

**Ecosystem structure and fisheries resources status in the southern part of Korean waters**

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We investigated the ecosystem structure of the southern part of Korean waters, using Ecopath and Ecosim software, to evaluate interactions between biomass and food web in 2004 (spring and autumn). The food web was based on the stomach content of dominant species. Ecopath input parameters describe the 32 groups according to morphological feature, habitat and food web. Biomass was calculated to apply the ecosystem model with each level density. A total of 202 species occurred in spring and 113 species occurred in autumn, respectively. Species composition of catch data showed fish 58.6%, cephalopoda 6.0%, and crustacea 35.4% among the total. Euphausiacea occupied more than half of total stomach occurrence.

**Management strategy evaluation and indicators for ecosystem-based fisheries management**

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Large numbers of indicators have been proposed for describing that state of marine ecosystems and detecting the impacts of human activities (such as fisheries) on such systems. Recently simulation testing and empirical (field-data based) applications have shown that there is a short list of indicators that could be used as the seed for ecosystem-based management. The list includes such things as relative biomass (or biomass ratios) of key groups, proportional habitat cover, simple diversity indices, size and trophic spectra, maximum (or mean) length of the catch (across species), size at maturity of key species types and physical system characteristics that define the system context. While this list is a mix of single value and two-dimensional indicators all are simple indices that require little processing post-collection and all consistently provide strong signals regarding system state and dynamics. Moreover, they are relatively easy to calculate, interpret, and generalise (across systems and through time); and are robust to noise, data gaps and assumptions. These features mean that it is feasible to imagine a system of robust ecosystem-based fisheries management that included indicators as a key advisory component. Key aspects of such a management scheme will also be discussed here.

**A spatially-explicit ecosystem model to examine the effects of fisheries management alternatives in the California Current**

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Fisheries managers off the west coast of the US increasingly must balance tradeoffs between complicated management issues. They also must build management plans that account for the dynamic oceanography and productivity of the region. Management tools such as spatial closures or climate-triggered fishing policies could address these issues, but a modeling framework is needed to test such potential policies. To address this need, we built an ecosystem model of the California Current System, extending from the US/Canada Border to Point Conception, California, and out to the 1200-m isobath. The model structure (Atlantis) includes the trophic dynamics of 44 functional groups in the food web, using nitrogen as a common currency between groups. Functional groups include habitat-forming species like kelp, cold-water corals and sponges, as well as vertebrates, cephalopods, benthos, zooplankton, phytoplankton, and detritus. The model is divided into 62 spatial zones, each with seven depth layers. This allows us to explicitly test hypotheses regarding migrations, movement behavior, and spatial management options such as marine protected areas. The model is forced with hydrodynamic flows, salinity, and temperature outputs from a high-resolution ROMS oceanographic model, allowing us to test the impacts that changes in upwelling or coastal currents have on nutrients and primary productivity. Separate

sub-modules simulate the dynamics of 29 fishing fleets, as well as fisheries data collection, assessment, and management decisions. Model outputs reproduce observed time series of primary productivity and the abundance of commercial groundfish stocks and other species sampled in trawl surveys.

**PICES XIV S8-2252 Oral**  
**EROD as bioindicator for monitoring of marine contaminants along the Dalian coast**

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There have been many efforts to find suitable biological parameters for pollution monitoring programmes in the past 20 to 30 years. The monooxygenase (MO)-activity of fish has been shown to be useful as an 'early warning' system for environmental contamination caused by polycyclic aromatic hydrocarbons (PAH), polychlorinated dibenzodioxins (PCDD) and certain polychlorobiphenyl (PCB). Ethoxyresorufin-O-deethylase (EROD) is one of the model reactions of the cytochrome P-450-1A1 mediated monooxygenase system. In this paper, EROD activity, measured by kinetics fluorescence spectrophotometry, was selected as an indicator of PAHs and PCBs effects in benthic fishes. EROD induction in fish liver exposed to organic contamination demonstrated the ability of this technique to be an available and efficient marker of exposure to specific pollutants. After it was determined that there existed a dose/effect relationship between EROD activities and specific pollutant concentrations, an initial assessment of biological effects on the fish *Hexagrammos otakii* was carried out in well-chosen stations of the coasts along Dalian. It was proved feasible that EROD activity could be used to assess specific contamination through combination with other analysis data of PCBs. It has to be noted that factors that have effect on EROD activities in organisms are various. Therefore, a regular biological effects monitoring had been carried out for three years along Changhai area of Dalian by measurement of EROD activities in fish, to find out the feasibility of studying such parameters in the field. The optimal conditions for analysis of EROD activity were further discussed. Moreover, a much faster and simpler method for the hepatic EROD activities measurement of fish, using a fluorescence plate-reader, is introduced, studied and discussed in this paper.

