North Pacific Anadromous Fish Commission (NPAFC)
North Pacific Marine Science Organization (PICES)

2005
NPAFC-PICES Joint Symposium

"The Status of Pacific Salmon and their Role in North Pacific Marine Ecosystems"

October 30-November 1, 2005
Lotte Hotel Jeju, Seogwipo,
Jeju Island, Republic of Korea

PROGRAM &ABSTRACTS

~~About the artist for the front cover art~~
The elegant woodblock print on the cover is the work of Tomoko Watanabe, a Japanese artist who lives in Vancouver, B.C., Canada. Tomoko was born in Saitama, Japan, and studied art at Dohto University, Mombetsu, Hokkaido, Japan.

Program

Registration
(Crystal Ballroom Foyer)

October 29, 2005 (Saturday) *17:30-19:30* *Pre-registration*

October 30, 2005 (Sunday) *08:00-14:00* *Registration*

Oral Presentations
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October 30, 2005 (Sunday)

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Abstracts – Oral Presentations

Getting the Message Out

Richard J. BEAMISH

Fisheries and Oceans Canada, Pacific Biological Station,
Nanaimo, British Columbia V9T 6N7, Canada

Total Pacific salmon catches are near historic high levels, yet most people fear for their health. The North Pacific Anadromous Fish Commission coordinates an effective network of enforcement that has virtually eliminated high seas fishing of salmon. Few people know this and even fewer know of the Commission. Science now recognizes that climate affects the carrying capacity of the oceans along decadal scales that can change quickly. Science also recognizes that we are changing our climate in away that past relationships between salmon and marine ecosystems will change. A common problem with future research is that money for sustained research on Pacific salmon that traditionally came from government is drying up. Thus it is time to find new sources of support for future studies on Pacific salmon. If we are to find new sources of support we need to think differently. We traditionally worked as individuals or as very small teams. We now need to integrate our activities on a larger scale and speak in a common language that our clients understand. When we communicate as a large entity by reporting to our clients about the state of salmon, the threats to salmon and the priorities for research, we earn trust. This was the original environmentalism. A return to environmentalism without advocacy will attract patrons as Pacific salmon remain the principal icon for environmental health in subarctic Pacific.

Pink Salmon Trends in Abundance and Biological Characteristics in the North Pacific

Vladimir I. RADCHENKO[1], Olga S. TEMNYKH[2], and Victor V. LAPKO[1]

[1]Sakhalin Research Institute of Fisheries & Oceanography (SakhNIRO)
196 Komsomolskaya Str., Yuhzno-Sakhalinsk 698023, Russia,
[2]Pacific Scientific Research Fisheries Centre (TINRO-Centre),
4, Shevchenko Alley, Vladivostok 690950, Russia

Pink salmon are the most widely distributed species of genus *Oncorhynchus*. In comparison with other Pacific salmon, pink salmon area is especially extended to the Arctic. Biannual cyclic recurrence of spawning stock conditions is inherent for pink salmon regional groups due to interchanging of the odd-year and even-year broodlines resulting from generations spawning in alternate years. These broodlines have been genetically isolated and usually differ by level of spawning stock and progeny abundance.

Catch dynamics remained one from the basic index of Pacific salmon stock conditions. Two periods with relatively high level with years of low abundance between them (approximately, 1945–1975) can be selected on the graph of total pink salmon harvest in the North Pacific. Comparison of cumulative curves revealed close coincidence of pink salmon catch dynamics both on the Asian and American side of Pacific (Chigirinsky 1993). Trend coincidence of catch dynamics among the odd-year and even-year broodlines was found for several fishery regions. Further analysis revealed almost the same degree coincidence in the Pacific Ocean on the whole. Observed relationship supposes an existence of the strictly determined response of both broodlines to the periodic dynamics of global factors determining conditions of pink salmon reproduction and survival.

Formation of seasonal groupings, or races, is inherent for pink salmon of both broodlines. In the Sakhalin-Kurile Islands region, three of them are selected: “spring” Japan Sea grouping, and “summer” (or early) and “autumn” (or late) oceanic races. Coastal fishery bases on the stocks of late oceanic race with significant portion of early oceanic race in even years. Increase of “summer” oceanic grouping portion occurred in the last years that related with lowering survival of late race and expected changes in total stock abundance. Situation is aggravated by the fact that pink salmon hatching notably contributing in total stock focuses on late oceanic race reproduction.

Pink salmon biological characteristics depend from level of stock abundance. Correlations occurring between pink salmon body size and abundance level were as positive as negative in different regions, broodlines and time series. The ambiguous relationship can testify that pink salmon size may depend not only on certain growth conditions, which are determined by forage and hydrological conditions. That can be related to complicate stock structure of regional pink salmon group. Seasonal races and ecological groupings have preferred development in different years that defines average size dynamics in specific region.

Trends' Shift for the Long-Term Changes in Abundance and Biological Indices of Pink Salmon from Sakhalin-Kuril Region: Possible Causes and Effects

Alexander M. KAEV, Alexander A. ANTONOV, Vladimir M. CHUPAKHIN, and Vyacheslav A. RUDNEV

Sakhalin Research Institute of Fisheries and Oceanography (SakhNIRO)
196, Komsomolskaya Street, Yuzhno-Sakhalinsk 698023, Russia

Changes in abundance, reproduction efficiency and biological indices are considered for fish from the three greatest pink salmon groups of Sakhalin–Kuril Region, spawning in rivers of the Iturup Island (southern Kuril Ridge), southeastern Sakhalin, and Aniva Bay coast (southern Sakhalin) for the recent 30–38 years.

In individual time periods, the antiphase changes in pink salmon abundance were observed during the contiguous years in different regions, when the odd-year broods dominated by abundance in one of the regions (Sakhalin Island), and the even-year broods dominated in the other region (Iturup Island). However, a general trend for changes in abundance was similar in all the regions: after the decline in abundance in the first half of 1980s, it increased up to the record values in the 1990s. Changes in numbers of the pink salmon returns depended greater on the fish survival during the sea life period than on the reproduction efficiency during the freshwater life period. All the multiple pink salmon returns were combining with the high fish survival in seawaters, whereas the increase in numbers of juvenile migrants did not always result in the increase in returns.

Having analyzed the long-term cycles, no changes proving the activity of density factors were found in populations. Neither a reliable decrease in body size and fecundity nor a retard in spawning migration of the fish majority under the increase in pink salmon abundance were observed. On the contrary, the largest fish sizes corresponded to the period of the record high pink salmon abundance in the 1990s. Such changes show that dynamics of the pink salmon stock is determined, to the greater extent, by the processes connected with global natural cycles. Moreover, judging from results obtained when comparing pink and chum salmon growth, these processes were not going identically in the western and eastern parts of North Pacific.

In recent years, under the high abundance of pink salmon, there is a stable trend to shifting the fish runs to the spawning areas for earlier dates. This shift is caused not only by the change in terms of spawning migration, but also by the change in ratio between the numbers of two pink salmon groups – with early and late dates of spawning. A decrease in abundance of the late group can prove the beginning of decrease trend in the total stock of pink salmon from the southwestern Okhotsk Sea.

Trends in Abundance and Biological Characteristics of Chum Salmon

Masa-aki FUKUWAKA[1], Tomonori AZUMAYA[1], Toru NAGASAWA[1], Alexander N. STAROVOYTOV[2], John H. HELLE[3], Toshihiko SAITO[4], and Ei-ichi HASEGAWA[4]

[1]Hokkaido National Fisheries Research Institute, Fisheries Research Agency,
116 Katsurakoi, Kushiro, Hokkaido 085-0802, Japan
[2]Pacific Scientific Research Fisheries Centre (TINRO-Centre),
4, Shevchenko Alley, Vladivostok 690950, Russia
[3]Auke Bay Laboratory, NMFS, NOAA,
11305 Glacier Hwy., Juneau, AK 99801-6094, USA
[4]National Salmon Resources Center,
2-2 Nakanoshima, Toyohira-ku, Sapporo, Hokkaido 062-0922, Japan

Chum salmon is the second most abundant salmon in the North Pacific. Catches of Pacific salmon increased in 1980s and reached at the highest level in 1990s. That increase was largely contributed by increase of pink and chum salmon catches. Simultaneously, body size of mature salmon decreased in many salmon stocks.

Japanese national hatcheries are monitoring biological characteristics of mature chum salmon. Results of monitoring showed that size at maturity decreased and age at maturity increased for chum salmon in 1980s. At the other hand, Japanese research vessels continue to monitor abundance and distribution of salmon using a research gillnet in high-seas areas of the North Pacific and Bering Sea. Results of high-seas monitoring survey showed that chum salmon CPUE was at a high level in 1990s. Body sizes in off-shore waters decreased since 1970s. Offshore distribution of chum salmon shifted to further north after 1976. Recently, chum salmon distribute mainly in the Bering Sea in summer and fall.

NPAFC nations conduct the BASIS survey in the Bering Sea during 2002–2006 cooperatively. R/V *TINRO* surveys mainly in Russian 200-mile zone and R/V *Kaiyo maru* surveys mainly in high-seas area. We show recent offshore distribution of chum salmon.

Contemporary Status of Chum Salmon in the Bering Sea and Trends in its abundance

Alexander N. STAROVOYTOV

Pacific Scientific Research Fisheries Centre (TINRO-Centre)
4, Shevchenko Alley, Vladivostok, 690650, Russia

TINRO-Centre has carried out surveys of nekton communities of upper epipelagic layer of the Bering Sea and adjacent Pacific waters of Eastern Kamchatka each year starting from 2002 in accordance with the BASIS program. The methods of these surveys, as well as calculations were already reported in full detail (e.g. Volvenko, 2000; Temnykh et al., 2002).

As it is shown by our data, in autumn period, abundance and biomass of immature chum salmon of all age groups (except juveniles) in the western part of the Bering Sea and adjacent waters of the Pacific ocean during last three years has exhibited strong trend in reduction. For instance, from 2002 to 2004 the abundance of chum salmon of 1+ age has dropped from 359.3 (2002)–331.1 (2003) down to 160.7 million individuals. Abundance of chum salmon of 2+ age and 3+ and older has changed in the following way: from 86.3 (2002) to 40.8 (2003) to 32.9 (2004) and from 15.9 (2002) to 6.7 (2003) to 4.2 (2004) million of fish. The decrease of abundance and biomass of immature chum salmon can be trace through change in average CPUEs during respective years. For instance, average CPUE of the chum salmon 1+ age in the entire of western Bering Sea has decreased from 28.9-17.8 down to 8.2 individuals per one hour trawling during 2002–2004 period. The average CPUEs of 2+ and 3+ age groups of chum salmon have dropped as follows: from 5.96 (2002) to 4.39 (2003) to 1.85 (2004) inds./hour and from 2.55 (2002) to 1.04 (2003) to 0.57 (2004) inds./hour, respectively.

Herewith the particularities of the chum salmon age groups distribution have remained unchanged in the western Bering Sea. The chum salmon of 1+ age as well as of 2+ age was numerous in central deep-water region of the Bering Sea (west part of Kommandor and Aleutian Basins). Older chum salmon individuals (3+ and older) were numerous nearby Kommandor islands and coastal area. During autumn 2004, the evident change in distribution of major concentrations of immature chum salmon from northwestern region in southeastern one (to border of Russian EEZ) was observed. It is known (Salo, 1991), that chum salmon during the first and second sea years of life in prefer mostly the Bering Sea and adjacent Pacific waters for summer and fall feeding migrations. Therefore, interannual dynamics of chum salmon abundance and biomass to a certain extent can serve as a descriptor of overall stocks' dynamics. Yet, the overall abundance of chum salmon of 2+ age in the western Bering Sea totaled 11% from the abundance of the younger age group (1+) during both years.

Trends in Abundance and Biological Characteristics of Sockeye Salmon in the North Pacific Rim

Douglas M. EGGERS[1] and James R. IRVINE[2]

[1]Alaska Department of Fish and Game, Division of Commercial Fisheries,
P.O. Box 25526, Juneau, AK 99002, USA
[2]Fisheries and Oceans Canada, Pacific Biological Station,
Nanaimo, British Columbia V9T 6N7, Canada

Trends in abundance, productivity, and average size of sockeye salmon populations were reviewed for available sockeye salmon stocks in British Columbia, Southeast Alaska, Central Alaska, Western Alaska. Sockeye salmon total runs and brood tables were collected for 3 stocks in British Columbia, 4 stocks in Southeast Alaska, 12 stocks in Central Alaska, and 10 stocks in Western Alaska. A meta-analysis of stock productivity using standard stock recruit methods demonstrated substantial spatial and temporal coherence in productivity among stock. Trends in total catch and abundance for a subset of sockeye salmon stocks, where total abundance was available, within the area were highly correlated. This coherence in trends in abundance, catch, and average weight among stocks suggests large-scale environmental processes affect sockeye salmon in the north Pacific Rim.

