fourier integral. Actually, the observed proportion was formed by several generations of eggs spawned in successive nights, with the survival for each generation a function of its age. The parameters of the Gaussian distribution as σ, $T_{0\text{-}I}$ (relative duration of the early stages) and T (total duration of the eggs development to larvae) were estimated by least squares to closely approximate to the observed values at all times within a day. They had the following values: σ = 0,06-0,07; $T_{0\text{-}I}$ = 0,12-0,18; and T fluctuated from 56 to 77 hours. The eggs survival during the early stages was estimated as 13-79% (mean 47%), and final egg survival – was 0-79% (mean 31%). These estimates can be used for modeling the early ontogenesis of this species.