**PICES XIV S8-2430 Oral**  
**Identification of ecologically and biologically significant areas in Pacific Canada**

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As part of its national Oceans program, Canada is in the process of assessing ecologically and biologically significant areas (EBSAs) so that effective marine conservation can be achieved. EBSAs are identified as those areas worthy of enhanced management action, and are expected to be areas where monitoring of ecosystem health indicators will be focused. Criteria for EBSA identification in Canada include consideration of the spatial extent of species aggregation(s); the presence of and relative abundance of unique species, ecosystem features, and non-indigenous species; the relative importance of areas in determining the reproductive and survival fitness of individuals and populations; and the resilience of populations or ecosystems features to human impacts. While there is presently a noticeable lack of coincidence between EBSAs and current mpas, it is expected that identification of EBSAs will lead to establishment of priority areas in the development of a regional marine protected area network.

**PICES XIV S8-2494 Oral**  
**Restocking changed ecosystem of the Yellow Sea and Bohai Sea**

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At present, many commercially high-valued, large-sized species have been depleted or replaced by low-valued, small-sized species in the Yellow Sea and Bohai Sea. Changes in species composition have been observed in the Yellow Sea, Bohai Sea. The ecosystem indicators varied with time and with different trophic levels. In the Yellow Sea ecosystem, anchovy (*Engraulis japonicus*) might be an indicator species. It has been the most abundant stock

and major prey for most piscivorous fish in the Yellow Sea for the last two decades and stock variations may affect ecosystem structure. At a lower trophic level, *Euphausia pacifica* and *Calanus sinicus*, are important food to many species. The diet variations of major predators may indicate the changes in food availability of the ecosystem. However, the decline of many traditionally important species indicates a need for restocking. Many methods have been used to rebuild such depleted stocks, including different fisheries management measures, such as input and output control of fishing wild stocks, closed area and season, minimum landing size and mesh size, *etc.*, and enhancement by releasing, transplanting and mariculture of introduced species, *etc.* Restocking of depleted fishes need more input by both manpower and financing, and ecosystem based management is required.

**PICES XIV S8-2218 Poster**

### **Main human threats to water ecosystems and commercial ichthyofauna of Russian Far East (Khabarovsk Territory)**

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Sustainable status of ecosystems is needed for the productivity and long-term exploitation of ecosystems. Human activities produce ecosystem changes with great economic deprivation. Changes of natural and climate factors are mainly gradual and can be forecast. Anthropogenic effects are mostly drastic, spontaneous and hard to estimate their damage. Productivity of ecosystems can suffer from different pollutants (industrial and domestic sewerage, mining and cutting, introduction of exotic species, genetic pollution of native populations) and from the inadvisable management of ecosystems and unequal distribution of fishing efforts.

Pollution of ecosystems has focused public attention, but resource management is not considered enough. The glaring example of the underexploitation influence on Far East marine ecosystem is the cessation of marine mammals catch in the early of 1990's leading to negative consequences. The presently abundant pinnipeds and white whale are serious competitors with humans, consuming such valuable commercial species as salmon. In addition, now resources of coastal waters are very poorly exploited.

Exploitation of freshwater biological resources is adversely effected by the ecological pollution of rivers and lakes (for example, "phenolic" problem of the Amur River) and also by poaching preventing from conservation and restoration of commercial species (for example, sturgeons on the Amur River). In winter when the self-purification of the Amur River is low, the pollution of waters by different substances results in changes of fish meat quality, weakening of immunity, and low food base for fry that effects the fish productivity of the Amur River.

Poaching is one of the main ecosystem impacts. People believe that administrative and prohibitive measures are not effective to resolve this problem but there is an international experience of such methods (for example, CITES). Economic measures against poaching are gradually developing.

**PICES XIV S8-2262 Oral**

### **Fish growth comparisons around Japan using NEMURO.FISH**

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NEMURO.FISH is a lower trophic level model of nutrients and zooplankton coupled with a bioenergetics model of fish consumption and growth. It has previously been applied to saury and herring. We applied the same kind of bioenergetics model, coupled with NEMURO, to common squid and chum salmon. Model squid and chum salmon migrate from spawning areas to nursery areas and graze on zooplankton, the concentration of which was calculated by 3-D NEMURO. The results show good agreement with body weights of fish/squid, and can explain the role of temperature and food density on their growth.