Chinook Salmon-Trends in Abundance and Biological Characteristics

William R. HEARD[1], Evgeny SHEVLYAKOV[2], and Rick McNICOL[3]

[1]U.S. Department of Commerce, NOAA, NMFS, Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Highway, Juneau, Alaska 99801, USA
[2]Kamchatka Research Institute of Fisheries and Oceanography (KamchatNIRO), 18, Nabarezhnaya Street, Petropavlovsk-Kamchatsky 683000, Russia
[3]Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, British Columbia V9T 6N7, Canada

Chinook salmon, *Oncorhynchus tshawytscha*, the least abundant and largest in size of the five major Pacific salmon species, are widely distributed throughout North Pacific Ocean and adjacent countries. While precise population data including numbers of Chinook salmon spawning in many rivers is poorly known, many populations only have a small portion of their historic abundance levels. Harvest data provide one measure of present trends in abundance for this species. Over the past decade commercial catches have fluctuated between 1 and 2 million fish annually with perhaps an additional 0.4–0.5 million fish caught in subsistence and recreational fisheries. Roughly half of the commercial catch is from the United States, divided about equally between Alaska and Pacific Northwest states, with the remainder caught in descending order by Canada, Russia, and Japan. Recreational and subsistence catches occur mostly in North America. Within the United States there are nine populations of Chinook salmon in the states of Washington, Oregon, Idaho, and California listed as threatened, or endangered under the U.S. Endangered Species Act (ESA). While no formal ESA–type listings occur in other countries certain populations in Canada and Russia are of special concern due to declines in abundance. We examine current escapement levels and harvest data in different regions for a number of populations including some where abundance trends are relatively stable. We also consider the role of hatcheries that, while equivocal in improving the status of some depressed wild stocks, are very important in helping maintain overall abundance trends in some regions. Chinook salmon are characterized by a high degree of life history variability notability the existence of diverse temporal migration patterns of adults returning to natal streams referred to as Spring-, Summer-, Fall-, or Winter-runs, and distinct stream-type and ocean-type forms or races. Stream-types are characterized by extended rearing of juveniles in freshwater (age-1 smolts or older) with adults migrating into natal rivers usually in spring or summer where they often remain for extended periods before spawning. In contrast ocean-types usually have a short freshwater rearing period (age-0 smolts) with adults entering natal rivers mostly in the fall and spawning shortly thereafter. Stream-and ocean-type forms also exhibit different marine migration patterns; the former tending to migrate to more distant open oceanic waters, whereas the latter remain more in waters adjacent to coastal regions. In North America both types may occur in the same river systems in the southern part of their range, while stream-type fish predominate in northern rivers. Apparently only stream-type fish occur in Russian rivers. Long term changes in sizes of Chinook salmon indicate a continuing decrease in average size at maturity for many stocks. A few stocks noted for unusually large Chinook salmon, however, still have individual fish weighing in excess of 40 kg. Anecdotal evidences suggests the species may be expanding its range by establishing new populations into higher latitudes, possibly due to the affects of global warming and climatic changes in the high arctic.

Coho Salmon - Trends in Abundance and Biological Characteristics

Leon SHAUL[1], Laurie WEITKAMP[2], Kent SIMPSON[3], and Joel SAWADA[4]

[1]Alaska Department of Fish and Game, Commercial Fisheries Division,
P.O. Box 240020, Douglas, AK 99824, USA
[2]National Marine Fisheries Service, NW Fisheries Science Center,
2725 Montlake Boulevard E., Seattle, WA 98112, USA
[3]Fisheries and Oceans Canada, Pacific Biological Station,
3190 Hammond Bay Road, Nanaimo, B.C. V9T 6N7, Canada
[4]Fisheries and Oceans Canada, Stock Assessment
417 2nd Ave. West, Prince Rupert, B.C. V8J 1G8, Canada

In the early 1960s, annual Pacific-wide landings of coho salmon reached a stable level averaging over 13 million fish (range 10–17 million) that persisted for over 3 decades, followed by a sharp decline in the mid-1990s to a 1997–2003 annual average catch of fewer than 6 million fish (range 4–7 million). The recent decrease was driven by reduced marine survival in Oregon, Washington and southern British Columbia in the 1990s combined with ongoing severe fishery restrictions in response to deterioration of stocks in those regions. Recent catches were also limited by long-term loss of freshwater habitat capability and by a steep downward trend in hatchery smolt releases. From 1997 to 2003, harvests remained historically high in Southeast Alaska and stable in central Alaska, but were low in western Alaska. Catches along the Russian coast since 1997 have averaged well below historical levels. A steep north-south gradient in marine survival that existed in the eastern Pacific from 1992 to 1999 moderated substantially from 2000 to 2004. The average survival rate of hatchery coho salmon in the Oregon Production Index rebounded three-fold from 0.8% in 1992–1999 to 3.2% in 2000–2004, while average survival of four wild indicator stocks in Southeast Alaska declined slightly from 17% and 15%. Improved marine survival, combined with fishery restrictions, has increased spawning escapement in most southern systems since 2000. The pattern of annual catches in Southeast Alaska and northern British Columbia suggests that abundance and conditions for marine survival were favorable in more northern areas from before 1920 until the early 1950s when the Southeast Alaska catch declined sharply and remained consistently depressed for over two decades. On average, variation in marine survival has accounted for 60% (range 41-87%) of observed variation in adult coho salmon returns to wild indicator systems from Washington to Southeast Alaska while freshwater factors, including spawning escapement, accounted for 40% (range 13-59%) of variation in adult abundance. Average head-on dressed weight of troll-caught coho salmon in Southeast Alaska showed no significant trend from 1969 to 2004, despite ocean regime shifts and a major increase in the abundance of coho and other salmon species returning to the region. However, the seasonal increase in average weight of troll-caught fish from July to September decreased significantly ($p = .02$) from a period of low salmon harvests (1969–1981) to a period of substantially higher harvests (1982–2004).

Ocean Diets of Pacific Salmon as an Indicator of Plankton Production

Vladimir I. KARPENKO[1] and Anatoly F. VOLKOV[2]

[1]Kamchatka Research Institute of Fisheries and Oceanography (KamchatNIRO),
18, Naberezhnaya Street, Petropavlovsk-Kamchatsky 683602, Russia
[2]Pacific Scientific Research Fisheries Centre (TINRO-Centre),
4 Shevchenko Alley, Vladivostok, 690950, Russia

Since the 1950s food habits of Pacific salmon have been studied from samples representing multiple salmon life history stages, and collected from their principal feeding areas within Russia's 200-mile economic zone. Data were gathered by various fishing gear designed to catch juvenile and adult salmon. Using a comparative analysis, we examined food habits, and plankton and nekton data to illustrate salmon feeding conditions in this area since the middle part of the last century. Our results showed that in the 1950s the principal food of plankton-eating salmon (pink, sockeye, and chum salmon) in offshore waters consisted of energetically valued hyperiids and euphausiids. In this area, the basis of juvenile salmon diets consisted of copepods, which also contribute substantially to the food of returning adult salmon. The diet was stable until the 1980s, when the contribution of pteropods and juvenile fish observed in salmon diets were more significant. Since that time, low energy organisms, including arrow worms, appendicularia, and salps, have appeared in the diets of salmon in relatively high numbers, particularly in the Bering Sea. Among plankton-consuming salmon, chum salmon demonstrate the most variable composition of the diet. Coho and chinook salmon consume mostly fishes. However, in some years and regions their diet included a higher proportion of crustaceans. The daily feeding rhythm of juveniles and immature salmon of all species was similar. Changes in the diet were associated with changes in plankton and nekton abundance. Regional features and salmon abundance also affected salmon diet composition. Aspects of salmon diets have affected the size and average age of maturation toward the end of the last century, which has influenced the productivity of salmon stocks and populations.

Regional Diversity of Juvenile Pink Salmon Diet in Autumn

Svetlana V. NAYDENKO, Alexander Ya. EFIMKIN, and A.E. LAZHENTSEV

Pacific Scientific Research Fisheries Centre (TINRO-Centre),
4, Shevchenko Alley, Vladivostok, 690600, Russia

Regional variability in the diet of juvenile pink salmon has been studied in the Bering, Okhotsk and Japan seas during autumn. Young pink salmon preyed mainly on amphipods, pteropods and euphausiids, as well as on copepods in the coastal areas. We have found that young pink salmon consumed only highly abundant planktonic species of these major groups of forage organisms. Juvenile pink salmon preyed primarily on amphipods (*Themisto pacifica*) in the southern Aleutian Basin of the Bering Sea, and mainly on pteropods (*Limacina helicina*) and amphipods in the Commander Basin. Young fish preyed intensively on amphipods (*T. pacifica* and *Primno macropa*) and euphausiids (*Thysanoessa longipes*) in the southern Okhotsk Sea. Amphipods (*T. pacifica, P. macropa*) dominated in young pink salmon diet in the deep regions, while copepods (mainly *N. plumchrus*) – in the coastal areas of the Japan Sea. Other highly abundant planktonic species were of minor importance as forage organisms for juvenile pink salmon.

Regional variability in the diet of young pink salmon is determined by the composition and abundance of available major planktonic groups and species.

Spatial and Temporal Limitation of Salmon Distribution

Tomonori AZUMAYA[1], Toru NAGASAWA[1], Olga S. TEMNYKH[2], and Gennady V. KHEN[2]

[1]Hokkaido National Fisheries Research Institute, Fisheries Research Agency
116 Katsurakoi, Kushiro, Hokkaido 085-0802, Japan
[2]Pacific Scientific Research Fisheries Centre (TINRO-Centre),
4, Shevchenko Alley, Vladivostok 690950, Russia

A thermal limitation of the Pacific salmon by sea surface temperature was known. However, sea surface temperature, where salmon distributed in summer, did not always consist with the temperature in winter. Characteristic of water mass in the North Pacific was examined using data by *Wakatake maru*. There were the Subarctic Front (the 4C isotherm at 100m depth) and the Subarctic Boundary (34 at 0 m), which were defined by Favorite et al. (1976), and Transition Domain at the North Pacific. Sockeye salmon was mainly distributed in the northern part of the Subarctic Front, chum salmon distributed from the Subarctic Boundary to the Bering Sea, and coho salmon distributed from the Subarctic Boundary to the Subarctic Front. This result indicates that the difference of distributions by species of salmon is depended on the characteristics of water mass. It is suggests that the limitation of salmon is not only sea surface temperature but also another factors.

Biological Characteristics of Pacific Salmon as Indicators of Ocean Conditions

John H. HELLE[1], Douglas M. EGGERS[2], Oleg F. GRITSENKO[3], Yukimasa ISHIDA[4], and Ellen MARTINSON[1]

[1]NMFS, Alaska Fisheries Science Center, Auke Bay Laboratory,
11305 Glacier Highway, Juneau, Alaska 99801, USA
[2]Alaska Department of Fish and Game,
333 Raspberry Road, Anchorage, Alaska 99518, USA
[3]Russian Federal Research Institute of Fisheries & Oceanography(VNIRO)
17, V. Krasnoselskaya, Moscow 107140, Russia
[4]National Research Institute of Fisheries Science, Fisheries Research Agency,
2-12-4 Fukuura, Kanazawa-ku, Yokohama, Kanagawa, 236-8648 Japan

After the Ocean Regime Change of 1976–77 the abundance of Pacific salmon in North America and Asia increased significantly. However, salmon that can change their age at maturity became older and all species of salmon in general became smaller from the early 1970's through the early 1990's. These changes in biological characters that occurred in North American and Asian salmon indicated that the carrying capacity for salmon in the Pacific Ocean may be limited. Changes in size and age may be influenced by density dependence under certain conditions. Nevertheless, changes in biological characteristics of salmon may be indicators of ocean conditions. During another period of high abundance of salmon, early 1900's through mid-1940's, salmon may have been larger than during the early 1970's to the present time. Could this change in size of salmon indicate that there has been a decline in ocean productivity from the early 1900's to the present time? In this paper we will present evidence that body size, growth, age, maturity, and lipid content of Pacific salmon may be indicators of changing ocean conditions.

Density-Dependence in Pacific Salmon Populations and its Assessment with Geostatistics

Vladimir V. SVIRIDOV and Olga S. TEMNYKH

Pacific Scientific Research Fisheries Centre (TINRO-Centre),
4, Shevchenko Alley, Vladivostok, 690950, Russia

Based on vast set of TINRO-Centre BASIS-related and archival epipelagic trawl surveys data we analysed density-dependence in Pacific salmon populations by means of geostatistical methods. Both CPUEs and biological parameters (including scale pattern analysis data) are analysed in relation to interannual dynamics of overall species abundance. The majority of studies on density-dependence in Pacific salmon populations are restricted to finding correlations between overall species abundance and its biological characteristics. However, such monitoring approach does not allow predicting the emergence of density–dependence in population, since it deals only with post-effects of density–dependence. In order to achieve this goal we have to apply fine-resolution analysis, of which a geostatistical approach can be a good choice.

The analysis of our data have showed that spatial statistics for CPUEs and biological parameters (including scale pattern analysis data) can be used as indicators of degree of density-dependence in Pacific salmon populations during their marine life period at different life stages (juvenile, immatures and matures). According to our data the increased overall Pacific salmon species abundance results in better define and more gradient spatial allocation of CPUEs, as well as in a higher heterogeneity of species biological parameters throughout the area of its presence. During the periods of lower abundance the Pacific salmon species seem to have move towards "simplified" spatial structure and lower variability of biological parameters. These observations seem to reflect adaptive strategy of Pacific salmon species, which is aimed at the decrease of density-dependence and avoidance of excessive competition through the transformation of species' spatial and biological structure.

Summer Growth of Post-Smolt Coho Salmon off the Oregon/Washington Coast, as Assessed by Plasma Insulin-Like Growth Factor I Level, Varies Inter-Annually and is Related to Subsequent Adult Survival

Brian R BECKMAN[1], Joseph FISHER[2], Cheryl MORGAN[3], and Susan HINTON[1]

[1]Northwest Fisheries Science Center, NOAA Fisheries, Seattle, WA, USA
[2]College of Ocean and Atmospheric Science, Oregon State University, Corvallis, OR, USA
[3]CIMRS, Oregon State University, Newport, OR, USA

Insulin-like growth factor-I (IGF-I) is a peptide hormone that directly stimulates cell division and growth, suggesting IGF-I might provide a reliable index of growth. We have conducted several experiments examining the relation of growth of individually tagged coho salmon to plasma levels of IGF-I. Overall, a significant and biologically relevant linear relation between individual growth and IGF-I exists. Food supply (nutrition), growth, and plasma IGF-I levels have been clearly linked in these experiments. In addition, growth – IGF-I relations are similar for fish maintained under differing temperature regimes, suggesting that IGF-I may be used as a growth index in environmentally relevant conditions.

