

PICES XIV S7-2610 Oral

Regimes and the relationship between farmed and wild salmon in British Columbia

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Salmon farming in British Columbia produces an average amount of salmon in an area of the ocean about the size of the Vancouver Airport that is more than double the total wild catch. About 4000 people have full time jobs in areas of the Province where these jobs are needed. Salmon farming is also controversial because there is uncertainty about the long-term effects on wild Pacific salmon. We show that some of these potential effects are related to decadal scale regime shifts that affect freshwater discharge and surface salinities in the spring.

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Natural sedimentation in large-scale aquaculture areas of Sungo Bay

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Sungo Bay is located east of Shandong Peninsula where scallops, oysters and kelp have been cultured in large scale. The experiment on natural sedimentation in aquaculture areas of Sungo Bay was made with sediment traps in 5 periods of one year. Scallop, oyster and kelp culture areas were chosen for the experiment, and the concentrations of TN, TP and POM in the particulate matter, both from the trap and from the sediment of the experimental areas, were measured. The result showed that the sedimentation rate of particulate matter was 278.8 g m⁻².d⁻¹ in these areas. One gram of sediment settling to the bottom could carry 190.4µg of TN, 472.5µg of TP, and 0.103g of POM. The peak value of the TN content in the sediment appeared in May, and the minimal value appeared in December. But the value of TP content was higher in the cold season than in the warm season. The N/P ratio of the sinking sediment was in the range of 0.67~2.0, but that on the bottom was in the range of 0.025~2.0. These experiment data can be served as a basis for the studies of the nutrient flux and the carrying capacity of a shallow sea for aquaculture.

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Seasonal assembly of seaweed species in the sustainable seaweed integrated aquaculture system in Korea

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Seaweeds are reappraised as a key biofilter and production component in the sustainable seaweed integrated aquaculture system (SSIAS) in Korea. The local seaweed cultivar species such as *Porphyra* sp., *Laminaria* sp., *Undaria* sp., *Enteromorpha* sp. and *Gracilaria* sp. have proven to be good candidate biofilters in lower temperature season and wild *Codium* sp. and *Ulva* sp. have been chosen in higher temperature season. The year around operation of SSISA in a closed inland tank culture is feasible with seasonally assembled seaweed species. The subsistence-scale finfish-shellfish-seaweed polyculture in net pen cultures has been popular in Korea. This integration and balancing of the extractive (seaweed) and feed (finfish) cultures could mitigate eutrophication and the self-pollution of aquaculture in the coastal area. The emerging need of balanced ecosystem approaches to mariculture would be incorporated and managed under the 'Ecosystem Based Management'. Therefore, the immediate application of the SSIAS is recommended.

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The current status of research and problems of invertebrate mariculture in the Russian Far East

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Research covering the field of mariculture and environment interaction is in its initial stage in Russia. Determination of potential carrying capacity of bays is one of the main concerns, and its solution is critical to the development of mollusk mariculture. The method of determining carrying capacity for seabed and suspended bivalve cultivation was developed for Posjet Bay by Soviet researchers in 1980s. Potential load on the bays was calculated by including the size of the cultivation areas, water exchange intensity, concentration of seston, quantity of the mollusks cultivated and filtration rate. This method may be used while research of other sea areas is being conducted. It will help in estimating the carrying capacity of Peter the Great Bay – the most suitable sea area for the development of mariculture in Primorye. Research on mariculture and environment interactions will result in studies of the bays' trophic resources and of mollusk's biosediment quantity during their cultivation. The experiments proved that changes in hydrobiont fermentative activity can serve as a diagnostic characteristic of environmental conditions changes. Economic aspects are highlighted in up-to-date mariculture projects in Russia. However, results of long-term research in various fields of study are essential to elaborate the biological basis for invertebrate cultivation. So, the duration of experimental work (*i.e.* project cost) depends to great extent on the scientific research available.