**PICES XIV S8-2614 Oral**  
**Evolution of ecosystem-based fishery management**

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Worldwide declines in marine fisheries have prompted calls for a paradigm shift from single-species management to ecosystem approaches to fisheries. Despite garnering much attention in the media and scientific conferences, confusion persists among many fishery scientists, managers, and public about terminology, as well as practical implications. Ecosystem-based management is set into the evolutionary context of traditional single-species management approaches by tracing the history of recent international fishery agreements, such as the FAO Code of Conduct for Responsible Fisheries and the Precautionary Principle and Precautionary Approach. The view is advanced that ecosystem-based management is a process, not an endpoint. An important feature of ecosystem-based management is an open public regulatory process that explicitly solicits and respects active involvement of diverse participants with different perspectives, including fishery and other marine scientists, resource economists, fishery managers, enforcement officials, all segments of the fishing industry, environmental representatives, residents of coastal communities, and other stakeholders. Identification and formal adoption of ecosystem-based management objectives are also important. For practical reasons, the unwieldy complexity of real-world ecosystems has prompted the development of models to examine ecosystem dynamics. Model outputs, combined with a multitude of other ecosystem considerations, are now being used to identify numerically and spatially appropriate ecosystem indicators for monitoring with available resources. The examples of the Alaska framework for evaluating ecosystem impacts of fishing using indicators and models and the Canadian process for moving from broad conceptual to specific operational EBM objectives will be summarized.

**PICES XIV S8-2347 Poster**  
**Ecosystem indicators for the recruitment of pelagic fish around Korean waters**

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Stocks of pelagic fish species showed long-term variability during the four decades around Korean marine ecosystems, owing to fishing impacts and changes in their environments. In this study, environmental effects were investigated to develop ecosystem indicators for the recruitment of major pelagic fish around Korean waters. Based on the hypothesis of advection-based recruitment, successful recruitment of pelagic fish species were dependent on the abundance and distribution of spawning biomass in the previous year, food availability and temperature in the major habitat of the pelagic fish around Korean marine ecosystems. 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 major pelagic species for 1968-2004. Based on the regime shift years, generalized additive models (GAM) were developed to explore relationships between recruitment, spawning biomass and environmental variables in the major habitat area of pelagic fish around Korean marine ecosystems. Surface current transportation, zooplankton biomass and temperature were selected as candidates of ecosystem indicators for pelagic fish species, such as jack mackerel, around Korean marine ecosystems.

**PICES XIV S8-2350 Oral**  
**Comparisons in ecosystem effects of fishing in Korean waters**

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To investigate characteristics of Korean fisheries resources, and to compare effects of fisheries on marine ecosystems in Korean waters, a self-organizing mapping technique was applied to classify groups with 86 marine species in Korean waters, based on six ecological variables. Trophic levels of catches in three marine ecosystems,

*i.e.*, the East/Japan Sea (EJS), Yellow Sea (YS), and East China Sea (ECS) were estimated, and the structure and composition of species groups for the ecosystems were analyzed. The piscivorous demersal fishes at high trophic levels decreased, whereas planktivorous pelagic fishes and crustaceans at low trophic levels increased in all the ecosystems. When fishing intensities in terms of F/Z ratio and fishing mortality (F) were compared by the ANOVA test, no significant differences were found among the decadal F/Z ratios, and among the ratios and Fs in the three ecosystems during the three decades ( $P>0.05$ ). However, when we assessed whether Korean fisheries were balanced in ecological terms as a function of annual catches and mean trophic levels, the decadal means of FIB (“Fishery is balanced”) index in the YS ecosystem decreased from -0.02 in the 1970’s to -0.43 in the 2000’s ( $P<0.001$ ). The decadal means of the index declined from 0.14 to -0.03 in the EJS ecosystem, and from 0.01 to -0.01 in the ECS ecosystem during the same periods ( $P<0.001$ ). There were also significant differences of FIB indices in three ecosystems during the four decades in Korean waters ( $P<0.001$ ). Therefore, fishing activity incorporating ecological terms such as trophic level was a good indicator to assess the effects of fisheries on Korean marine ecosystems.

