NPAFC International Symposium on Bering-Aleutian Salmon International Surveys (BASIS): Climate Change, Production Trends, and Carrying Capacity of Pacific Salmon in the Bering Sea and Adjacent Waters

November 23-25, 2008
Metropolitan-A, Seattle Sheraton Hotel, Seattle, WA, USA

Registration:
November 22, 17:00-19:00 (Lobby on the ground floor)
November 23, 7:30-12:00 (Metropolitan-A Foyer on the 3rd floor)

TENTATIVE PROGRAM (updated Sep 1, 2008)

**Presenter*

November 23 (Sunday)

1. Introduction

8:30-9:00 Welcome, Introduction, and Awards — *E. Farley, J. Helle, and V. Fedorenko*

2. Overviews of Climate Change, Bering Sea Ecosystems, and Salmon Production

Chairperson: Y. Ishida

9:00-9:30 **Overview-1: Projected changes in the physical environment relevant to western Alaska salmon**
N.A. Bond, J.E. Overland, and M. Wang* ………………………………………………… 1

9:30-10:00 **Overview-2: Contemporary status and tendencies in dynamics of Bering Sea macrosecosystem**
*V.P. Shuntov and O.S. Temnykh**…………………………..……………………………….. 2

10:00-10:30 **Overview-3: Abundance and relative contribution of hatchery and wild salmon in the North Pacific Ocean**
G.T. Ruggerone, R.M. Peterman, B. Dorner, and K.W. Myers* …………..……………… 3

10:30-10:50 *Break*

3. Biological Responses by Salmon to Climate and Ecosystem Dynamics

3-1. Migration and Distribution of Salmon

Chairperson: K. Myers

November 24 (Monday)

3-2. Food Production and Salmon Growth

Chairpersons: S. Kang and T. Azumaya

3-3. Feeding Habits and Trophic Interaction

Chairpersons: N. Davis and V. Sviridov

November 25 (Tuesday)

3-4. Production Trends and Carrying Capacity of Salmon

Chairperson: M. Kaeriyama

4. Discussion and Summary on BASIS 2002-2006: Where Do We Go from Here?

Chairperson: E. Farley

14:00-14:20 **The SALSEA Programme – a new initiative to improve understanding of the distribution and migration of salmon in the North Atlantic**
Presenter TBA (NASCO) **43**

14:20-14:40 **Future salmon research: insights from the Long-term Research and Monitoring Project**
D. Beamish **44**

14:40-15:00 *Break*

15:00-15:10 **Session Summary-1: Migration and Distribution of Salmon**
K. Myers

15:10-15:20 **Session Summary-2: Food Production and Salmon Growth**
S. Kang and T. Azumaya

15:20-15:30 **Session Summary-3: Feeding Habits and Trophic Interaction**
N. Davis and V. Sviridov

15:30-15:40 **Session Summary-4: Production Trends and Carrying Capacity of Salmon**
M. Kaeriyama

15:40-17:00 **Discussion: Where do we go from here?**

POSTER SESSIONS

November 23-25, 2008
Metropolitan-A Foyer (3rd Floor), Sheraton Seattle Hotel

3. Biological Responses by Salmon to Climate and Ecosystem Dynamics

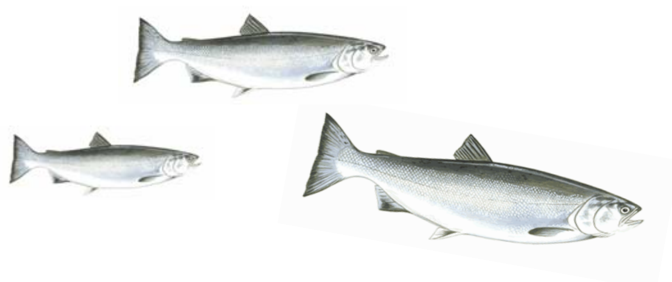
3-1. Migration and Distribution of Salmon

3-2. Food Production and Salmon Growth

3-3. Feeding Habits and Trophic Interaction

3-4. Production Trends and Carrying Capacity of Salmon

ABSTRACTS



Overview-1: Climate Change

Projected Changes in the Physical Environment Relevant to Western Alaska Salmon

Nicholas A. Bond[1], James E. Overland[2], and Muyin Wang[1]

