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Early Marine Period Life of the Pacific Salmon

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Summary

Represented manuscript is the first generalized summary on the biology of juveniles in 5 species of Pacific salmon - pink, chum, sockeye, coho and chinook at their early marine period in Asiatic coastal waters. Twenty years (1974-1993) of investigations carried out by the author in the coastal waters of Kamchatka in comparison with the same ones done in North America were assumed as a basis of this work. The purpose was to determine the causes of mortality and to estimate juvenile elimination at the early marine period in the coastal waters of Kamchatka and in other reproductive zones of Pacific salmon.

The manuscript consists of three sections including: 1 - the stating of a problem (3 chapters devoted to the history, materials and methods and the characteristics of coastal waters as the habitats for salmon juveniles), 2 - the ecology of juveniles of 5 species (5 chapters in the first section) and 3 - the factors determining survival and broods production (3 chapters in the second section), a summary, references (655 pages) and a supplement of 2 figures and of 2 tables.

The first chapter has been devoted to the history of investigations concerning the early marine period in Asian salmon. The results of many years of investigations at the coastal waters of Hokkaido, Iturup, Sakhalin, Primorye, Kamchatka and other Far East areas have been discussed in comparison with that at other reproductive regions (the figure).

For the purpose of estimating the role of the early marine period of juveniles in the forming of generation numbers authentically, there was assigned the area of most typical range between reproducing *Oncorhynchus* sp. representatives in Asia - Korf-Karaginski region in the Bering Sea to make standard testing. Collected data were processed with generally accepted and original methods.

In the third chapter there is a short description of the initial habitats for salmon juveniles after migration into the sea, that were estuaries, shores, harbours, bays and off-shore coastal waters of Kamchatka and other Far East areas. Climatic, oceanographic and production capacity features were examined and comparatively analyzed in areas within the Far East region.

The distribution of salmon juveniles and their behaviour into the subdivided river estuaries (highly stratified by type (I) and mixed (II) ones) were significantly different; juveniles staying into the mixed estuaries longer. There was examination of the direct influence of water temperature and salinity on the survival in juveniles, the optimums for different salmons had been determined.

In the structure of mesoplankton within neritic zone there were determined two biocenoses - a coastal and a neritic one with the boundary along 10 ± 5 m isobat. Many-years structural, number and biomass changes in mesoplankton of Korf-Karaginski aquatory were the result of climatic and oceanological conditions. The structure of plankton communities was compared in regions.

Less than 10 piscivorous species have been found predating on salmon juveniles, it being known that general consumers differ with areas: in Hokkaido waters it is Japanese dace, in Sakhalin waters - the Siberian char (southwest) and Asian smelt (northwest), in Amur estuary - the lamprey, in Kamchatkan waters - the Siberian char and Asian smelt (west coast), Asian smelt and the Arctic char (north-east coast). Furthermore, at the coastal waters of Kamchatka bird-predation was noted on salmon juveniles with the Arctic and common terns and with the kittiwake. The data on the extent of juvenile elimination as a result of avian-mammalian predation has been discussed.

Part 1. Ecology of species. Determinative keys for species identification over the expedition have been demonstrated. The description of each species comprised the characteristics of down stream migration, distribution in the coastal water, body size, the feeding and biochemical indexes.

Asiatic pink salmon migrate to the sea during a period of at least 4 weeks and more than 3 months depending on location, the cases of more long migration were noted only in several rivers (Amur, Poronai, Kichiga). Down stream migration in Kamchatkan juveniles has been assigned from June 11-20 - the most favourable time to ensure maximum survival. Feeding in the coastal waters is not long for pink salmon juvenile, so they migrate off-shore very soon. Usually, the migration process carries the traits of pulsation.

Pink salmon entering the sea are small, and most of the juveniles have a residual yolk sac of 20% of body weight in the rivers and of 12% in the coastal waters. Such fishes have been adopted rather worth to the sea habitats being prey to a great extent. Maximum growth rate in pink salmon juveniles is marked at the beginning of August when assimilating feeding resources off-shore of the bays. During this period daily linear and mass growth take 2-3mm and 6-8 % accordingly. Growth variability and circuli dynamics in different reproductive regions have been examined.

First are demonstrated the results of examination of the blood morphological structure in pink salmon over down-stream and off-shore migrations, what indicates two physiological groups of fishes - "fresh-water" and "sea-water" adapted.

The feeding of pink salmon young was studied in different coastal zones, daily feeding dynamics and feeding rations were estimated. In littoral zone in July the rations took 2,1-11,9% of body mass; in Litke Strait at the beginning of August and some seaward at the late August-September it took 12-15% and 3-4% of body mass accordingly. The dynamics of biochemical parameters had an undulatory character that tells of conditions while the juveniles inhabit coastal zones. It was assigned that zol index about 18 indicates pink salmon readiness to migrate to sea, the difference in total caloricity in fishes of abundant or not abundant generations has been determined with the food supply level.