## **PICES XIV S8-2215 Oral**

### **Modelling study of the new production and the microbial food loop impact in the Yellow Sea Cold Water Mass**

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The Yellow Sea Cold Water Mass (YSCWM), as an important oceanic phenomenon in the marginal sea of China, is always an interesting issue in the study of this region, and the research achievements of the bioactive elements have been acquired in recent years (Diao *et al.*, 1985; Wang, 2000). It is verified that the YSCWM brings significant influence to the geochemical and biological processes in the Yellow Sea. The YSCWM begins to appear in April, reaches its maximum in May or June, and disappears at November or December. During the period of its existence, the seasonal thermocline hampers the upwards nutrients translation from bottom layer (Wang, 2000).

A coupled pelagic-benthic three-box model was developed by Wan *et al.* (2003b) based on the Jiaozhou Bay model (Wu *et al.*, 2001), and is applied to study the ecosystem of the YSCWM, and includes the important impact of the microbial loop and nutrient effects from both atmospheric deposition and sediment eudation. Initialized by the *in situ* dataset from the project of “*Ecosystem Dynamics and Sustainable Utilization of Living Resources in the East Sea and the Yellow Sea*”, the model simulates the seasonal variability of the vertical structure of the ecosystem of the YSCWM. The investigation “*Ecosystem Dynamics and Sustainable Utilization of Living Resources in the East Sea and the Yellow Sea*” covers most of the region in the Yellow Sea and East China Sea. Seven cruises are carried out in June, November 2000 and January, April, May, June, July 2001, respectively. The simulation region is from 34.2°N to 36.6°N in the south-north direction, 121.6°E to 124.4°E in the west-east direction and the mean depth is about 69m, with all together 11 observation stations included. The model is run from June 16, 2000 to June 15, 2001 initialized by *in situ* observations on June 16, 2000. Due to limitation of available data, part of the initial values such as Bbac, Det, Btin and Btip are obtained by diagnostic method according to the observed pelagic and benthic data in the East China Sea (Song, 1997), the northern of South China Sea (Liu *et al.*, 2000) and Ebenhoh *et al.* (1995).

The modeling results estimate that the annual production in the YSCWM is  $83.2 \text{ gC m}^{-2} \text{ yr}^{-1}$  and annual mean daily production is  $228.47 \text{ mgC m}^{-2} \text{ d}^{-1}$ . Zhu *et al.* (1993) estimated the mean primary production ranged from 200 to 500  $\text{mgC m}^{-2} \text{ d}^{-1}$  in most area of the Yellow Sea, and the annual mean value is  $425 \text{ mgC m}^{-2} \text{ d}^{-1}$ . By the comparison between the results of Zhu *et al.* (1993) and our simulated results, it is concluded that the primary production in the YSCWM is low and the annual mean production is also lower than the mean value in the whole Yellow Sea.

The phytoplankton production sustained by N comes from river, atmosphere and bottom eudation, *etc.* and is called new production and the other sustained by regeneration N is called regeneration production. In this paper, the new N for the YSCWM is considered to come from two sources: the atmospheric deposition and sediment eudation. Based on analysis of the inorganic nitrogen sources, it is concluded by our model system that the *f* ratio, the percentage of new production to total primary production, is 33.0%, the simulated annual total new production is  $27.4 \text{ gC m}^{-2} \text{ yr}^{-1}$  in the YSCWM, and belongs to the lower value in the coastal sea. Yang *et al.* (1999) found that the regeneration production occupied more than 60% of the primary production from the investigation in the

Yellow Sea, which means that the  $f$  ratio is no more than 40% in the Yellow Sea. Tian *et al.* (2003) also found that the  $f$  ratio is about 30% in the Yellow Sea by using a three-dimensional pelagic ecosystem dynamic model. The ratio of phytoplankton biomass to zooplankton biomass ranges from 0.36 to 1.53 calculated by using *in situ* observation data. So a conclusion can be drawn that the microbial food loop plays an important role in the zooplankton growth in the YSCWM.

The analysis of simulated microbial loop shows the influence of annual variation. During the spring bloom, there is more phytoplankton in the upper water layer and the contribution of microbial loop to zooplankton growth just accounts for 20 percent. The contribution of the microbial loop in the whole water volume is 40.43% in spring and increases with the decrease of primary production in summer and autumn. In these two seasons, an interesting phenomenon emerges that the impact of the microbial loop in the middle water layer is a little lower than in the upper water layer, which is in good agreement with the observation that a chlorophyll *a* maximum emerges in subsurface layer (20~30m) during the same period (Xia *et al.* 2001; Wang *et al.* 2002). The winter primary production maintains a low level even with rich nutrients in upper water layer, and the impact of microbial loop is higher relatively in the whole layer during the same time.