The ecological significance of plasma IGF-I levels has been explored in a series of research cruises off the Oregon-Washington coast. Sampling has been conducted over a two week period in June for the years 2000 through 2004. Catch has ranged from 100 to 450 post-smolt coho salmon per cruise, with over 1200 fish sampled in total. Plasma IGF-I levels were significantly and positively correlated with scale increment width and growth of coded wire tagged (CWT) smolts. Moreover, these relations were consistent over different sampling years.

Significant differences in mean June IGF-I level have been found between years, suggesting that ocean growth differs between years. A positive relation was found between mean June IGF-I level and survival of adult Oregon Production Index coho in the following year. This suggests that inter-annual variation in ocean conditions results in altered growth rate of juvenile coho salmon and that these growth differences affect subsequent adult survival. Thus plasma IGF-I levels measured in post-smolt coho salmon may predict adult survival the following year. In addition, this suggests that plasma IGF-I levels in coho salmon might be used to assess the condition of oceanic waters as these relates to salmon performance.

Further analysis suggests that plasma IGF-I levels may also be used to assess intra-annual variation in salmon food supply and ocean conditions. Consistent regional differences in June IGF-I levels have been found within the Oregon – Washington coastal area. Consistently higher IGF-I levels found in coho salmon from the outer shelf off northern Washington. Thus assessment of plasma IGF-I levels in juvenile coho salmon may link salmon growth to regional scale variation in ocean conditions and salmon food supply.

This work has been supported by funds from the Bonneville Power Administration and NOAA Fisheries.

A Shift of Pink Salmon Dominance in Hokkaido from Even- to Odd-Numbered Years in Relation to Coastal Environments during the Early Life

Mitsuhiro NAGATA[1], Daisei ANDO[1], Makoto FUJIWARA[1], Yasuyuki MIYAKOSHI[1], and Hiroki ASAMI[2]

[1]Hokkaido Fish Hatchery, Kitahashiwagi-3, Eniwa, 061-1433, Hokkaido Japan
[2]Hokkaido Wakkanai Fisheries Experimental Station,
Suehiro 4-5-15, Wakkanai, 097-0001, Hokkaido, Japan

Pink salmon occur mainly in eastern Hokkaido, especially in the Okhotsk Sea. Numbers of pink salmon were low from the 1970s to the 1980s with two-year cycle dominance in odd-numbered years, but in the early 1990s the population size increased sharply, especially in even-year lines, exceeding 10 million. Subsequently, a shift from odd- to even-year dominance occurred. Although dominance by the even-year line was maintained from 1993 to 2002, a shift back to odd-numbered year returns subsequently occurred. Fortunately, we have monitored the distribution of juvenile pink salmon and the ocean environment in the Abashiri coastal waters of the Okhotsk Sea since 2002. Although the Okhotsk Sea usually is covered with sea ice during the winter, the maximum area, arrival and disappearance of sea ice varies year by year. Sea ice disappeared in 2002 and 2004 in early March, one month earlier than in 2003 that had the latest timing in the past 10 years. In addition, movement of the front of the Soya Warm Current in 2003 to the Abashiri coast was delayed. Consequently, SST in May 2003 ranged from 5.3- to 6.8 C, much colder than in warm years (8.2–9.7 C in 2002, 5.5–12.0 C in 2004). Zooplankton abundance in the coastal waters in May was higher in 2002 and 2004 than in 2003. Pink fry were widely distributed along the coast in May 2002 and 2004, while fry in 2003 were restricted to the littoral zone and densely-distributed. The final number of fry captured along the coast from May to July 2003 was 5,000, much lower than the numbers caught the other two years (18,000–20,000). More interestingly, abundance of adults in 2004 from pink fry that experienced the cool 2003 year was much lower than in 2003 with the warm year 2002, resulting in the shift of dominance. These results suggest that shifting between dominance lines might result from cool ocean conditions that cause long residence of pink fry with dense distributions in the littoral zone.

Open Ocean Distributions of Asian and North American Salmon, Interannual Changes, and Oceanographic Conditions

Katherine W. MYERS[1], Natalia V. KLOVATCH[2], Oleg F. GRITSENKO[2], Shigehiko URAWA[3], and Thomas C. ROYER[4]

[1]School of Aquatic & Fishery Sciences, University of Washington, Seattle, WA, USA
[2]Russian Federal Research Institute of Fisheires & Oceanography (VNIRO), Moscow, Russia
[3]National Salmon Resources Center, Sapporo, Japan
[4]Center for Coastal Physical Oceanography, Old Dominion University, Norfolk, VA, USA

Knowledge of the open ocean distributions of Asian and North American salmon and oceanographic conditions in the open ocean regions that they occupy is vital to understanding the status of Pacific salmon and their role in North Pacific marine ecosystems. Pacific salmon species and populations, as well as different age and maturity groups, have evolved to take advantage of different ecological niches in the open ocean. Climate-driven changes in oceanographic conditions in open ocean feeding areas and along migratory routes of Asian and North American salmon can result in spatio-temporal differences in their distribution and migration patterns. This paper reviews information (including some previously unpublished data) on open ocean distribution, migration routes, migration timing, and resident (feeding) areas of Asian and North American salmon, and considers what these data can tell us about interannual changes in environmental conditions on small to mid-scales.

DNA Markers Track the Distribution and Migration of Sockeye Salmon in the Bering Sea

James E. SEEB[1], Richard L. WILMOT[2], Natalia VARNAVSKAYA[3], Charles M. GUTHRIE[2], and Christopher HABICHT[1]

[1]Gene Conservation Laboratory, Alaska Department of Fish and Game,
333 Raspberry Road, Anchorage, Alaska 99518, USA
[2]Auke Bay Laboratory, NOAA Fisheries,
11305 Glacier Highway, Juneau, Alaska 99801, USA
[3]Kamchatka Fishery and Oceanography Research Institute (KamchatNIRO),
18, Naberezhnaya Street, Petropavlovsk-Kamchatsky 683000, Russia

Fluctuations of major populations of sockeye salmon in both Western Alaska and Asia prompt interest in marine migratory patterns as well as the composition of harvests. We describe cooperative efforts to develop and apply DNA baselines to tackle these critical questions. We developed DNA baselines from collections of approximately 96 sockeye salmon each from 100 spawning locations draining into the Bering Sea and southeastern Sea of Okhotsk. Data from the same set of markers was collected from 3,300 sockeye salmon captured by the RV *TINRO*, *Kaiyo maru*, FV *Great Pacific* and FV *Sea Storm* during Bering Sea cruises in the summers of 2002–2004. Allocation of these mixture samples to stock of origin enabled a better understanding of the relative distribution of Alaskan and Russian stocks during these months. Stock distributions in August showed the highest proportions of western-originating stocks on the western side of the Bering Sea and the highest proportions of eastern-originating stocks on the eastern side. When all samples were taken in combination, the Bristol Bay stocks were the most abundant which is a direct reflection of the relative production of Russian and Alaskan stocks. Although Russian sockeye salmon stocks contribute less than half of the stock mixtures in every sample except the most southwesterly sample, their presence in samples from the central Bering Sea basin and Aleutian Islands indicates that they migrate eastward at least half way across the Bering Sea. Alaskan sockeye appear to migrate throughout the Bering Sea and predominate on the northeastern Continental Shelf including the western side near Russia. Stock distributions divided into ages one and two-plus ocean fish showed generally higher proportions of Russian stocks in the two-plus ocean mixtures than in the one ocean mixtures. This pattern may indicate that larger proportions of two-plus ocean fish from Alaska migrate south into the North Pacific relative to stocks originating from Russia or that Russian one ocean fish are in the North Pacific and migrate north as two-plus ocean age. Of the immature fish captured on the northeastern continental shelf, 90% were one ocean fish, so stock compositions could only be calculated on this age group (these were again almost exclusively Alaska-origin stocks). This pattern may indicate that one-ocean fish favor different environmental variables than two-plus ocean fish and that Russian one ocean fish generally do not utilize the northeastern continental shelf.

Spatio-Temporal Variation in Vertical Distributions of Pacific Salmon

Robert V. WALKER[1], Vladimir V. SVIRIDOV[2], Shigehiko URAWA[3], and Tomonori AZUMAYA[4]

[1]Fisheries Research Institute, School of Aquatic and Fishery Sciences,
University of Washington, Box 355020, Seattle, WA 98195-5020, USA
[2]Pacific Scientific Research Fisheries Centre (TINRO-Centre),
4, Shevchenko Alley, Vladivostok 690950, Russia
[3]National Salmon Resources Center,
2-2 Nakanoshima, Toyohira-ku, Sapporo 062-0922,
[4]Hokkaido National Fisheries Research Institute, Fisheries Research Agency,
116 Katsurakoi, Kushiro, Hokkaido 085-0802, Japan

The vertical distributions of Pacific salmon vary by species and with life history stage, location, season, and time of day. We will review research reported by scientists of Japan, Canada, Russia, and the United States using nets, by-catch inferences, ultrasonic tags, and archival data storage tags. We will also analyze new data from BASIS research cruises and archival tags. An understanding of vertical use of marine habitat by salmon is useful for directed fisheries and research, to avoid bycatch in other fisheries, and to evaluate potential effects of oceanographic changes.

Spatial Scales of Ocean Environmental Effects on Northeast Pacific Salmon

Franz J. MUETER[1], Brian J. PYPER[2], Randall M. PETERMAN[3], and Peter W. LAWSON[4]

[1]Sigma Plus Consulting,
697 Fordham Drive, Fairbanks, AK 99709, USA
[2]S.P. Cramer & Associates, Inc.,
600 NW Fariss Road, Gresham, OR 97030, USA
[3]School of Resource and Environmental Management, Simon Fraser University,
8888 University Drive, Burnaby, B.C. V5A 1S6, Canada
[4]National Marine Fisheries Service, Northwest Fisheries Science Center,
2032 SE OSU Drive, Newport OR 97365, USA

Much attention has been given to understanding how oceanographic conditions affect productivity of Pacific salmon. Quantifying spatial scales of coherence among salmon productivity and marine environmental conditions provides valuable insight into the location and timing of key processes that determine survival. We synthesize recent correlation and modeling analyses that emphasize the importance of regional-scale process in determining marine survival rates and recruitment of salmon. Comprehensive studies of pink, chum, and sockeye salmon from throughout the Northeast Pacific showed that survival rates of these stocks were positively correlated across "regional" spatial scales of roughly 500–800 km. This covariation, or evidence of shared environmental influences on survival rates, appeared to be largely due to processes operating during early marine life. Positive correlations were also found between survival rates and regional-scale measures of coastal ocean conditions such as sea-surface temperatures, further supporting the hypothesis that the early marine period is critical to the survival of juvenile salmon. Models developed for coho salmon revealed similar associations between salmon productivity and coastal conditions. These studies suggest that regional-scale measures of ocean conditions may be much better indicators of marine survival rates than broad-scale indices of climatic or oceanographic conditions.

Results from Otolith-Marking Experiments Designed to Improve Stocking Strategies Based on the Spatial Distribution of Juvenile Chum Salmon in Relation to Coastal Seawater Temperatures

Mitsuhiro NAGATA[1], Yasuyuki MIYAKOSHI[1], Daisei ANDO[1], and Hiroki ASAMI[2]

[1]Hokkaido Fish Hatchery,
Kitahashiwagi-3, Eniwa, 061-1433, Hokkaido Japan
[2]Hokkaido Wakkanai Fisheries Experimental Station,
Suehiro 4-5-15, Wakkanai, 097-0001, Hokkaido, Japan

In 2002 we initiated a project designed to determine the optimal timing to stock juvenile hatchery chum salmon in rivers along the Abashiri coast of the Okhotsk Sea. Some of the 34 million juveniles stocked in the Abashiri River annually were otolith-marked in 200 ppm alizarin complexone (ALC) solution with different day degrees before hatching. 1.4–2.0 million ALC-marked juveniles were stocked annually in mid-May to investigate inter-annual differences. An additional 1.9 million ALC-marked juveniles were stocked in late April 2003 and 0.7 million late May 2004. Juveniles stocked in mid May 2002 and 2004 were captured by a surface trawl net 1 km off the coast in late May. In contrast, juveniles stocked in mid May 2003 were not observed along the coast until early June, along with those stocked earlier in late April of the same year, but they were captured in littoral areas in mid/late May using beach seines. In addition, specific growth rates (SGR, 0.0051) for the initial three weeks for marked juveniles stocked in late April 2003 subsequently captured 1 km off the coast was lower than SGR (0.0062–0.0089) for juveniles stocked in mid-May. Juvenile chum rapidly disappeared from near the coast after late June when SST > 13 C, e.g. marked juveniles stocked in late May 2004 remained along the coast for only three weeks. This migration coincided with changes in zooplankton abundance and salmon diet. Relatively high juvenile abundances were found in coastal waters from May to June in 2002 and 2004 SST ranged from 8 to 13 C because the Soya Warm Current arrived early; this water temperature occurred only in June 2003 along the coast. In contrast, SSTs from 7 to 12 C were found in the littoral zone in May 2003. Therefore, offshore movement of juvenile chum salmon after downstream migration appears to depend on seawater temperature rather than fish size, especially when water mass less than 8 C restricts their movement offshore. We should avoid stocking juvenile chum salmon when coastal water temperatures are < 7 C or > 12 C, which may affect growth and survival in their early life.