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Influence of environmental factors to forecast the yield of mollusks on marine farms (Sea of Japan)

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To develop scientific methods for the long-term prediction of mollusk productivity, the first stage is to study the effects of hydrological parameters on the Japanese scallop and the technology of its cultivation. This work is in the first stage of research. All operations, from obtaining spat on artificial substrata (collectors) until commercial harvests are performed under natural conditions in a semi-closed Minonosok Bay on floating industrial installations. This work is based on the following materials: average daily air temperatures for many years, seawater temperature and salinity data provided by the Possyet hydrometeorological station (1930-2004), and the state hydrometeorological service. In addition, data were also included from many-years of observations (1970-1990) on the scallop *Mizuhopecten yessoensis* cultured under natural conditions in semi-enclosed Minonosok Bay (Possyet Bay) on floating installations (one near-shore and three seaward systems of ropes), in which scallop spat that settled onto the collectors was counted (specimens/collector). This study describes the results of statistical analysis of thermohaline characteristics during four periods of the annual developmental cycle of the Japanese scallop. The departures from mean values of duration of biological periods and their thermohaline characteristics, were calculated. To analyze the interconnection of periods, correlation matrices of mean period durations and seawater temperature and salinity mean values have been analyzed for each period. The yield of the Japanese scallop, *i.e.* the amount of spat settled on collectors, expressed in specimen/m² provided a criterion to estimate the effect of thermohaline conditions. Good-harvest and low-harvest years were recognized on the basis of an analysis of the distribution of harvest deviation from the trend. Based on analysis of the results, all parameters undergo considerable interannual variability. One can trace a downward trend in the duration of the larval period. The duration of the larval settling period was corroborated by the lowest variability. A close positive link was recorded between neighbouring periods for thermohaline characteristics of the periods. Comparison of the durations of all four periods in development of Japanese scallop did not change between 1970-1990 and 1999-2003, although it could be remarked that the max and min duration decreased.

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Use of a visual method of estimation of Japanese mitten crab ovaries by maturity stages

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Characteristics of Japanese mitten crab *Eriocheir japonicus* (Crustacea: Decapoda, Grapsidae) ovaries color at different maturity stages were determined according to the Munsell Book of Color (1976). Mature females collected in a branch of the Artemovka River (Primorsky Krai) at 5 kms from the mouth in September 2003 were the target of our research. Ovary maturity stages were determined using standard histological preparations. It was established that during the research period, mature female gonads were at the 1-5th stages of development. For visualization of the received data they were transferred into (R, G, B) system by Munsell Conversion programme. As a result, it was possible to identify ovary color from the beginning of development up to mature gonads, including the following colors: light-yellow, yellow, beige, bright-violet, light-brown, brown, dark-violet and dark-brown. It is marked that the greatest variety of colors is observed at the 4th stage. The received data can be used in aquaculture for visual differentiation of *E. japonicus* ovaries by maturity stages.

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Perspectives of salmon sea ranching in the coast of the Okhotsk Sea and in estuaries of rivers

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The role of sea ranching in estuarine and coastal waters is very important for the artificial reproduction of salmon. The efficacy of artificial propagation depends on the ecological rate of estuarine and marine ranching. For example, the potential of hatcheries on the Taujskaya Guba of the Okhotsk Sea depends on the efficacy of marine ranching. The objective of ranching is to provide abundant returns of adult salmon to the coast and to increase hatchery efficacy. For example, the return rates of chum and coho salmon released as smolts from open net-cages was higher than those recorded from the wild stock along the North Okhotsk Sea coast. This difference can be explained by the additional feeding of juveniles as the food base of the coastal areas is poor and areas for favorable foraging in nature can be reached only by the bigger smolts, and by their physiologies, *i.e.* the quality and survival rate of ranched smolts are higher than those of wild individuals. However, having a big smolt is not always profitable as poor quality feed can result in a weak and defective animal. Improving spawner quality may develop as the key biological technology as the ability to maintain spawners in cages set on the sea coast develops. First results of chum salmon spawning were encouraging. In salt water, fish are not infected by saprolegniosis and, therefore muscle fibers retain their red coloration. This technology allows populations to avoid the effects of overfishing in spawning rivers. Analysis of salmon ranching reveals that although there are positive examples and good results, returns of hatchery-reared salmon are not always stable and at several hatcheries, the run of the farmed population is insignificant compared with the wild population. The most promising way to improve artificial propagation is to use the technology of keeping spawners in sea water for spawning and to develop cage ranching of salmon in estuaries of small rivers.

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Crustacean cultivation in artificial conditions: Promising trends in aqua- and mariculture in Russia

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In recent years, there has been a trend in Russia toward a revival of mariculture, resulting from the newly emergent and great demand for delicatessen foods, and a sharp decline in the abundance of certain hydrobionts (red king crab). The items for which new culturing techniques are being developed include both – freshwater and marine species. Farmed animals may include the freshwater crayfishes (Decapoda, Astacinae) – *Astacus leptodactylus* and *A. astacus*, and the freshwater giant shrimp (*Macrobrachium rosenbergii*). The red king crab (*Paralithodes camtschaticus*) is the main cultured marine species. Culturing of this species in Russia is being

done with two objectives in mind: (1) reproduction aimed at natural population recovery, and (2) additional rearing of pre-recruits to attain marketable size. The scientific research is conducted along such directions as the biological basis for raising the cultivation effects, feeds and production of feeds, disease and prevention, and equipment. In addition to the restoration of natural stocks, and to securing supplies for the delicacy product markets, this generation of culturing technology and the establishment of aquaculture facilities for crustaceans in Russia may ensure quite a number of jobs and raise the living standards in small communities.