The modeling quantitative analysis indicates that the annual mean contribution of the microbial loop to zooplankton growth in the whole YSCWM water volume is 60.4%, which is similar to that in Taiwan Strait (Huang *et al.*, 2002). This result addresses the crucial role of the microbial loop in the cycle of the ecosystem energy and matter in the YSCWM, especially in autumn and bottom layer. But the ratio of the zooplankton biomass to primary production stays at an abnormally high value in the YSCWM most of the year. Although the effect of the microbial loop on the growth of zooplankton is very important, it is difficult to explain the high ratio. This problem will be studied in future work.

**PICES XIV S8-2598 Oral**  
**A biological production index for the northern California Current**

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Predicting effects of changing ocean climate on living marine resources can improve resource management. Here, we consider the predictability of zooplankton production in the Northern California Current as an index of food supply for juvenile salmon and other pelagic fishes. Our approach uses a simple NPZ-type biological production model coupled to a simple model of wind-driven upwelling and mixing to reconstruct biological production for seven years with observed nutrients, phytoplankton, and zooplankton. Key parameters were adjusted to provide a “best fit” to the observations. The model was then used to hindcast production for years without plankton observations, resulting in a longer index of seasonal zooplankton production. This index shows promise as an indicator of food supply for juvenile salmon, although its utility in resource management has not yet been evaluated.

**PICES XIV S8-2588 Oral**  
**Multiple indicators track major ecosystem shifts in the Bering Sea**

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Observations over the previous five years show persistent warm and ice-free conditions in the southeastern Bering Sea compared to the mid-1990s, despite large variability in climate indices. These conditions follow a major climate transformation around 1977 accompanied by a major reorganization of the marine ecosystem. Over the last decade annual fisheries surveys in the south indicate a continued decline in recruitment to cold water stocks such as Greenland turbot and snow crab. However, walleye pollock is characterized by a large, rather stable population. We find multiple indicators since the mid-1990s that the sea-ice driven, benthic-dominated, shelf ecosystem of the northern Bering Sea is giving way to a more pelagic subarctic ecosystem as well. There is decreased benthic productivity south-southwest of St. Lawrence Island, northward expansion of the foraging

range of gray whales, and Yupik observations of changes in behavior of walrus in response to changes in sea-ice cover. There is a substantial increase in pelagic fish species in recent years, *i.e.* juvenile pollock and pink and chum salmon. Although a large shift to cold climate conditions is a possibility due to large climate variability in high latitudes, that the Bering Sea is part of larger climate changes in the Arctic and that it is difficult to remove the heat already gained by the ocean in recent years from diminished sea ice areas, supports the continuation of the trend toward subarctic ecosystems in the Bering Sea, with profound impacts on marine mammals, and commercial and subsistence fisheries.

***PICES XIV S8-2377 Oral***  
**Application of modified NEMURO Model to Jiaozhou Bay**

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Anthropogenic activities and oscillation in climatic conditions have important impacts on marginal sea ecosystems. Jiaozhou Bay is a semi-enclosed bay at the westside of the Yellow Sea and is strongly influenced by human activities. Knowledge of its nutrient composition, biological structure, and evolution mechanism is needed urgently for marine ecosystem based management (EBM). Ecosystem modeling is scientific and effective method to deal with them.

NEMURO Model is a simple but mature ecosystem model which is designed and promoted by North Pacific Marine Science Organization (PICES). Eleven nutrients and plankton variables, except for phosphorous, are considered in this box model. The Jiaozhou Bay ecosystem is reported to be controlled mainly by phosphorous and silicate, so a Modified NEMURO Model was designed and applied in our work.

Modeling results and analysis show that: 1. Total Phytoplankton Biomass (TPB) has an obvious annual cycle with one summer peak. The TPB maintains at a stable low level (0.3~0.4  $\mu\text{molN/L}$ ) during the whole January and February until March when it goes higher, and then peaks at 2.65  $\mu\text{molN/L}$  in mid June. The TPB goes down after June until it returns to the same stable low level the next January. 2. Silicate concentration in deep layer (T<sub>SiO3d</sub>) and half saturation constant of it (K<sub>Si</sub>) are of much importance in this ecosystem compared with those of nitrate. TPB is more sensitive to those of silicate according to sensitivity analysis. What is interesting, the concentration of silicate in the deep layer is crucial to the composition of phytoplankton. The ratio of small phytoplankton (PS) to large phytoplankton (PL) becomes less than 1.0/1.0 when T<sub>SiO3d</sub> is reduced by 20%, while it becomes higher when T<sub>SiO3d</sub> is raised. That means there may be a trend of community succession from PL-domain to PS-domain when concentration of silicate decreases, just as it is observed in Jiaozhou Bay. 3. The cycle of phosphorous is our innovation in this work. HPO<sub>4</sub>, DOP and POP were added as new variables. The results show that consideration of phosphorous limits primary production of PS and effects the composition of phytoplankton. Further research on verifying the biological process parameters regarding phosphorous is needed.