Long-Term Changes of Some Biological Characteristics and Run Timing of Chum Salmon (*Oncorhynchus keta*) in Namdae-Cheon, Eastern Area of Korea

Young Hee HUR, Chae Sung LEE, Sukyng KANG, Ki Baik SUNG, and Chul Ho LEE

Salmon Research Team, East Sea Fisheries Research Institute, NFRDI
424-1, Songhyun-ri, Sonyang-myeon, Yangyang-gun, Gangwon-do 215-821, Republic of Korea

Artificial releases for the resources enhancement of chum salmon fingerings in the Korean Waters has long history, however, since 1985 four rivers including Namdae-Cheon (38 06N 128 39E) located in Gangwon-do, northern part of South Korea, were exploited the catch of return chum salmon for spawning have been increased. The migration route of chum salmon released in Korean Waters are not clearly known though, they leave Korean coastal area before summer comes, move to North Pacific and spend a few years there and then return to their home stream for spawning (Lee et al, 2002).

The purpose of this paper is to show the some changes of biological characteristics and those of run timing of chum salmon to Namdae-cheon, which is composed over 60% of returning chum salmon to rivers for spawning in the Korean Waters, from 1985 to 2004 and some discussions on the possible mechanism to cause these changes in relation to environmental factors such as Korean coastal water temperature and precipitation in the river and biological factors.

Daily and yearly length composition by sex for 1985 to 1990 and from 2001 to 2004 and age compositions and growth rate from 1985 to 1998 and from 2002 to 2004 of return chum salmon were analyzed. Daily catch statistics of return chum salmon for spawning by sex were analyzed to understand the run timing of chum salmon into river from 1985 to 2003. For the environmental factors, coastal water temperature near the mouth of Namdae-cheon from 1984 to 2003 in October to November (National Fisheries Research and Development Institute, 1985–2003) and precipitation data in October to November for 1993–2003 (Yangyang International Airport, 2004) were used.

The length compositions for female were 3–7 cm larger than those of male in the late 1980s, however, similar between sexes in 2000s. The length compositions have become larger in 2000s compared to 1980s, especially in male.

Daily length compositions in both sexes in 2004 showed larger chum salmon have returned earlier and the smaller fish returned later, which suggest larger fish matured earlier in the same return season. And also except in 1985–1987, length of return chum salmon and date showed negative relationship in the late 1980s and 2000s same as 2004.

Age compositions of return chum salmon for spawning to Namdae-cheon are from 2 to 5 years old with the main age groups are 3 and 4. However, for female in late 1980s the proportions of age 3 and 4 groups were about the same, however, in 1990s and 2000s the age 4 became dominant. Mean fork length of female for age 3 has tendency to be smaller from 1985 to 1998. However, for male showed increasing trend since 1990. In 1980s the length of female was larger than male, though, in late 1990s there are not different between sexes for both age 3 and 4 groups.

The proportion of female for the returned adults in Namdae-cheon ranged 34–43% for the late 1980s and increased to 45–55% in 1990s and 2000s except 2001. For the group by returning season, the proportion of female was lower in earlier returning groups and it has become increased in late returning group.

The timing to return home stream of matured chum salmon for spawning have become earlier as years go. Main returning season of chum salmon were in mid-November in 1980s, in early November in 1990s and in late October in 2000s.

Run timing did not show significantly related to water temperature in the coastal area and river. However extremely cold year as 2002 delayed the return season and advanced warm year as 1990. Precipitations of the river and daily relative returning chum salmon have positive relation at 5% significant level.

The Impacts of Global Warming on Abundance and Distribution of Pacific Salmon of Asian Origin

Masahide KAERIYAMA[1], Akihiko YATSU[2], Masayuki NOTO[2], Hyunju SEO[3], Sukyung KANG[4], Suam KIM[3], and Seiichi SAITO[1]

[1]Graduate School of Fisheries Science, Hokkaido University, 3-1-1 Minato-cho, Hakodate, Hokkaido 041-8611, Japan
[2]National Research Institute of Fisheries Science, Fisheries Research Agency, 2-12-4 Fukuura, Kanazawa-ku, Yokohama, Kanagawa 236-8648, Japan
[3]Department of Marine Biology, Pukyong National University, 599-1 Daeyong 3-dong, Nam-gu, Busan 608-737, Republic of Korea
[4]National Fisheries Research and Development Institute, 408-1 Shirang-Ri, Gijang-Eup, Busan 619-902, Republic of Korea

Global warming scenarios caused by increase in the greenhouse gas concentrations should influence the future health of Pacific salmon ecosystems. The life history of salmon offers a useful framework for quantifying climate-related risk factors around the North Pacific Rim. In this paper, we evaluate the impacts of global warming on Pacific salmon of Asian origin. Asian chum salmon originated in Japan and Korea spend the first summer in the Okhotsk Sea after early marine life in their coastal waters, then move to the Western Subarctic Gyre for the first winter at sea. Thereafter, they migrate between summer feeding grounds in the Bering Sea and wintering grounds in the Alaskan Gyre for a period of usually up to four years, and finally return to their natal rivers to spawn. Annual somatic growth by age of adult chum salmon retuning to the Ishikari River was estimated using the back-calculation method from scale. In last decades, abundance of Japanese chum salmon population reached a record level despite low abundance of Korean chum salmon population. Marine survival of Hokkaido chum salmon populations was significantly related with body size at release, but neither by Aleutian low pressure index (ALPI) nor sea-surface temperature (SST) around coastal Hokkaido in spring, although there is some correlation between survival rate and the SST in the Okhotsk Sea. These indicate that their survival was more affected by body size of juvenile and coastal conditions in the early marine life period than oceanic environment. Their somatic growth in the first year has increased since the late 1980s, despite somatic-growth reduction in third and forth years based on the population density-dependent effect. These results may suggest the linkages of climate change in the Okhotsk Sea relating to the global warming, such as increase in the sea surface temperature and reduction in the ice cover area in the 1990s.

Patterns in Salmon Production in the Northeast Pacific: Inverse Production Regimes Revisited

Peter W. LAWSON[1], William PETERSON, Robert FRANCIS, Steven HARE, Nate MANTUA, and Laurie A. WEITKAMP[1]

[1]U.S. National Marine Fisheries Service,
Northwest Fisheries Science Center, Newport Research Station,
2032 SE O.S.U. Drive, Newport, Oregon, 97365, USA

Until recently it seemed clear that the North Pacific alternated between persistent warm and cold regimes at a frequency of 20–30 years. A warm regime dominated from 1927–1946, a cool regime from 1947–1976, and a warm regime from 1977–1998. Salmon abundance in Alaska and the Pacific Northwest during these regimes varied inversely, with higher abundance in Alaska during warm regimes and higher abundance in the Pacific Northwest during the cold regime. This pattern was closely related to the Pacific Decadal Oscillation (PDO). For four years starting in 1999 a different pattern emerged, with high salmon abundances throughout the northeast Pacific and a different climate signal dubbed the "Victoria Pattern." System behavior shifted again in 2003, but the implications of this shift are not yet clear. Changes in zooplankton populations also reflect these patterns. We reanalyze climate data to separate a global warming signal from shorter term PDO and ENSO variability and attempt to show that salmon are responding to regional variability in marine conditions as indexed by climate. We speculate that recent departures from the patterns exhibited during most of the 1900s can be attributed to systemic changes associated with global warming.

Bioenergetic Responses by Pacific Salmon to Climate and Ecosystem Variation

David A. BEAUCHAMP

U.S. Geological Survey, University of Washington, School of Aquatic and Fisheries Sciences,
Box 355020, Seattle, Washington 98105-5020, USA

Salmon growth can respond to changes in temperature, food availability, food quality, and activity. Climatic variability can affect one or more of these factors, because different climate regimes are associated with different temporal-spatial patterns of temperature, salinity, and other oceanographic features which can alter ocean distribution patterns of salmon and cause shifts in assemblages of other organisms. Consequently, climate variability can simultaneously change the availability or productivity of exploitable prey, and the intensity of competition or predation experienced by salmon at various stages or ocean life. Variability across multiple factors can potentially confound understanding and prediction of salmon growth or survival. Bioenergetics models can account for changing thermal and food conditions explicitly, and are valuable analytical tools for isolating and evaluating the relative contribution of different factors (e.g., temperature, food availability, food quality) to the consumption and growth of salmon during different life stages. Model simulations, coupled with data on growth trajectories, diet composition, and thermal experience, provide estimates of: 1) consumption rates on each prey (measures of both the importance of various prey to the energy budget of salmon, and the predation impact of salmon on prey species); 2) feeding as a proportion of the theoretical maximum consumption rate (a measure of relative food availability), and growth efficiency (g growth/g food consumed: a measure of how hard the consumer had to work to achieve the observed growth rate). Conversely, data on spatial-temporal heterogeneity in temperature, prey availability, and prey quality could be synthesized into maps reflecting the distribution of high or low growth regions associated with the distribution, growth performance, and survival of salmon during specific life stages. Examples of bioenergetic modeling applications will be illustrated for juvenile pink salmon in the Gulf of Alaska which demonstrated significant interannual variability in stage-specific distribution, diet, growth, consumption, and associated size-selective smolt-adult survival. Current bioenergetics models for salmonids provide valuable diagnostic and analytical tools. However, as modeling applications become more predictive and demanding, modifications and improvements will be required to address important topics like behavior, variable activity costs, seasonal and ontogenetic energy allocation, and foraging models.

Progress on a Range-Wide Data Inventory for Pacific Salmon: A Synthesis of Multi-Party Monitoring Activities on Sockeye Salmon (*Oncorhynchus nerka*) Stocks and Populations in Bristol Bay, Alaska and Fraser River, British Columbia

Peter RAND[1], Cathy KELLON[1], Xanthippe AUGEROT[1], Mart GROSS[2], Jim IRVINE[3], Chris JORDAN[4], Masahide KAERIYAMA[5], Peter MOYLE[6], Jeff RODGERS[7], Daniel SCHINDLER[8], and Sergey SINYAKOV[9]

[1]State of the Salmon, OR, USA
[2]University of Toronto, ON, Canada
[3]Fisheries and Oceans Canada, Pacific Biological Station, BC, Canada
[4]NOAA Fisheries, WA, USA
[5]Hokkaido University, Hokkaido, Japan
[6]University of California, Davis CA, USA
[7]ODFW, OR, USA
[8]University of Washington, WA, USA
[9]KamchatNIRO, Kamchatka

The State of the Salmon Consortium has recently launched an effort to summarize monitoring of anadromous salmon (*Oncorhynchus spp.*) across the North Pacific. This effort has three main objectives focusing on providing better information to meet the needs for salmon conservation: (1) assessing salmon viability in a consistent manner across the entire natural range for the species, (2) ranking data quality with an eye toward reform and identifying key data gaps and providing a cost-effective means to fill them, and (3) helping to foster freer dialogue and data sharing among the diverse entities involved in salmon management. Our effort will provide a foundation from which we can gauge biological responses to a dynamic ocean environment, a central theme of this conference.

Here we report on long term monitoring efforts focused on sockeye salmon (*Oncorhynchus nerka*) in two large river basins in North America (Fraser River in British Columbia and Bristol Bay in Alaska) as a general proof of concept of our survey approach, and as an exercise to compare and contrast on-going efforts at monitoring stock and population dynamics for an important species of great commercial value. Our survey design includes a classification key that allows a great variety of monitoring activities to be binned into discrete classes based on the level of biological understanding of the stocks and populations being monitored. We further identify which of four key population parameters (spatial distribution, diversity, abundance and productivity) are measured, and assess the quality of those data. The survey, along with background work lead by the IUCN Salmonid Specialist Group, also compares stock boundaries established by fisheries management entities with population boundaries based primarily on genetic criteria. The degree that individual populations are aggregated into managed stock units should provide an objective measure of how existing monitoring activities are tracking real changes in biodiversity, especially in the context of perturbations from natural and anthropogenic sources. In addition to reporting these preliminary results, we include a time line for completing the survey for the entire range of the species.

Zooplankton Variability Affected by Physical Environments during Early Ocean Life of Juvenile Chum Salmon in the Coastal Waters of Eastern Hokkaido, Okhotsk Sea

Hiroki ASAMI[1], Hiroshi SHIMADA[2], Mayumi SAWADA[2], Hajimu SATO[3], Yasuyuki MIYAKOSHI[4], Daisei ANDO[4], Makoto FUJIWARA[4], and Mitsuhiro NAGATA[4]

[1]Hokkaido Wakkanai Fisheries Experimental Station,
Suehiro 4-5-15, Wakkanai, Hokkaido 097-0001, Japan
[2]Hokkaido Central Fisheries Experimental Station,
Yoichi, Hokkaido 046-8555, Japan
[3]Hokkaido Abashiri Fisheries Experimental Station,
Masuura, Abashiri, Hokkaido 099-3119, Japan
[4]Hokkaido Fish Hatchery,
Kitagashiwagi-3, Eniwa, Hokkaido 061-1433, Japan

Ocean conditions during the period of early ocean residence of chum salmon may be important in determining the early marine survival. Zooplankton variability might be one of the most important factors affecting on the early survival of juvenile chum salmon, as the main preys of juvenile are zooplankton. The coasts in the Okhotsk Sea are covered with sea ice until early spring and occupied by the coastal waters mixed with the ice melting and terrestrial water in middle spring. Soya Warm Current (SWC) also becomes to prevail in late spring. Therefore chum juveniles in these coastal waters experience extreme changes in the ocean environment. We studied the relationships between zooplankton variability and physical conditions during the early life of juvenile chum salmon through 2002 to 2004 in the coasts of Abashiri Bay, eastern Hokkaido. The surveys were conducted once in ten days throughout April to July, establishing twelve stations (10–40 m depths) in the Bay. Zooplankton were collected by vertical haul with Norpac net (0.45m in mouth diameter, 0.33 mm mesh size) from the near bottom to the surface at each station. Dominant zoopolankters were composed of the taxa of hydrozoans, cladocerans, copepods, euphausiids and appendicularians in three years. Copepods were the most dominant taxa. Coastal-cold water copepods, *Pseudocalanus newmani*, were always predominant in three years. In addition to this species, oceanic-cold water copepods (*Neocalanus* spp.) and coastal-cold water species (*Eurytemora herdmani*, *Acartia hudsonica*, *Tortanus discaudatus*) were more abundant in 2004. Although these species were less abundant than *Pseudocalanus newmani* in copepod community, these copepods were dominant in the stomach contents of chum juveniles in 2004. Physical environments were very different among three years. SWC developed strongly in 2002 and the sea ice stayed more longer in 2003. Coastal waters in 2004 changed from low temperature and salinity to high temperature and salinity gradually. Both sea ice and SWC are thought to be key factors affecting on zooplankton variability in the coasts of Okhotsk Sea.