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Reproduction of chum (*Oncorhynchus keta*) and masu (*O. masu*) salmon at salmon hatcheries in Primorye (Peter the Great Bay)

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Chum and masu are major Pacific salmon species in the rivers of southern Primorye. Human management became the reason of reduction of chum and masu salmon abundance. Two salmon hatcheries were established in the middle of the 1980s on the Barabashevka and Rjazanovka rivers. Chum salmon is the basic object of hatchery reproduction. About 20 million eggs are cultivated and about 18 million fry were released in recent years. Returns of adult fishes varied from 0.07-1.2 %, averaging 0.25-0.35 %. About 90% of the chum salmon returning to the rivers of Peter the Great Bay are the result of hatchery cultivation. Masu salmon cultivation in hatcheries has a short history. The first experiments were conducted by TINRO scientists in the Rjazanovka experimental hatchery from 1988-1990. By the end of 1990s, both hatcheries started to cultivate this species commercially. Fry cultivation and release occurred according to the following plan: 1) recruitment of natural populations due to release fishes in average weight, 0.4-0.9 g to the rivers; 2) release of one-year-old fishes (smolts) with an average weight of 18-20 g. The quantity of fry released by the two hatcheries gradually increased from 0.25 million up to 3.5 million, and during last 4 years, it has been about 1.5 million, on average. Smolts are released less, on average about 30 thousand per year.

PICES XIV S7-2587 Invited

International efforts to apply environmental risk assessment to marine aquaculture

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The ecological risk assessment framework developed by the World Health Organization of the United Nations is widely used in other industries that impact the environment and the analytical techniques have been internationally accepted. Two international workshops, one held in Canada sponsored by ICES, and a second held in the United States sponsored by FAO, have attempted to apply the WHO framework to ecological risk assessment for marine net-pens and have independently developed similar guidelines. A third international conference sponsored by NOAA on the role of aquaculture in the marine ecosystem held in Hawaii, has also endorsed a scientific risk assessment approach but did not develop details about how to do this. This NOAA sponsored meeting did recommend the use of models for decision support as marine aquaculture industries grow and data becomes available. The FAO sponsored meeting called for countries to develop case studies for the major aquaculture industries in their marine waters with a potential follow-up meeting to present these case studies. This approach may also be appropriate for PICES research on aquaculture as it may impact carrying capacity, ecosystem function and socioeconomics.

PICES XIV S7-2356 Oral

Integrating seaweed cultivation into brackish water aquaculture - Chilika Model

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Chilika, one of the largest brackish water wetland ecosystems in Asia, is situated on the east coast of India. Over the years, Chilika Lagoon has been threatened by siltation, eutrophication, changes in salinity regimes, fresh water weed proliferation, decrease in fish productivity, increased aquaculture, changes in species

composition and excessive removal of bioresources. Most of the agriculture fields around the lake were turned into aquaculture ponds and subsequently abandoned. More recently, it has been found that the income level of family members has gone down substantially due to various problems associated with intensive aquaculture. Because of these problems many people have become jobless. People from different parts of the Chilika region started migrating to the cities due to lack of any other job opportunity. Therefore, seaweed cultivation and processing was examined as an alternate source of livelihood. During the investigations, a strain of *Gracilaria verrucosa* was isolated which produces high quality agar. Various methods of culture and cultivation of *G. verrucosa* were investigated as well as the culture of *Paenus monodon*. It has been found that seaweed cultivation is slowly gaining acceptance among various communities, although this industry provides a lower return. Thus we have initiated large-scale cultivation of *G. verrucosa* at different locations with community participation. A model has been developed and successfully implemented in and around Chilika Lake where a person can earn \$80-90 per month through seaweeds cultivation. A large number of NGOs and villagers have developed keen interests in this programme.