Down stream migration of Asiatic chum salmon to sea is the longest - from March (Hokkaido Island) to September (Igniter River). On Kamchatka mass migration of fry takes place in June-July, often following undulatorily keeping this manner during the forward off-shore migration. However, during this period there are found reverse migrations to the river outlets like it is known in other regions. Like pink salmon, chum salmon have residual yolk sacs of about 25% of their body mass, the percentage being higher in abundant generations.

The body size data set of downstream migrants and of coastal residents is presented. Examined growth rate in chum salmon is lower compared with that of pink salmon. The maximum

daily growth rate - about 2mm and 2g in length and in mass accordingly, have been estimated at the beginning of August. The higher growth rate is assessed in Kamchatkan juveniles when comparing the growth rate in juveniles from different regions. The results of the examination of circuli at the scale and of the blood morphological composition during the feeding of juveniles has been represented.

Food composition, fullness, daily feeding dynamics and food consumptions of chum salmon juveniles in coastal zones have been studied. Daily fresh waters rations varied from 3,7 to 16,3% to body mass and in estuaries - from 6,4 to 16,5% to body weight. As a rule, decreased food supply for juveniles at the river low stream and at the estuaries provokes subsequent migration to the sea. Stretched out migration and feeding processes in the coastal waters determine high biochemical differences of juveniles. It is found that changes of biochemical parameters in chum salmon have been determined by the total number of feeding pink and chum juveniles against a background of interspecific competition.

Sockeye salmon migrate to sea from the rivers of Kamchatka in May-August being most active in June-July. The feeding period in coastal waters is comparatively short excluding underyearlings (0+), which inhabit there longer. In North Kamchatkan coastal waters sockeye salmon are represented with three age groups: 0+ - 67,4%, 1+ - 30,2% and 2+ - 2,4%. Over 18 observation years underyearlings and yearlings prevail by number in a half cases each. Most underyearlings have 1-4 circuli, that have been initiated under the body length of 3,5-4,2 cm. Sockeye salmon underyearlings being 4 cm in length and about 1g in mass, as a rule, are larger compared to pink salmon or chum salmon. Year-to-year body size variation in sockeye salmon of all age groups during feeding in coastal waters has been adduced. Sockeye salmon growth rate is high and similar to that in chum salmon which indicates close ecological proximity. Growth rate in yearlings is higher than in underyearlings.

Because of complex age structure sockeye salmon have a relatively large feeding spectrum and significant satiety variation being most high in underyearlings. Food items in the older age group sockeye salmon are similar with that in coho and chinook juveniles sampled in the littoral zone, with the distance from shore becoming closer to the spectrum of pink and chum.

The results of sockeye salmon underyearlings and yearlings blood plasma and biochemical indexes studies has been demonstrated.

Coho salmon migrates to sea from Kamchatkan rivers in May-August, but in some areas they migrate in September. The timing of down-stream migration and body-size indexes in coho salmon from different age groups within areal have been analyzed. Generally, coho salmon juveniles inhabit during 15-20 days in littoral zone, in small bays and harbours - during a month or longer. In relatively closed aquatories (Avacha and Uka Bays) coho salmon juveniles can inhabit more than two months. Only the fall cooling of coastal waters makes them migrate off-shore.

In Karaginski Bay coho juveniles are represented by four age groups: 0+ - 3,0%, 1+ - 50,8%, 2+ - 44,9% and 3+ - 1,3%. Data on the seasonal and year-to-year body size variation in coho salmon of different age groups have been discussed. Coho salmon juveniles have a high growth rate being the maximum in August - early September; daily linear rate takes 2mm, mass one - 1-3g. In closed aquatories (Avacha Bay) the growth rate is 20-30% lower as compared to that in open ones (Karaginski Bay), which should be explained by food supply level.

Coho salmon feeding spectrum includes more than 40 species, basic component in all zones are fish larvae and juveniles. In some years coho salmon consume a lot of underyearlings of pink, chum and sockeye salmons.

Chinook salmon is the most poorly examined Asiatic species of the genus *Oncorhynchus*. The timing of down-stream migration is unknown, juveniles have been discovered in coastal waters in June-August. Chinook juveniles feeding during long period - up to October migrating off-shore with water temperature decreasing up to 6,2-6,5°C.

In Karaginski Bay chinook juveniles are represented by the next age groups: 0+ - 3,5%, 1+ - 71,9% and 2+ - 24,6%. More underyearlings (50,6%) are marked in July-August 1987 in Bolshaya River estuary (West Kamchatka). Body size data set of fishes from different age groups during feeding in coastal waters has been represented. There was examined chinook salmon growth rate, maximum meanings 1,84mm and 2,32g are noted in from August 11-20 when leaving for the off-shore.

Predatory feeding is typical for chinook juveniles, basic components forming the ration are juveniles of herring, capelin, sandlance, sculpins, smelts, pollock, pink and chum salmon. A comparison of food composition in chinook salmon from different areas of Asiatic and North American regions has been carried out.

At the second part of a manuscript there were analyzed salmon mortality data during marine period and some environmental factors affected in complex or separately the forming of abundance and total generation production.