Translating Climate Variability into Salmon Production: Potential Mechanisms for Chinook and Coho Salmon in Southeastern Alaska, U.S.A.

Laurie A. WEITKAMP[1] and Joseph A. ORSI[2]

[1]U.S. National Marine Fisheries Service, Northwest Fisheries Science Center, Newport Research Station, 2032 SE O.S.U. Drive, Newport, Oregon, 97365, USA
[2]U.S. National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Highway, Juneau, Alaska, 99801, USA

Climate variability influences Pacific salmon productivity through a combination of bottom up (resulting in rapid growth) and top down (predation) processes, which vary in both time and space. In addition, due to species-specific differences in life history traits such as size at ocean entry, diet, or habitat use, the mechanisms through which climate variability affects salmon productivity may differ between salmon species, even for individuals inhabiting the same area. Accordingly, climate conditions that are favorable for one salmon species may be less favorable for other species, because of the particular mechanisms involved. The possibility of contrasting mechanisms controlling salmon productivity was investigated using juvenile Chinook and coho salmon from southeastern Alaska. In this region, both species enter marine environments at approximately the same size and time and share considerable diet overlap, yet their marine survival rates are quite different. Marine survival rates for coho salmon have been extremely high in recent years compared to southern populations, while survival rates for Chinook salmon have been unremarkable.

Examination of distributions, diets, and characteristics (e.g., body size, growth rates, lipid content) of these two species during the first summer in the ocean indicated possible mechanisms whereby the common climatic conditions resulted in high productivity of coho salmon and lower productivity of Chinook salmon. For example, coho salmon were consistently larger, had higher growth rates, and higher stomach fullness than Chinook salmon, suggesting that juvenile coho salmon receive greater benefit from bottom up processes than do juvenile Chinook salmon. The most apparent difference between the two species, however, was their associated fish communities. Coho salmon were typically caught together with juvenile pink and chum salmon. These two species were both smaller and more abundant than coho salmon, and likely formed an effective buffer against predation for coho salmon. By contrast, juvenile Chinook salmon were typically caught with few, if any, other fishes, suggesting potentially high vulnerability to predation due to the lack of alternate prey. These differences in predation vulnerabilities resulted from relatively minor differences in distributions. These study results illustrate that the mechanisms by which climate variability is translated into salmon productivity may vary not only in time and space, but also with the species in question.

Interannual Variations in Water Mass Properties, Phytoplankton, Nutrients and Juvenile Salmon, Age-0 Pollock and Herring Distributions during Fall in the Eastern Bering Sea

Lisa B. EISNER, K.D. CIECIEL, Edward V. FARLEY, JR., James M. MURPHY, J. POHL, and John H. HELLE

U.S. Department of Commerce, NOAA, NMFS, Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Highway, Juneau, Alaska 99801, USA

Surveys were conducted during fall 2000–2004 on the eastern Bering Sea shelf, as part of a multiyear international research program, Bering-Aleutian Salmon International Survey (BASIS). Stations were spaced 15–30 km apart between 54°N and 68°N from inshore (30 m depth contour) to the shelf break, although spatial coverage varied from year to year. Forage fish were captured with a surface net trawl and oceanographic data were obtained from conductivity-temperature-depth (CTD) vertical profiles and laboratory analyses of discrete water samples. Oceanographic variables include temperature, salinity, density, nutrients (nitrate, ammonium, phosphate, silicate), chlorophyll a, and phytoplankton taxonomic characteristics (based on phytoplankton species identification and chlorophyll a size fractionation). Interannual variations in water mass characteristics, phytoplankton biomass and taxonomic variations, nutrient concentrations and distributions of forage fish (primarily J. salmon, age -0 pollock, herring) are compared over the southern and northern shelf. A long-term goal of our research is to characterize interannual and spatial variations during fall in the eastern Bering Sea ecosystem. This interannual variability will be discussed in relation to reduced sea ice coverage and recent warming along the eastern Bering Sea shelf.

Linking the Status of Canadian Salmon with the Status of North Pacific Ecosystems

James. R. IRVINE and Brian E. RIDDELL

Fisheries and Oceans Canada, Pacific Biological Station,
Nanaimo, British Columbia V9T 6N7, Canada

A new system of salmon status categorization will provide useful indicators of ocean conditions and climate variability in the North Pacific Ocean. Under Canada's new Wild Salmon Policy, biological status is being assessed and categorized for ~200 largely independent lineages of chinook, sockeye, coho, chum, and pink salmon. Knowledge of the status, and changes to status of these Conservation Units, combined with information on biological characteristics of fish returning from the ocean and their marine distribution, should prove to be a powerful tool that will aid in assessing the marine ecosystem. Each Conservation Unit will be categorized into one of three status zones based on the abundance and distribution of spawners within it, or proxies thereof. Intensive studies will determine the relative importance of factors operating in freshwater versus the ocean. Assessments will be designed to determine the role of natural vs. anthropogenic factors (e.g. fishing) as well as limiting stages of the life history (e.g. early marine or later) and geographic distribution (near shore vs. offshore). For instance, declining or poor status for coho salmon or ocean type chinook salmon populations may be indicative of poor conditions in coastal regions close to point of natal stream entry, while similar status for stream type chinook may reflect survival problems in the open ocean. These types of information collectively can provide important clues on marine health and carrying capacity.

A Review of the Critical Size, Critical Period Hypothesis for Juvenile Pacific Salmon

Edward V. FARLEY, JR.[1], Jamal H. MOSS[1], and Richard J. BEAMISH[2]

[1]NMFS, Alaska Fisheries Science Center, Auke Bay Laboratory,
11305 Glacier Highway, Juneau, Alaska 99801, USA
[2]Fisheries and Oceans Canada, Pacific Biological Station,
3190 Hammond Bay Road, Nanaimo, BC, V9R 5K6, Canada

Size-selective mortality during the juvenile life history stage of teleost fish is generally believed to be related to growth rate. For Pacific salmon (*Oncorhynchus* spp.), size-dependent mortality can occur during various life history stages including freshwater residence, early marine residence, as juveniles during their first marine winter, and later periods of marine residence. Mechanisms of size-selective mortality include predation on smaller individuals within a cohort or overwinter mortality due to starvation of smaller fish. For juvenile Pacific salmon, size-selective mortality during the first winter at sea has been linked to ocean conditions during their first summer at sea. This idea, known as the critical size, critical period hypothesis, proposes that juvenile salmon must achieve sufficient size during their first summer at sea to have energy reserves to meet the increased metabolic demands incurred during winter. In this paper, we review studies of the critical size, critical period hypothesis for juvenile Pacific salmon. The results suggest that early marine growth of juvenile Bristol Bay sockeye (*O. nerka*), Prince William Sound hatchery pink (*O. gorbuscha*), and British Columbia coho (*O. kisutch*) salmon from geographically distinct regions (Bering Sea, northern Gulf of Alaska, coastal British Columbia) is important and that these salmon must attain sufficient growth during their first year at sea to survive subsequent years at sea. Annual differences in early marine growth and comparisons between Bristol Bay sockeye salmon and Prince William Sound pink salmon growth during 2001 are discussed in relation to ocean conditions along the eastern Bering Sea and Gulf of Alaska shelf.

Spatio-Temporal Variation in Distribution Patterns of Major Predatory Fishes in Russian EEZ and Traumatization of Pacific Salmon

Vladimir V. SVIRIDOV, Igor I. GLEBOV, Alexander N. STAROVOYTOV, Alla V. SVIRIDOVA, Mikhail A. ZUEV, Evgeny E. LOBODA, Vladimir V. KULIK, and Maxim A. OCHERETYANNY

Pacific Scientific Research Fisheries Centre (TINRO-Centre),
4, Shevchenko Alley, Vladivostok, 690950, Russia

Research on the spatio-temporal variability of injures of the Pacific salmon is important for studying the influence of natural mortality factors on natural and artificially produced salmon during their mass joint summer–autumn foraging migrations. Estimates of various predators' contribution on the Pacific salmon's total natural mortality are difficult to obtain due to the methodological complexities of this issue. Spatio-temporal variation in distribution patterns of major predatory fishes in Russian EEZ is analysed based on TINRO-Centre archival trawl survey data for 1980–2004 period. Species analysed include Anotopterus nikparini, Alepisaurus ferox, Lampetra tridentata, L. camtschatica, Lamna ditropis, Squalus acanthias, Prionace glauca and Somniosus pacificus. Traumatization of Pacific salmon is analysed based on data of four complex epipelagic trawl surveys by TINRO-Centre in the western Bering Sea and the adjacent Pacific waters (summer surveys - from July 15 to August 24, 2003 and from June 6 to July 17, 2004; autumn surveys - from September 14 to October 25, 2003 and from September 11 to October 23, 2004). Temporal (diurnal and seasonal) specificity of distribution patterns is elucidated in study presented. Our data testify that relative abundance of predatory fishes is subject to strong geographic variation. Spatial differences in predators' abundance are noted between large-scale geographical units (Bering, Okhotsk and Japan Seas and adjacent waters off North Pacific) and small-scale geographical units (shelf, continental slope, deep-water basins; upper epipelagic layer, lower epipelagic layer, upper mesopelagic layer, lower mesopelagic layer).

Our results testify that information of diurnal dynamics of predatory fishes' vertical distribution is important in studying the mortality factors of Pacific salmon. Due to the time and region-specific vertical distribution patterns of predatory fishes, their abundance in the upper epipelagic layer (a typical layer of salmon presence) is often a poor indicator of possible predation intensity. Information on when and where particular predator is most abundant may reveal locations and time periods at which Pacific salmon are most vulnerable to predation.

Traumatism of Pacific Salmon by Predators in Driftnet Catches in the Russian Economic Zone in 2004

Alexander V. BUGAEV and Evgenii A. SHEVLYAKOV

Kamchatka Research Institute of Fisheries and Oceanography (KamchatNIRO),
18, Naberezhnaya Street, Petropavlovsk-Kamchatsky 683602, Russia

This document includes data on wounds, scars, and marks on Pacific salmon caught during a gillnet survey by the R/V *Ecopacific* in the northwest North Pacific Ocean and southwest Bering Sea in summer–fall 2004. A classification scheme to systematize visual observations of various types of wounds caused by two major predator groups (piscivorous fish and seals) is suggested. The incidence of wounds caused by fish and seals on mature and immature salmon in gillnet catches was assessed. Three general trends in the results apply to all species of salmon caught by gillnets during their prespawning migrations. First, traumatism by fish and seals does not depend on salmon body size at either the intra- or inter-specific level. Second, the highest percentages of wounds were caused by seals (37–69% of wounds in North Pacific waters adjacent to Kamchatka; 89% in southwest Bering Sea) and two piscivorous species, longnose lancetfish and North Pacific daggertooth (25–47% of wounds in North Pacific waters adjacent to Kamchatka). The percentages of wounds caused by lampreys were relatively low (4–16% in the North Pacific waters adjacent to Kamchatka; 11% in the southwest Bering Sea). Third, the percentages of regenerated wounds (scars) in mature salmon increased at the end of the prespawning migration, indicating that the energy expended to regenerate injured tissues may delay maturation of salmon. In this study, it was difficult to distinguish between natural wounds, which occurred before salmon were caught in the nets, and artificial wounds, which occurred after salmon were caught, particularly because of the length of fishing operations (~10 hr) and the ready availability of driftnet-caught salmon to predators. The results, however, can be used an indicator of general background conditions that influence natural predation of salmon during their prespawning migrations in the open ocean.

Abstracts – Poster Presentations

Identification Local Stocks of Sockeye and Chinook Salmon by Scale Pattern Analysis from Trawl Catches of R/V "*TINRO*" Worked by Program of the Bering-Aleutian Salmon International Survey (BASIS) in Summer–Autumn 2003

Alexander V. BUGAEV

Kamchatka Research Institute of Fisheries and Oceanography (KamchatNIRO),
18, Naberezhnaya Street, Petropavlovsk-Kamchatsky 683602, Russia

Previous results of the identification by scale pattern analysis demonstrate the dominance (68–76%) of Bristol Bay sockeye salmon (age .1 ~ 70%) in the west part of Bering Sea (biostatistical districts 8 and 12) from trawl catches R/V "TINRO" in July and August. In September and October the percent of these fishes gets evidently lower (27–38%). This age group among the Asian stocks is the most frequent in the complexes of Chukotka and North-Eastern Kamchatka (13–15% in summer, 23–38% in autumn), either of Western Kamchatka (11–17% in summer, 21–35% in autumn). Among fishes (age .2 ~ 25%) mostly Asian stocks dominated, where representation of the Eastern Kamchatka sockeye salmon was the most significant (20–38% in summer, 47–59% in autumn). The stocks of Chukotka and North-Eastern Kamchatka contributed 3–33% in summer and 12–21% in autumn. West Kamchatka sockeye salmon occurred in the catches as in summer (8–18%), as in autumn (20–29%). In July and August in the district 12 the dominance (59%) was Alaska sockeye salmon. In the area 8 this stock did not contribute over 21%. In autumn the contribution of age .2 American sockeye salmon was obviously decreased to 12% in the district 12. Northward, in the district 8, the fishes from Bristol Bay were not observed.