PICES XIV S7-2493 Oral

Use of ecosystem models for study and management of coastal estuarine ecosystems in Korea

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An ecosystem model was developed to describe the estuarine plankton of western coastal systems in Korea. The model is composed of 12 state variables including picophytoplankton, nanophytoplankton, microphytoplankton, heterotrophic bacteria, protozoa, microzooplankton, mesozooplankton, POC, DOC and nutrients such as ammonium, nitrite+nitrate, orthophosphate. Allometric relationships and density-dependent feedback control terms were used and forcing variables such as solar radiation and water temperature was included in the model. The ecosystem model was developed in Fortran using differential mass balance equations that were solved numerically using the fourth-order Runge-Kutta (explicit) technique. The model was calibrated by adjusting the parameters that were not identified from literature. After calibrating the ecosystem model, forcing and state variables were validated using historical data and field data collected from 2001 to 2004. Comparison of model predictions and field data for the principal forcing variables and state variables of primary producers showed generally good agreement. Using the validated model, environmental factors controlling the phytoplankton dynamics and responses of the plankton to the environmental changes were investigated.

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On some ways of preservation of local fish populations

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In modern times, the cost of fishery production is increasing, but so are the costs of preservation and restoration of local fish populations with low abundance. That is why the development of economical biotechnology and equipment becomes more and more important now. At the Ichthyology Department of Moscow State University, some methods of fish growth control and modular equipment for fish farming have been developed. By manipulating such powerful factors as temperature and salinity, for instance, gives many possibilities to optimize traditional technologies and to construct new technologies to stimulate growth and development processes, with the aim to get high-quality fish fry. The equipment provides a possibility to regulate ambient conditions. Modules could be produced and equipped at work, delivered by any type of transport, installed and adjusted to start usage within several days. Using a principle of modularity, it is possible to quickly establish inexpensive fish farms for cultivation of different freshwater or marine fishes. Considering biodiversity preservation principles, these modular mini-enterprises will help to save the genetic structure of populations and the gene pool of rear species of fish and support the intra-specific biodiversity of commercially important fishes.

PICES XIV S7-2540 Poster

Selenium content in marine organisms from the Russian coast of the Sea of Japan

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Selenium content was analyzed in 10 species of algae and sea grasses, 18 species of molluscs, three species of echinoderms and 14 species of fish from the coastal zone of Primorye, the Sea of Japan. The determination of selenium fluorescence method conducted on analyzer of the liquids "Flyuorat-02-3M" ("Lyumeks", Russia). Primary colour filter UFS-2 (the wavelength = 366 nm); secondary colour filter ZHS-17 (the wavelength to fluorescences F = 520 nm). The Reagent - 2,3-diaminonaphtaline. Selenium concentration in the common species of sea algae and sea grasses does not exceed 0.8 µg/g dry weight. The maximum content was revealed in *Sargassum (S. myabei)* – 1.06 µg Se/g. The analysis of selenium accumulation in organs of shellfish has shown that selenium concentration was higher in shellfish than in algae and sea grasses, and reaches 10.8 µg /g in the gills of *Mercenaria stimpsoni*. On average, this value was within the range of concentration 2-3 µg/g in muscle and 4-6 µg/g in hepatopancreas and gills. Selenium concentration was determined in three species of *Echinodermata*. The average level of selenium corresponds to its level in shellfish. Selenium concentration in fish caught in Sivuchiey Bay and Posyet Bay varied in the range 1-6 mkg/g. The maximum amount of the selenium, 6.2 mkg/g, was discovered in the liver of herring, *Clupea pallasii*, and the minimum, 1.1 µg /g, in the muscle of striped plaice, *Pleuronectes pinnifasciatus*. Results have shown that Primorye seaside is a selenium-deficient province. The average content of selenium in organs of investigated species is sufficiently low. Seafood is considered as an important source of necessary micronutrients in the daily human diet. So, it is necessary to develop the technology of marine organisms cultivation in selenium-rich environment.

PICES XIV S7-2259 Poster

Increasing sea urchin settlement productivity using various forms of melioration

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As sea urchin stocks are reduced by exploitation in all places, alternative measures are required to provide the market as well as to support its natural populations. Evidently, in order to preserve and maintain many sea urchin populations in good condition it is necessary to conduct various meliorative actions. A scheme for such actions has been worked out in FSUE at "TINRO-centre". It involves: transplantation of juvenile and mature animals from sites lacking macroalgae to sites with abundant kelp where gray sea urchins are intensively fished; making near-bottom substrate for kelp cultivation for sea urchins additional feeding; collection of juveniles at artificial collectors; settling of natural and artificially cultivated juveniles at specially prepared sites for growing up to commercial size. Transplantation of juvenile and mature sea urchins to sites with abundant kelp and as well as their additional feeding using artificially cultured kelps make possible to improve marketable quality of gonads and to increase sea urchins reproduction. These actions will maintain high productivity of traditional fishing sites and increase the quantity and biomass of gray sea urchins at sites with unfavorable conditions for its reproduction and growth.