***PICES XIV S8-2433 Oral***  
**Ecosystem indicators and integrated conceptual model: Fisheries managements perspective in the South-East Pacific**

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The Chile-Peru Eastern Boundary ecosystem is one of the most productive systems of the planet. This richness takes place mainly by coastal upwelling induced by winds blowing predominantly towards the Equator and by advection towards the Pole of nutrient-rich water. In this ecosystem, El Niño events are the most important in determining interannual variability. Nevertheless, after the El Niño of 1972-73, a regime shift was observed, and associated with it was a clear decrease in the anchovy fishery after the mid 80's. From the mid 70's, a remarkable increase of sardine landings and in lesser quantity of jack mackerel and horse mackerel landings was observed. A second regime shift was observed after 1985, associated mainly with anchovy recovery and sardine decrease.

We developed an integrated conceptual model of different local and large scale phenomena that affects the marine environment and the distribution and abundance of the main pelagic resources of northern Chile. This model is

based on the analyses at different scales of environmental, biological and fishery data. The model describes the inter-decadal (associated with regime shifts) and interannual (associated with El Niño events) fluctuations in the Equatorial Pacific Ocean, South-East Pacific and northern Chile spatial scales, and the effects in the annual cycle, planetary waves dynamics and coastal upwelling. In this framework, the interdecadal fluctuations play an important role in the sequence of alternating anchovy-sardine-anchovy regimes. An identification and development of ecosystem indicators and proxies is also proposed, in order to support the fisheries management decision making process.

**PICES XIV S8-2354 Oral**

### **A comprehensive ecosystem-based approach to management of fisheries resources in Korea**

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Most fish stocks in Korean waters are known to be overexploited, and some stocks have been depleted due to the increase in fishing intensity and over-capitalization of fishing fleet. In addition coastal fishing grounds have deteriorated due to coastal pollution and land reclamation in Korea. Traditional management tools in Korea fisheries are mostly indirect control devices, such as mesh size restriction, minimum size of fish limits, closed areas/seasons, boat licenses, and gear limitation. After extending its fisheries jurisdiction in 1994, a TAC-based management system has been adopted for a few selected fish stocks. A number of difficulties are associated with the practical management by indirect control devices and by the TAC-based management system. The biological and economic effects of these management approaches have not been verified yet. The necessity of the ecosystem-based management considering habitat, environment, and ecological interactions of species is recently stressed worldwide. In this study, a comprehensive ecosystem-based integrated management program is developed to accomplish sustainable exploitation and efficient management of fisheries resources at the ecosystem level in Korea. The program has three management systems: 1) the offshore large ecosystem management system, 2) the inshore self-regulatory ecosystem management system, and 3) the marine ranching ecosystem management system. We suggest specific management plans that include detailed management objectives and associated indicators and reference points for the three management systems, based on the geographical and ecological characteristics of each management system considering the current state of fisheries management in Korea.

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### **Ecosystem parameters and stability: Theoretical considerations**

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An earlier developed approach to modelling of biological processes and ecological systems has established that any ecosystem may be described by equations using three types of dimensionless parameters: relative concentration of limiting element, the generalized kinetic parameter (relative resistance) of any trophic link and substance flux (relative rates of processes) between various ecosystem components. This approach reveals ecosystem-level parameters or indicators. Such parameters are: the maximal rate of photosynthetic production and the general contents of limiting element in all ecosystem components. The ecosystem parameters (but not the parameters of actually trophic links) also are substrate constants (analogues of Michaelis constant) and relative resistance of trophic ecosystem links.

The analysis shows that stability of an ecosystem is defined by a ratio of the total concentration of limiting element and its substrate constants for different trophic links. The ecosystem stability is less than the difference in rates of processes (relaxation times) of various trophic links. It is also established that the choice of the function describing the dependence of process rate of a trophic link on substrate (food) concentration essentially influences on ecosystem stability and relaxation time of a system to a steady state.