The results of the identification local stocks of chinook salmon have demonstrated a rather obvious volume of the Alaskan complex in summer and fall 2003 in the western Bering Sea (districts 8 + 12), what was 47% (June–August) and 37% (September–October). The volumes of the Asian complexes were 53 and 63% in summer and fall respectively. It should be noted that the scales from the trawl catches are of a low quality what can cause some distortion in the results. However, as the scale baseline has been represented only by the most abundant stocks of Asia and North America, than at the level of a tendency we can suggest a high percent of American chinook salmon in the Economic Zone of RF in the Bering Sea. That has been also indicated by high meanings of chinook salmon stock abundance assessment from the data of trawl surveys on the R/V "TINRO" in the western Bering Sea in the summer and fall period 2003.

The Infection of Sea Lice *Lepeophtheirus salmonis* (Caligidae) of Pacific Salmon (*Oncorhynchus* spp.) from the Driftnet Catches in the Russian Economic Zone in 2004

Alexander V. BUGAEV

Kamchatka Research Institute of Fisheries and Oceanography (KamchatNIRO),
18, Naberezhnaya Street, Petropavlovsk-Kamchatsky 683602, Russia

Data on sea lice *Lepeophtheirus salmonis* infestation of Pacific Salmon in the Pacific Ocean waters adjacent Kamchatka and in the Bering Sea in summer–fall 2004 are represented. Dynamics of infestation intensity and extensity is demonstrated. The most large species (Chinook salmon) and the most abundant species (pink salmon) are found maximum infested. Infestation frequency of the most mass species of Pacific Salmon (pink, chum and sockeye salmons) in the year of observation is proportional to the abundance of these species in Asian part of areal, i.e. pink salmon is the most infested (average prevalence about 50%, intensity about 2 specimens 1–10) the next is chum salmon (average prevalence about 24%, intensity about 2 specimens 1–12) and than sockeye salmon (average prevalence about 9%, intensity about 1 specimens 1–2). The maximum infestation extensity among mature fishes of three abundance-dominant species is recorded in August on finishing the prespawning migration.

Dynamics of Biological Parameters and of Chum Salmon *Oncorhynchus keta* (Walbaum) Abundance in the North-East Coast of Kamchatka and Reasons to Determine the Dynamics

Lidiya O. ZAVARINA

Kamchatka Research Institute of Fisheries and Oceanography (KamchatNIRO),
18, Naberezhnaya Street, Petropavlovsk-Kamchatsky 683602, Russia

The north-east coast of Kamchatka (Karaginski and Olutorski Bays) is one of principal areas of chum salmon reproduction. Average contribution of this chum to the total salmon harvest in Kamchatka takes 4.5%. For the period 1957–2004 the minimum and maximum returns of chum salmon to this part of peninsula were 30 times and more different from each other.

Feeding area of North-East Kamchatka chum salmon and of the other Asian stocks, including Japanese, is almost the same during marine period of life. Feeding areas of Asian and of North American chum salmon are less coinciding.

The aim of this study was to figure out the reasons of chum salmon stock abundance fluctuations and variations of biological parameters. The task was to make analysis of the dynamics of chum salmon abundance and biological parameters for 1976–2004.

From 1957 the abundance of North-East Kamchatka chum salmon began decrease. The minimum returns were in 1971–1975, the maximum in 1986–1990. The abundance decreased for the next five years and began recover gradually from late 1990s.

The stock abundance changes of North-East Kamchatka chum salmon were accompanied with the changes of biological parameters. Age composition went extensive transformations: from 1976–1980 to 1986–1990 relative abundance of 2+ fishes got decreased from 4.5 to 0.9%, of 3+ fishes – from 60 to 39.6%, the percent of older age groups got increased – from 35 to 53.3% for the 4+ and from 0.5 to 6.2% for the 5+ fishes. For 2001–2004 the ratio between the age groups was: 2.8 for 2+; 39.9 for 3+; 40.9 for 4+; 16.2 for 5+; and 0.2 for 6+. Average age of maturation got older.

From 1976 a size-weight reduce has been observed. Average length and weight of chum salmon were: 64.8 cm, 3.69 kg in 1976–1980; 63.2 cm, 3.66 kg in 1986–1990; and 62.3 cm, 3.5 kg in 2001–2004.

By the periods mentioned above the average fecundity of North-East Kamchatka chum salmon went reducing from 2709 to 2435 and than to 2228 eggs.

On our view the dynamics of chum salmon abundance and biological parameters is determined by the abundance of trophic competitors (pink salmon and Japanese hatchery chum salmon) and by global changes of climate and oceanography, transforming conditions of feeding in the ocean.

Food Supply and Trophic Relationships of Pacific Salmon (*Oncorhynchus* spp.) and Atka Mackerel (*Pleurogrammus monopterygius*) in the Western Part of Bering Sea in Fall 2002–2004

Alexander V. ZAVOLOKIN and Alexander Ya. EFIMKIN

Pacific Scientific Research Fisheries Centre (TINRO-Centre),
4, Shevchenko Alley, Vladivostok, 690950, Russia

In recent years pacific salmon biomass and their percentage in nekton have increased. These fish are one of the dominant species in the upper epipelagic zone (0–50 m). Furthermore young-of-the-year (YOY) atka mackerel forages in this layer of water column. And it biomass in some years is comparable with biomass of abundant salmon species.

In this work we examined food supply and trophic relationships of all size groups of co-occurring chum (*Oncorhynchus keta*) and sockeye *(O. nerka)* salmon as well as pink *(O. gorbuscha)* juveniles and YOY atka mackerel, used data of feeding spectrum dynamics and zooplankton abundance. The work was based on data of complex epipelagic surveys of TINRO-Centre in fall 2002–2004. Trawling, plankton and feeding sampling were made under unified approach, accepted in TINRO-Centre.

Most of the diets (65–100% in terms of biomass) of co-occurring pink, chum and sockeye juveniles in the Komandor Basin and western part of Aleutian Basin in fall 2002–2004 comprised two prey – hyperiid amphipod *Themisto pacifica* and euphausiid *Thysanoessa longipes*, excepting 2003, when *Th. longipes* were replaced by pteropod *Limacina helicina*. Prey composition of YOY atka mackerel was similar to that of salmon juveniles, but fraction of copepod *Neocalanus plumchrus* was much more higher.

Diet of co-occurring adult immature chum and sockeye salmon also comprised few preys. Two dominant food items constituted 57–86%. In 2002 and 2004, hyperiid amphipod *Th. pacifica* and euphausiid *Th. longipes* were also prevalence prey. Small nektonic organisms became more impotant in the diet of larger fish. In fall 2003, the chum stomach contents consist mostly of pteropods and small squids. At that chum salmon fed almost exceptionally on pteropod *Clione limacine*, and sockeye salmon fed mainly on small squids, pteropod *L. helicina* and amphipod *Th. pacifica*. It is important to notice that above mentioned plankton species constituted only 6–20% of total plankton biomass in the upper epipelagic zone.

All fish showed similar diel feeding rhythms. The maximum fullness was in the afternoon to midnight and decreased from night to morning.

Salmon juvenile diets were very similar. Schoener's feeding similarity indexes varied from 0.58 to 0.95. Similarity of diets of atka mackerel and salmon juveniles was lower (0.20–0.77), because copepods were more important prey of atka mackerel.

Feeding similarity of adult chum and sockeye salmon was the highest for fish of 300–400 mm body length (0.53–0.81) and decreased for larger fish (500–600 mm – 0.39–0.40). Only in 2003, similarity of its diets was much lower (0.21–0.26) as a result of chum feeding on pteropods. Although adult sockeye salmon, salmon juveniles and YOY atka mackerel fed on the same prey in that year likewise its fed on in 2002 and 2004.

In summary, (1) co-feeding on few food items (mainly 2–3 species), which fractions in plankton is low, but sufficient for fish feeding, (2) absence or low part in the diet of chaetognaths, which has little energetic value, (3) feebly marked feeding specialization, (4) stable and similar feeding rhythms of fish, and (5) high feeding similarity indexes – all these evidences indirectly testify to low potential for feeding competition between major salmon species as well as with YOY atka mackerel in the western part of Bering Sea.

Diurnal Rhythms of Pacific Salmon Feeding

Anatoly F. VOLKOV and Natalia S. KOSENOK

Pacific Scientific Research Fisheries Centre (TINRO-Centre),
4, Shevchenko Alley, Vladivostok, 690950, Russia

Research on diurnal rhythms of salmons feeding is important for the subsequent calculation of daily diet and evaluation of food sufficiency. The acquisition of such data requires a presence of sufficient datasets of trawling conducted in round-the-clock manner. The TINRO-Center survey by RV "TINRO" in the western Bering Sea during autumn 2004 allowed for such data acquisition. Based on data averaged for several biostatistical areas (regions), it was shown that small-size immature individuals (before 30 cm) of 5 Pacific salmon species are characterized by similar diurnal feeding patterns. They feed most intensively between 11 a.m. and dusk. Afterwards food gets digested relatively quickly and sufficiently, resulting in stomachs being mostly empty by 6 to 7 a.m., when the sun rises. Older immature and mature individuals are characterized by less clear diurnal dynamics. This is probably connected to food composition, as well as to less strong relationship between forage activity and time period of the day. It takes more time to digest larger food items. If the degree of digestion is well defined, it is possible to define diurnal feeding dynamics patters well enough in some cases. In cases when Hyperiidae are the primary food items it would be impossible to define precisely the time of food intake.

Quality Characteristics of Sockeye Salmon *Oncorhynchus nerka* Smolts Ozernaya River Stock in 1991–2002 Years and Growth Features of 1994-Generation in the Fresh-Water Period of Life

V.A. DUBYNIN and Victor. F. BUGAEV

Kamchatka Research Institute of Fisheries and Oceanography (KamchatNIRO),
18 Naberezhnaya Street, Petropavlovsk-Kamchatsky, 68300, Russia

The Ozernaya River sockeye salmon stock is the most abundant in Asia currently. In 1984–1991 adult escapement in Kurilskoye Lake varied from 2.05 to 6.00 million (3.07 in average) sockeye salmons. Outstandingly high number of juveniles produced by the escapement created a significant press to zooplankton community of this nursery-feeding lake. Thus, forage base for juvenile sockeye salmon has got undermined. Extremely worth conditions of feeding in the lake, especially in the second part of 1990th determined a very small smolt size. The smolts were the smallest for the whole 62-year period of observations. Scale samples from two and three years old sockeye salmon smolts emigrated to the sea in 1997–1998 and from mature fish of 2.2, 2.3, 2.4, 3.2, 3.3, 3.4 ages from the catches in the Ozernaya River for 1999–2002 were studied. A part of 2+ smolts in 1997 and of 3+ smolts in 1998 demonstrated unusually small number of sclerits in the second annual scale zone. These fishes (generation 1994) were rather frequent among mature sockeye salmon with two or three fresh-water years from the returns for 1999–2002. If to neglect the extremely unfavorable conditions for juvenile growth formed in Kurilskoye Lake in 1996, than the second zone of fresh-water growth frequent in the Ozernaya River sockeye salmon stock in returns 1999–2002 can be reckoned as additional, what can extensively transform the age composition of return. Therefore the second zone of growth in the central part of scale of these sockeye salmons, despite a frequent occurrence of small number of sclerites in this part among fishes, should be reckoned as annual zone.

Specification of Criteria for Estimation of Chum Salmon and Sockeye Salmon Gonad Maturation in the Course of Anadromous Migration

S.B. GORODOVSKAYA and V.I. SHERSHNEVA

Kamchatka Research Institute of Fisheries and Oceanography (KamchatNIRO),
18, Naberezhnaya Street, Petropavlovsk-Kamchatsky, 68300, Russia

Both mature and immature individuals occur in salmon aggregations in the waters off Kamchatka in the course of anadromous migrations.

The criteria currently used were established in 1964 on the materials by Soviet Union-Japan Fishery Commission.

Our purpose was to specify these chum and sockeye salmon gonad maturation criteria with using a complex of histological and biochemical methods.

The peculiarity of chum and sockeye salmon oocyte's structure is a poor process of vacuolization to capture only peripheral and circumnuclear plasmatic zones, i.e. it goes just during primary phases of previtellogenesis (two initial stages of development). There are clear-bounded ampoules full of spermatogonia and small spermatocytes of consequent orders in the gametes of immature males. The process of reproduction of spermatogonia previous the wave of intense spermatogenesis (II stage of development) occurs in the milts.

It has been found, that water content in the gonads of immature chum and sockeye salmon females is always over 70%. The content of mineral substances (ash) can be a criterium to estimate immature males. The content of mineral substances in the milts of immature chum salmon or immature sockeye salmon has not been over 1.8% or 2.5% respectively.

A quick estimation of maturation extent with using of histological and biochemical methods is impossible in the terms of field observation. Therefore the gonad weight and the gonad-somatic index of fishes were analyzed with male and female gonad maturation extent and the content of mineral substances in milts or of water in ovaries. The meanings of gonad weight and GSI were demonstrated by immature fishes, which have not been recruited for spawning in this year.

Table. The corrections (A) to the criteria (Б) to estimate immature salmons from gonad weight (g) and from gonad-somatic index.