PICES XIV S7-2339 Poster

Principle of ecologically environmental capacity and its application to planning and management of coastal aquaculture in China

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China's aquaculture production exceeds its fish capture landings. Fisheries (aquaculture) were playing an important role in food supply and became one of the most vital support industries and economic activities in rural development during the past 20 years. Expansion of coastal aquaculture and sea-farming stimulated a rapid increase in production, and also created much rural employment. The goal is to increase aquaculture to improve the welfare of farmers and develop the rural economy. However, an urgent problem is the adverse

environmental impacts accompanying the accelerated development of the industry. This article offers a new viewpoint to illustrate coastal aquaculture planning and management. Based on a division of different functional areas, the concept and principle of ecologically environmental capacity (EEC) are applied to guide the industry in aquaculture area. EEC is an integrated concept: within a special area, biological production of unit water bodies does not jeopardize environment, keep relative ecosystem stabilization, maximize economical benefit, accord with qualification of sustainable development, and attain maximum yield. EEC expresses that biological totality increases under environment conditions available, does not disturb the coastal environment, does develop sustainable biology production industry which is the long-range aim and standard of aquaculture development. Concerning polluted environments (aquaculture reduced) in coastal China, restoration is needed using “aquaculture does remedy aquaculture” as our guideline. According to the principle of environmental ecology, the pollutants from animal production will be transferred or recycled by food chains, e.g. adding costly plants to animal production system, both animal and plant benefit from each other. This can develop an ecological production model.

PICES XIV S7-2297 Oral

Proposal of site selection guidelines for fish farming in Japanese coastal waters

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Environmental deterioration around fish farms has been widespread in Japanese coastal areas. A lot of effort has been paid to improve farm environments and various kinds of measures have been proposed. However, only a few measures have been put to use. The most practical way for environmental management of fish farms is to locate fish farms within the range of assimilative capacity and to control the stocking density of cultured fish. In this context, we proposed two indices for site selection guidelines. An ‘ED’ (Embayment Degree) index is calculated from the distance from the mouth of a bay to a fish-farm site, the width of a bay, the water depth of a site and the maximum depth at the bay mouth. Another index, ‘ISL’ (Index of Suitable Location) is calculated from the water depth and current velocity under a fish cage. Current velocities can be estimated using plaster balls easily and simultaneously at many stations. Biotic and abiotic factors at the fish farms were found to change along gradients of fish production and ED or ISL, suggesting that these indices are effective for estimating the assimilative capacity. ED can be used as a simple indicator for the site selection. ISL can be of a wider application to assess the assimilative capacity under a variety of topography.

PICES XIV S7-2212 Oral

A first exploration on differential impacts of bivalve mollusc on the two phytoplankton groups, diatom and dinoflagellate

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Last year, we reported on preferential control by cultured bivalve molluscs on dinoflagellate biomass during field surveys in a coastal bayment where diatoms and dinoflagellates were dominant phytoplankton. Here we present novel findings from indoor controlled experiments on differential impacts of the scallop, *Chlamys farreri*, on the diatom, *Skeletonema costatum*, and the dinoflagellate, *Prorocentrum* sp. Feeding experiments indicated that *Prorocentrum* sp. was more efficiently grazed from the algal mixture by the scallops than *S. costatum*, regardless of the changes of algal cell density (0.5-20×10⁶ cell/L) and changes of species contribution to the algal mixture (*Prorocentrum* sp. to *S. costatum* cell number ratio 1:8 - 8:1). Digestion efficiency for the ingested algal cells was high (>99%) and was similar for both algal species at a feeding rate up to 5 mm³ d⁻¹ ind.⁻¹, but decreased slightly (to 96%) at a feeding rate of 5-15 mm³ d⁻¹ ind.⁻¹. Concentrations of nutrients (dissolved inorganic nitrogen, phosphate and silicate) were higher in scallop-occupied seawater than in natural seawater. When inoculated together in scallop-occupied seawater, *S. costatum* outcompeted *Prorocentrum* sp. both in quantity and growth rate. These results indicate that scallops preferentially feed on *Prorocentrum* sp. compared to *S. costatum*, and decrease the competitive capacity of *Prorocentrum* sp. in scallop-occupied seawater. These effects might contribute to the preferential control by cultured bivalve molluscs on dinoflagellate biomass in the field.