Salmon juveniles inter- and intraspecific interactions included food competition and "prey-predator" relation, the first type interaction existing longer. Feeding selection in pink and chum salmon had been discussed being high preference of some crustaceans noticeable in several coastal water zones.

In the coastal waters of North-West Kamchatka salmon juveniles, representing different age groups, were feeding in different time, what makes feed competition less intensive. However, food similarity analysis for two groups of food competitors - pink, chum salmons and sockeye, coho, chinook salmons - indicates of food competition intensification in the years of harvest pink salmon generations. This species has an influence not only on the forming of abundance and on biological parameters of other salmons, but on its' own structure too. The effects occurring under the different abundance of consumers and different forage conditions have been described.

"Prey-predator" relation takes place between juveniles of coho, chinook and sockeye salmons of older age groups and underyearlings of pink, chum and sockeye salmons. The extent of pink (0,13-21,1%) and chum salmon elimination (0,24-8,0% of generation) in the estuaries of 7 rivers in Karaginski area was estimated.

10 chapter includes the analysis of a role taken by salmon juveniles in coastal ecosystems, where the latter persisting as a prey of piscivorous fishes and birds from one hand, and as a consumer of zooplankton, fish larvae and fryes from another hand.

Zooplankton consumption in salmon juveniles within two feeding aquatories in North-East

Kamchatka (Uala and Karaginski Bays) was estimated. For the first aquatory daily consumption over the abundant or not abundant years consisted of 1,3% of total biomass of plankton organisms just after juvenile migration to the sea and of 2,1% to the end of feeding period. Food consumption in juveniles of all salmon species over the whole feeding period (40 days) in Karaginski Bay in 1987 took 457,2 t, in 1988 it mounted to 14075,4 t, what takes 1,01 and 27,3% of total plankton biomass over the years accordingly. Food consumption to hatchery salmon juveniles in Avacha Bay, building hatcheries in Avacha and Paratunka Rivers, take 414,4 t.

The extent of consumed by salmon juveniles larvae and young of some commercial species: herring, capelin, smelts, flounders, pollock and sandlance, was analyzed. Cases of feeding on herring juveniles were described in details. There was done an attempt to estimate the losses in herring stock abundance as a result of predation; significant herring larvae elimination was noted in 1981, 1983, 1987 and in 1989, maximum - in 1982. Directions to further research on the field of this interest have been proposed.

In the coastal waters of Kamchatka, like in other Asia areas, objects generally affected by predation were pink and chum salmons, being smaller juveniles with residual yolk sac eliminating mainly. In Karaginski Bay the Arctic char and Asian smelt consumed up to 11,2-28,8% of pink salmon generation and 1,8-16,8 % of chum salmon. Into some river estuaries pink salmon generation has been reduced in 60%. The number of consumed pink salmon juveniles in total over the 18 years observation was 115, 4 mln samples, of chum - 51,25 and of sockeye - 3, 89 mln samples.

Final chapter is dealing with the features of forming salmon abundance and production in early marine period. Salmon juveniles elimination has been determined with hydrological regime, forage conditions, predation and disease factors. Except directly affecting the survival of Kamchatkan salmons temperature and salinity in coastal waters, there is noted mediated influence of forage base. High juvenile mortality takes place in the years of early migration down the river coinciding to the timing of mass development of zooplankton. Optimum conditions has been found when the biomass of zooplankton is 200mg/m^3 in June and 400mg/m^3 in July.

Data set on the extent of salmon juvenile elimination within Far East areas as a result of predation has been represented. Since 1987 there is registered mass invasion of all salmon juveniles with trematoda Cryptocotyle sp. larvae in coastal waters of North-East Kamchatka, what causes 10% elimination in some generations. The invasion affects fishery commodity output because parasites are persisting in adult salmons.

Pink salmon mortality in Karaginski area, being significantly variable, especially in not abundant generation, has been estimated on the basis of a complex determinative factors. Accordingly to the data of direct counting survey it varied from 53,1 to 94,4% of generation during the initial period (40-45 days) and from 55,4 to 95,8% during the last period (360 days).

Original methodology has been devised to correct the abundance of pink salmon fishery return a year before the spawning. More precise abundance forecast comes true when any abnormal environmental conditions are absent. Generally, a mistake of deviation is not much than 10% if generation is abundant, when generation is unabundant it is higher. Other methods how to make a forecast more precise and their efficiency have been considered.

The measures to mount the survival and productivity include three general directions: 1 -

biological melioration, 2 - hatchery and 3 - rational stock exploitation. Terms application in different Far East areas and the efficiency of these measures have been estimated. For example, liquidated predation press in North-East of Kamchatka during 18 years should enlarge salmon catches in 80 thousand tonnes. Lower meanings have been assessed for South-West and North-East Sakhalin. Biomeliorative measures are especially effective in the areas developed salmon hatchery, for example in Sakhalin. Salmon hatchery development has been suggested to the areas where natural populations have been sufficiently affected. Monitoring investigations at the unified model testing area have been suggested to explotate salmon stocks rationally in different areas.

The end maintains short conclusions, practical recommendations and prospects for future investigations.