Species	Sex	May		June		July		August
		A	**Б**	**A**	**Б**	**A**	**Б**	**A**
Chum	Females	< 15.0 < 0.84*	< 15.0	< 35.0 < 1.47*	< 25.0	< 40.0 < 1.84*	< 25.0	< 45.0 < 2.11*
	Males	< 3.5 < 0.19*	< 2.0	< 5.0 < 0.20*	< 5.0	< 15.0 < 0.70*	< 8.0	< 1.9 < 0.07*
Sockeye	Females	< 26.0 < 1.69*	< 15.0	< 28.0 < 1.46*	< 20.0	< 34.0 < 2.08*	< 25.0	< 39.0 < 2.17*
	Males	< 3.3 < 0.13*	< 2.3	< 5.0 < 0.29*	< 3.0	< 7.5 < 0.48*	< 5.0	< 17.0 < 1.04*

Note**:** * gonad-somatic index.

Changes in Abundance and Biological Indices of the Kunashir Island Pink Salmon

Larisa V. ROMASENKO

Sakhalin Research Institute of Fisheries and Oceanography (SakhNIRO)
196, Komsomolskaya Street, Yuzhno-Sakhalinsk 693016, Russia

Changes in pink salmon catches at the Kunashir Island corresponded to the general trend of those changes for the Sakhalin–Kuril Region in total. After a period of the comparatively high catches in the 1970s, their recession took place. Then, beginning from the mid 1980s, the pink salmon catches were increasing, reaching the maximum values in the 1990s. At the same time, this trend of increasing in catches was accompanied by the abrupt increase in differential between the even- and odd-year pink salmon catches.

Pink salmon abundance and biological indices began to be studied in the 1990s. Its catches in individual years were determined to be in complete accordance with the pink salmon entries to the island's rivers ($R = 0.92$). Under the 7-fold fluctuations in numbers of fish entered the island's rivers in different years, the number of juvenile migrants depended significantly on their parents' numbers ($R = 0.78$). However, the number of adult returns weakly depended on the yield of juvenile migrants ($R = 0.52$). This is caused by the phenomenon that during the sea life period, pink salmon survival decreased for those broods, which had more abundant juvenile migrants ($R = -0.57$).

Having analyzed the interannual changes, it was ascertained that under the increase in pink salmon returns to the Kunashir Island compared to the previous year, the later run of their main group to the island was observed ($R = 0.77$), and fish were smaller ($R = -0.68$). However, those relations became weaker if comparing the long-term trends of the studied indices, or if considering the number of all the pink salmon group from the southwestern Okhotsk Sea as the abundance. Besides, the dates of pink salmon runs to the Kunashir Island and their mean body lengths also depended on the ratio between numbers of the pink salmon seasonal groups (with early and late dates of spawning), appeared to be significantly different in even and odd years.

The analysis of these data shows that despite the distinctive features common for salmon reproduction in the Kunashir Island waters, changes in the pink salmon stock dynamics of this island corresponded significantly to the long-term trends observed for the other pink salmon stocks in the Sakhalin–Kuril Region.

The Dynamics of Salmon Abundance in the Amur River

Vladimir A. BELYAEV, V.B. ZVYAGENTSEV, and C.F. ZOLOTUHIN

Intragency Ichthyological Commission
27 Tverskaya Street, Moscow 125009, Russia

Within the Amur River watershed there are met five species of the genus *Onchorhynchus*: chum, pink, cherry, coho and chinook (the latter two are regarded as rare). Among the most numerous and commercially valuable salmon are chum and pink, their harvest and biological parameters having been extensively and thoroughly described for a long-term period.

In the early 1920s the target fishery species in the Amur was summer chum (in 1910 its maximum catch was estimated as 53.4 th tons). However, since 1914 onward during 18 years the catches declined. The stock depletion was caused by two major factors, as follows: 1) overharvesting, and 2) unfavorable conditions for incubation and hatching in winter during the recent years (Smirnov 1947, Nikolsky 1954, Rosly 2002). Later in 1930–1938 the marked increase of the summer chum stocks was reported, although in the 1940s the overall decline in abundance reached the stabilization of abundance at a low level.

Likewise for summer chum, the 1910 maximum harvest for autumn chum was estimated as 43 th tons.

It should be stressed that in the early 20th century the super-population of Amur chum was the most abundant one in the North Pacific.

In the 1920s–1930s Amur pink played rather a significant role in harvesting of salmonids within the Amur watershed and reached from 10 th to 14 th tons, with the overall abundance of 20 mln specimens (Rosly 2002).

In the Amur River fisheries history, several main periods can be identified. The first period extended from the late 19th century till 1924, when within the Amur watershed the human impact was limited to harvesting plus climatic changes, the second one was influenced by fisheries, economy, climatic factors, whereas the third period comprised all the above plus the construction of two hydro power stations on the larger Amur tributaries – the Zeya and the Bureya rivers

The paper will extensively discuss all the three periods.

The author identifies the causes of the salmon abundance fluctuations in the Amur, as follows:

1) excessive harvesting (primarily due to illegal harvesting);
2) hydrological conditions within the Amur watershed, including:
   a) changes in the Amur water content related to the Zeya and the Bureya hydro power stations construction;
   b) altered environment at spawning grounds due to timber harvesting practices, fires, pollution, etc;
3) oceanological conditions during the marine life cycle in various areas:
   a) coastal, and
   b) open ocean ones.

Spatio-Temporal Variation in Vertical Distribution of Pacific Salmon and Ecologically Related Nekton and Plankton Species in Russian EEZ

Vladimir V. SVIRIDOV, Igor I. GLEBOV, Alexander N. STAROVOYTOV, Natalia S. KOSENOK, Alexander Ya. EFIMKIN, Alexander M. SLABINSKY, Nikolai S. VANIN, Oleg E. BASYUK, Alla V. SVIRIDOVA, Mikhail A. ZUEV, and Evgeny E. LOBODA

Pacific Scientific Research Fisheries Centre (TINRO-Centre),
4, Shevchenko Alley, Vladivostok, 690950, Russia

The research on diurnal variation in vertical distribution of Pacific salmon and ecologically related nekton and plankton species is important for understanding dynamics of their biological environment. In order to estimate species abundance correctly we have to account for diel changes in level of catches, which may be influenced by species vertical distribution. The purpose of the following study was the investigation of spatio-temporal variation in vertical distribution of Pacific salmon and ecologically related nekton and plankton species in pelagic layer of Russian EEZ based on three long-term diel studies (Aleutian basin area – September 8–12, 2003 and August 23–September 5, 2004; Navarin shelf area – August 5–7, 2004) and archival trawl survey data for 1980–2004 period (2914 stations in the Bering, 6056 - Okhotsk, 2164 – Japan Sea and 7105 – northwest Pacific Ocean). The results on vertical distribution of Pacific salmon and ecologically related species are described separately for every season of year, time of day (daytime, nighttime), large-scale geographical unit (Bering, Okhotsk and Japan Seas and adjacent waters off North Pacific) and small-scale geographical unit (shelf, continental slope, deep-water basins; upper epipelagic layer, lower epipelagic layer, upper mesopelagic layer, lower mesopelagic layer). The estimates of ontogenetic, interregional, diel and seasonal variability in vertical distribution patterns are provided for Pacific salmon species and other major nekton and plankton species of the upper epipelagic, lower epipelagic, upper mesopelagic and lower mesopelagic layers. The differences and similarities in vertical distribution patterns are discussed in relation to species ecology and life cycles.

Temporal (diurnal and seasonal) specificity of vertical distribution patterns of species studied is elucidated in study presented. Our data testify for geographic variation in vertical distribution patterns of Pacific salmon and ecologically related species. This necessitates the adoption season-specific and geographic-specific correction factors in order to obtain correct abundance estimates and to get a correct picture of CPUEs spatial distribution. Moreover, the vertical distribution of many species may change significantly within daytime or nighttime period taken separately. Comparisons of vertical distribution patterns of Pacific salmon and ecologically related species are important for understanding trophic interrelationships between different components of pelagic ecosystem.

Spatial-Ages Composition of Chum Salmon in the Western Part of the Bering Sea in 2002 and 2003

Elena A. PANCHENKO

Pacific Scientific Research Fisheries Centre (TINRO-Centre),
4, Shevchenko Alley, Vladivostok, 690950, Russia

This work is based on data of three epipelagic trawl salmon surveys of the TINRO-Centre in the western part of the Bering Sea in autumn 2002 and summer–autumn 2003. In autumn 2002 and 2003 immature two-years-old chum salmon (0.1) dominated all regions. The percentage of juveniles was also significant. In 2003 they were present in all examined regions, except for Komandor Basin. In 2002 juveniles dominated in shelf zone. In other regions they constituted no more than 4%.

During autumn immature chum salmon were absolutely dominant. The percentage of mature chum salmon was low. During the summer immature chum salmon were also prevalenced in Komandor and Aleutian Basins. The percentage of mature individuals was high in shelf regions.

Spatial distribution of different age groups does not vary greatly between seasons and years. During the summer and autumn immature chum salmon (0.1–0.2) dominated in deep-water and shelf break areas. Mature chum salmon 0.3–0.4 age groups dominated in shelf zone. Accordingly average length of immature chum salmon decreased from shelf zone towards deep-water basins. Age-, season- and year-specific analysis of chum salmon migrations peculiarities is carried out in relation to its abiotic and biotic environment.

Juvenile Salmon Feeding in the Eastern Bering Sea

Natalia A. KUZUNETSOVA

Pacific Scientific Research Fisheries Centre (TINRO-Centre),
4, Shevchenko Alley, Vladivostok, 690950, Russia

In the Bristol Bay (Leg 1) juvenile pink (11–22 cm) fed fishes, mainly juvenile pollock and sand lance (80.4%), as well as in the Nunivak area (Leg 2) - (36%) in 2004. But the share of Brachuyra megalopa (30.1%), Euphausiacea (14.0%), Copepoda (7.3%) and Hyperiidea (3.9%) was high there. The number of plankton species made 13% of food in 2003.

Fishes and Coelenterata had major importance in a diet of juvenile chum (11–25 cm). Juvenile pollock (42–50.5%) and sand lance dominated of all fishes. The share of Mysidacea, Brachuyra megalopa and Pteropoda was appreciable in 2003. The number of plankton species increased in 2004, Euphausiacea, Hyperiidea, Mysidacea, Pteropoda, Brachuyra megalopa and Copepoda occurred as well.

Juvenile pollock (45%), Euphausiacea and Brachuyra megalopa made the basis of juvenile sockeye (15–30 cm) food in 2003. Fishes, mainly juvenile pollock (56–70%) prevailed in 2004, though the number of plankton species increased, but in total they were no more, than 5–25%. Usually nekton plays the great role in sockeye feeding of more than 30 cm.

Juvenile coho (23–39 cm) and chinook (18–34 cm) being typical predators, fed juvenile fishes: pollock, sandlance, capelin, herring, smelt and Pleuronectidae, as well as juvenile squids. Feeding spectrum extended owing to zooplankton, share of which was 5–17% of total food for coho and 5–10% for chinook in 2004.

In summer, pink and chum salmon behave themselves as predators, consuming juvenile fishes in coastal waters, in autumn while growing and running to more open waters, they feed zooplankton (large fraction) (Gorbatenko, Chuchukalo, 1989; Volkov, 1996; Kuznetsova, 2004). Prevalence of fish food in a diet of juvenile pink, chum and sockeye in coastal areas of Alaska is connected with high concentration of juvenile fishes. Small and average fractions prevailed in zooplankton. The large fraction of zooplankton made no more than 8.6% at shoals and 33% at shelf (Volkov et. el., 2004). In summer of 1985, share of large fraction was 75% of total zooplankton biomass both in neritic and in over shelf communities (Shuntov, 2001).

Approximately, in 2004 diurnal ration for pink (10–20 cm) was not less 5.5–5.6% of body weight, for chum (10–20 cm) – 3.7–4.3%.

Spatial Variations in Feeding and Condition of Juvenile Bristol Bay Sockeye Salmon in Relation to Ocean Conditions along the Eastern Bering Sea Shelf

Edward V. FARLEY, Jr.[1], Natalia A. KUZNETSOVA[2], James M. MURPHY[1], Lew HALDORSON[3], and Milo ADKISON[3]

[1]NMFS, Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Highway, Juneau, Alaska 99801, USA
[2]Laboratory of Applied Biocenology, Pacific Scientific Research Fisheries Centre (TINRO-Centre), 4, Shevchenko Alley, Vladivostok, 690950, Russia.
[3]Juneau Center, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, 11120 Glacier Highway, Juneau, AK 99801, USA.

Stomach contents of juvenile Bristol Bay sockeye (*Oncorhynchus nerka*) salmon collected during August–September (2000–2004) Bering-Aleutian Salmon International Surveys are analyzed. The most common diet item is age 0 walleye pollock (*Theragra chalcogramma*) followed by larval sandlance (*Ammodytes hexapterus*) and euphausiids. Principal components analysis of diet data identified prey assemblages associated with the distribution of juvenile sockeye salmon. These prey assemblage differences were generally associated with two dominant ocean domains along the eastern Bering Sea shelf including the coastal (well mixed – less than 50 m depth) and middle (well stratified – greater than 50 m and less than 100 m depth) domains. Density dependent feeding will be tested by regressing a feeding index on catch per unit effort. When possible, the diel periodicity of the feeding index will be examined to identify the feeding periods of juvenile sockeye salmon. A condition factor, defined as the ratio of the weight of each fish to its expected weight based on the length-weight regressions will be estimated within year and domain to test for significant differences in condition factor between years and domains. Differences in diet, feeding index, and condition factor will be discussed in relation to earlier analyses on growth and survival of juvenile Bristol Bay sockeye salmon and in relation to ocean conditions along the eastern Bering Sea shelf.

Stock-Specific Abundance Estimates of Bristol Bay Juvenile Sockeye Salmon

James M. MURPHY[1], Edward V. FARLEY, JR.[1], and Christopher HABICHT[2]

[1]NMFS, Alaska Fisheries Science Center, Auke Bay Laboratory,
11305 Glacier Highway, Juneau, Alaska 99801, USA
[2]Gene Conservation Laboratory, Commercial Fisheries Division, Alaska Department of Fish and Game,
333 Raspberry Road, Anchorage, Alaska 99418, USA

Kriging spatial models are used to estimate abundance of different stocks and ages of Bristol Bay juvenile salmon during pelagic research surveys conducted between 2000 and 2004. Genetic material colleted during the research surveys are used to estimate juvenile sockeye salmon stock mixtures with single nucleotide polymorphism (SNP) genotyping assays; and freshwater ages are estimated from scales. Obtaining reliable abundance estimates of juvenile salmon is essential to understanding marine survival in salmon. The addition of stock and age data improves our ability to interpret abundance patterns of juvenile sockeye salmon and our ability to provide insight into marine survival in sockeye salmon.

The Chemical Analysis of Salmonidae Otolith in Korean Waters

Dongwha SOHN[1], Suam KIM[1], and Sukyung KANG[2]

[1]Department of Marine Biology, Pukyong National University, Busan, Korea
[2]National Fisheries Research and Development Institute, Korea

The chemical analysis on trace elements was conducted to reveal the depository relationship between fish otolith and rearing water. Rearing waters, the otoliths of hatchery-reared fry and juvenile (Age 1+) chum salmon, and juvenile cherry salmon (Age 1+) were collected from three major hatcheries (Yangyang, Samchuk and Uljin of Korea) in spring 2002. Juvenile chum salmon reared in freshwater longer than 1 year was only collected from Uljin hatchery. Trace elements in the otoliths and waters were analyzed using inductively coupled plasma mass spectrometry (ICP-MS). Some trace elements/Ca such as Sr/Ca and Ba/Ca in the rearing waters seemed to be well reflected in the otoliths of chum salmon fry and juvenile cherry salmon. Comparison of Sr/Ca in otoliths of fry and juvenile chum salmon indicated that salmon fry otolith showed higher Sr/Ca ratio than juvenile salmon. Furthermore, the otolith of juvenile salmon showed higher Sr/Ca concentration than otolith of the cherry salmon. Zn/Ca ratio of fry and juvenile salmon revealed higher ratio in earlier stage. Species-specific accumulation of trace elements was found in juvenile chum salmon and cherry salmon.

Density Dependent Growth of Sockeye Salmon on the Coastal Shelf

Ole A. MATHISEN[1] and Lowell FAIR[2]

[1]University of Alaska Fairbanks
[2]Alaska Department of Fish and Game

Length measurements by age and sex groups are taken in the trunk streams of many sockeye salmon escapements. This eliminates the problem of mixed stocks. It is therefore possible to assess the growth pattern of sockeye salmon from such measurements. For the cyclic Kvichak River run in Bristol Bay, we know that the average length decreases 2–3 cm during the peak years. We know further that all sockeye salmon runs in Bristol Bay display the similar decrease in average length. This density dependent growth appears to take place the last year of ocean residence when the increases in weights are the greatest. Aside from these cyclic changes no downward trend in average length has been detected.

Length measurements from other major streams like the Chignik, Karluk, and Copper Rivers fail to display the same changes. This material will be expanded with data from streams in British Columbia and the Kamchatka Peninsula.

The working hypothesis is that the sockeye salmon runs to the various fishing districts are segregated on the coastal shelf during the final maturation process. Density dependent growth occurs when the feeding biomass of all salmon exceeds a certain limits, which then represents an estimate of the carrying capacity of the coastal areas in question.

Preliminary Results on the Ecology of Juvenile Chum Salmon in the River and Coastal Waters in Korea

Chae Sung LEE[1], Young Hee HUR[1], Sukyung KANG[1], Chul Ho LEE[1],
Joo Kyeong KIM[1], and Yang HYEON[2]

[1]Salmon Research Team, East Sea Fisheries Research Institute, NFRDI
424-1, Songhyun-ri, Sonyang-myeon, Yangyang-gun, Gangwon-do 215-821, Republic of Korea
[2]Institute of Biodiversity Research,
202 Hosu Bld. 785-4, Hoseong-dong 1ga Dugjin-gu, Jonju-city, Jollabuk-do, 561-211, Republic of Korea

There are five anadromous Salmonidae species distributed in the Korean waters, i.e., *O. keta, O. masou, O. gorbuscha, O. kisutch, O. nerka,* however, the distributions of *O. gorbuscha, O. kisutch, O. nerka* are limited to North Korea. Among these only chum salmon (*O. keta*) are artificially cultured and released for the resources propagation.

The amount of chum salmon catch in Korean rivers was approximately 100 individuals in 1969 when the provincial salmon hatcheries were built. Since then in spite of many efforts the annual catch of chum salmon was very small till the end of 1970s. However, since the early 1980s another five rivers including Namdae-Cheon (Yangyang) located in Gangwon-do, northern part of South Korea, were exploited the catch of return chum salmon for spawning have been increased and owing to these increase to catch salmon at sea have been allowed for set net fishery, from 1990 and the catch was 104,000 individuals (29,542 from rivers and 74,571 from the coastal area). The catch have been increased since then and reached to 221,000 individuals in 1997, and 21,500,000 fries were released in 1999, which was the highest record till now. However, in 2000 catch was decreased sharply to 17,000 individuals both from rivers and sea. Accordingly, the release of fries was decreased to 5,320,000 in 2001. The catch is somewhat increased since then, though, it is still less than 1,000,000 individuals. In 2005 the release of fries was 14,730,000.

The return rate was less than 0.4% for the broods released in 1984 to 1986. And then it increased to 1.5% for that released in 1987 and fluctuated from 1.0 to 1.5% for those broods of 1988–1995. However, it had dropped to 0.7% for that of 1996 and further dropped to 0.2% that for 1997. For those broods in 1998–2001 was ranged to 0.2–0.5%.

For the effective chum salmon resources enhancement and to increase the return rate through reduction of mortality in their early life history in the river and to understand the ecology and migration time to the coastal area of chum salmon we have conducted follow-up survey after releasing chum salmon fingerings in the rivers since 1991. The number of fingerling was counted and length and weight of chum salmon were measured.

Chum salmon fingerings have released in Namdae-cheon from early Feburay to late March. The mean total lengths at releasing to the river were 4.2–6.5 cm and they seemed to stay in the river for 20 to 60 days. The mean total length were ranged 6–9 cm when they moved to the coastal area.

In addition, we analyzed stomach contents of chum salmon fingerings and demersal organisms in the river and studied fish fauna during their staying in the river to study the feeding ecology and food webs for chum salmon fingerings from February to May in 2005. We also have conducted follow-up studies in the coastal areas from May to July using charted commercial purse seiner and collecting zooplankton.

Preliminary Studies on Metazoan Parasites of Chum Salmon (*Oncorhynchus keta*) in Korea

Jeong-Ho KIM[1], Chul-Ho LEE[2], and Chae-Sung LEE[2]

[1]Faculty of Marine Bioscience & Technology, Kangnung National University,
Kangnung, 210-702, Republic of Korea
[2]Salmon Research Team, East Sea Fisheries Research Institute, NFRDI,
Yangyang, 215-821, Republic of Korea

Parasites as 'biological tags' have been used for fish population studies. For example, parasites have been successfully used for studying stock structure, stock identification and migration routes of anadromous fishes such as Pacific salmons (*Oncorhynchus* spp.).

Most of *Oncorhynchus* species migrating to East Coast of Korea is *O. keta,* although Cherry salmon (*O. masou*) was also recorded from the Korean peninsula. The annual catches and releases of *O. keta* in Korea have been increased, but no systematic and clear information, such as migration routes, are available yet. The information on their parasites is not available, either.

We investigated metazoan parasites of 80 *O. keta* (Fork length ranges from 56.2 cm–70.5 cm, Total weight ranges from 2.35 kg–6.67 kg) caught in 2004. Whole fish were frozen and transported to the laboratory, where they were measured, thawed and dissected to investigate metazoan parasites. External parasites were examined, fixed with 10% buffered formalin or 70% ethanol, and identified. Gastrointestinal tracts were opened longitudinally, and the contents rinsed into beakers and examined for endoparasites. The parasites were fixed with APG or 10% buffered formalin, and stained when necessary. All parasites found were identified to the lowest taxon as possible, and the prevalence of infection for each parasite was measured.

Parasite species found were 1 digenea (1 *Digenea* sp.), 3 cestoda (*Eubothrium* sp., *Nybelinia* sp. plerocercoid, 1 cestoda sp.), 3 nematoda (*Anisakis simplex* larva, *Contracaecum* sp. larva. *Hysterothylacium* sp. larva), and 1 copepoda (*Lepeophtherius salmonis*). All the fish examined had at least 1 parasite species. The most abundant parasite was *Eubothrium* sp. (93.8% of fish examined were infected), and the number of *Eubothrium* sp. from infected fish were ranged from 29 to more than 100 per individual fish. Due to difficulties in the identification of intestinal cestodes, the data recorded may be possibly changed by further investigation. One digenea species was recorded from 25 individual fish, and some nematoda species recorded were not possible to conduct precise identification. With the digenea and 1 unidentified cestoda, Nematoda species recorded here await further species identification. *L. salmoniswere* recorded from the skin of fish examined, but the prevalence of infection was low (6% of fish examined were infected).

More detailed and large-scale studies will provide more important and precise information on the parasitic fauna of *O. keta* in Korea. And this will be helpful for clarifying migration routes, stock identification and obtaining other biological information of *O. keta* in Korea.

Genetic Stock Identification and Gene Flow Estimation among the Chum Salmon Populations in the North Pacific Using the Nucleotide Variations in mtDNA, COIII-ND3-ND4L Region

Youn-Ho LEE[1], Geoyoung KANG[1], Woongsic JUNG[1], Goeun KIM[1], Choong-gon KIM[1], Ki-Baek SEONG[2], Sukyung KANG[2], James E. SEEB[3], Peter BEERLI[4], Yong-Jin WON[5], and Suam KIM[6]

[1]Korea Ocean Research and Development Institute, Ansan P.O. Box 29, 425-600, Korea
[2]National Fisheries Research and Development Institute, Busan 619-902, Korea
[3]Alaska Department of Fish and Game, Anchorage, AK 99518, USA,
[4]Florida State University, Tallahassee, FL32306, USA,
[5]Iwha Woman's University, Seoul, Korea
[6]Pukyung National University, Busan 608-737

Korea Genetic stock identification has employed a number of different methods. In terms of accuracy, reproducibility and comparability, single nucleotide polymorphisms (SNPs), which use difference in DNA sequences are getting more acceptances. For the chum salmon, we identified 53 variable sites within the 744 nucleotide-long region of mtDNA, COIII-ND3-ND4L, from the comparison of 186 individuals, 48 from Korea, 44 from Japan, 45 from Alaska, 29 from Canada and 20 from the United States. SNPs in these variable sites comprise 49 haplotypes, some of which are specific to a certain population. Based on these SNPs, population-specific PCR primers were designed in a way that the most 3'end nucleotide becomes specific to each haplotype and that the second to the last nucleotide at the 3'end mismatches the conserved nucleotide at the site. PCR with these primers amplified DNA distinctively depending on the origin of samples. On the other hand, some haplotypes are common in different populations, indicating presence of individual migration among them. Parsimony network of individual genealogies corroborates such gene flow and shows close genetic relationship between Korea and Japan populations and among Canada, Alaska, and the United States populations. Major gene flow occurs asymmetrically from Alaska to Canada populations (16+/-6) individuals per generation), from the United States to Canada populations (5.7+/-1.9), from the North America to the Asia populations (1.4+/-0.2), and from Japan to Korea populations (10+/-3). In the last example of the gene flows (from Japan to Korea), however, human-mediated transplantation of stocks for hatchery operation should be considered in its interpretation.

Acoustic Method for Monitoring and Ecosystem Studies of Pacific Salmon in the Bering and Okhotsk Seas (Summer–Autumn 2003–2004)

Alexander NIKOLAEV

Pacific Scientific Research Fisheries Centre (TINRO-Centre),
4, Shevchenko Alley, Vladivostok, 690950, Russia

The acoustic methods used by TINRO-Centre (laboratory of fisheries hydroacoustic) for study of Pacific salmon behavior in the Bering and Okhotsk Seas in summer – autumn 2003–2004. The uniform technique used for collecting acoustic data by EK-500 (Simrad) scientific echo sounder and system for registration and postprocessing of acoustic data FAMAS (Fishery Acoustic Monitoring and Analyses System, TINRO-Centre).

The FAMAS provides visualization and accumulation of acoustic data in real time, data processing and analysis of acoustic images, organization and maintenance of database acoustic and biological measurements, assessment of large zooplankton stock by a two-frequency algorithm. Processing of acoustic data is combined with biological database for providing assessment of biomass and numbers by length and age. The FAMAS algorithms are provides assignment of mixed species echosigns and species spatial distribution data in survey area and in water column.

Experimental investigations of acoustic technique using for registration and assessment of salmon abundance at anadromous and catadromous migrations in the Okhotsk Sea and western Bering Sea, Pacific water off eastern Kamchatka and Kuril Islands have been carried out. The salmon depth distribution varies depends thermocline depth and salmon swimming activity much higher in daytime.

The vertical and spatial distribution of salmon in upper epipelagic layer are determined on base acoustic data. The daily and seasonal variation of salmon vertical distribution depends of thermal water structure are revealed. The two-frequencies algorithm used for research of large zooplankton daily migration. Spatial distribution and some parameters of its daily vertical migrations in the western Bering Sea was obtained.

The experience of using of acoustic technique in research of Pacific salmon demonstrated that acoustic method give many advantages, in particular for echosigns registration and estimation of vertical distribution of salmon. Merits and demerits of an acoustic method and direction of it perfection by results of surveys are discussed.