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In preparation for the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, an international group of modeling centers carried out sets of global climate simulations. A total of 23 different coupled atmosphere-ocean general circulation models were employed under common emission scenarios. The objective of this paper is to describe a protocol for using these simulations towards the projection of environmental factors known or suspected to be important to salmon stocks of western Alaska. Our method relies on critical evaluation of the models' 20th century hindcasts. The first step has been to determine the degree to which each available model was able to replicate the spatial pattern, temporal scale and magnitude of variance associated with the leading mode of variability in North Pacific SST, i.e., the Pacific Decadal Oscillation (PDO). The subset of 12 models successful at replicating the PDO were then examined further using a technique known as Bayesian Model Averaging (BMA). This technique provides weighted ensemble means and estimates of uncertainties in the models' predictions for individual parameters in specific regions. For example, Kuskokwim river chum salmon have been found to be sensitive to springtime air temperatures in western Alaska and winds in the vicinity of Unimak Pass (Shotwell et al. 2005); application of BMA indicates that the trends in these two parameters are likely to be deleterious to this particular stock. Other physical parameters that have been analyzed for the Bering Sea include maximum ice extent in spring and SST in summer. In general, our examination of the output from the global climate models indicates it is feasible to begin making projections for regional applications, as long as the physical environmental controls for a specific population or region are known. We consider our technique to be a reasonable way to achieve an early indication of the likely changes in selected fish populations. It should be considered as complementary to direct simulations, in which climate scenarios are used to force regional ocean numerical models, which in turn are linked to biological models, i.e., dynamical downscaling.

Overview-2: Bering Sea Ecosystems

Contemporary Status and Tendencies in Dynamics of Bering Sea Macrosecosystem

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In the Bering Sea the transition from 20 towards 21 century was noted for 8-10 year cyclicity of climate-oceanological processes. Period of 2002-2006 can be regarded as warm, with transition to colder period starting from 2007. Biota response to cyclicity, mentioned above, was equivocal and multidirectional in relation to different hydrobionts in various locations of Bering Sea. Annual dynamics of plankton abundance in the Russian EEZ within the Bering Sea stayed within the range of interannual variability. Sharp decrease of macroplankton biomass in shelf zone of eastern Bering Sea during 2002-2006 was observed. Within Russian EEZ of Bering Sea maximum nekton productivity was observed in 1980-s, which is attributed to very high walleye pollock biomass. In early 1990-s major part of epipelagic layer experienced lowered nekton abundance both in the Bering Sea and in many other areas of North Pacific. During last 10 years gradual increase in nekton abundance was noted. This is related to increase in Pacific salmon, walleye pollock, and, possibly, other fish and squid species abundance. Benthic fish communities experienced similar tendencies. The 2000-s is the period of maximum abundance of Pacific salmon since the start of research of their marine life period. Within the Bering Sea and adjacent Pacific waters off Aleutian Islands their abundance over 2 mln. t. This very abundance did not result in negative effect upon their feeding intensity and environment due to high abundance (primarily within basin and shelf break zones) of major food components – macroplankton and small nekton. Due to adequate food supply, no sharp food competition and strong influence of density-dependence upon Pacific salmon abundance was observed. Generally, Bering Sea macrosecosystem biota is characterized by the normal functional status. Evidently the warm period resulted in increase of Pacific salmon reproductive success within northern areas and pronounced northern migration trend (this was most evident for eastern Bering Sea). Undoubtedly, expansion of southern species into the Bering Sea is a result of its significant warm up in late summer (Pacific saury, Pacific pomfret). However, in 2000-s total abundance estimates of immature Pacific salmon (age .1 and older) have exhibited trend towards decrease. Critical analysis of current ideas on causes, that drive ecosystem changes, is provided. Insufficient understanding of these mechanisms is emphasized. In particular, no adequate explanation can be provided for some phenomena that took place in the eastern Bering Sea shelf zone (grey whales (*Eschrichtius robustus*) mass mortality in Alaskan waters, high abundance of coccolithophore (*Emiliania hyxleyi*) in late 1990-s - early 2000-s in central and eastern shelf zone and multifold decrease in macroplankton biomass (despite of high biomass of small- and medium-sized fractions of zooplankton).

Overview-3: Salmon Production

Abundance and Relative Contribution of Hatchery and Wild Salmon in the North Pacific Ocean

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Pacific salmon have undergone significant fluctuations in adult abundance during the past 50 years even though managers have attempted to minimize fluctuations through the release of numerous hatchery salmon. We reconstructed total abundance (catch plus spawning escapement) of wild versus hatchery salmon in each region of the North Pacific Ocean to evaluate effects of climate change and species interactions on abundance of wild salmon. Wild adult pink salmon were the most numerous salmon species during 1952-2000 (averaging 264 million per year, or 70% of the most abundant three species), followed by sockeye salmon (63 million per year, 17%), and chum salmon (47 million per year, 13%). Wild coho and Chinook salmon abundance averaged approximately 13 million and 3.5 million fish, respectively, during the 1990s (preliminary estimates), and 90% or more of their production was from North America. After the 1976/1977 climatic regime shift, abundances of wild pink and sockeye salmon increased on average more than 50%, whereas abundance of wild chum was lower in recent decades compared with the 1950s and 1960s. In western Alaska (Bering Sea), most wild salmon abundances increased significantly after the mid-1970s. However, significant declines in abundance were observed in some stocks following the 1989 ocean regime shift and/or the 1997/98 El Nino. Annual releases of juvenile salmon from hatcheries increased rapidly during the 1970s and 1980s and reached approximately 5.1 billion juvenile salmon per year during the 1990s and early 2000s. During the 1990s, production of hatchery-origin adult salmon averaged approximately 79 million chum, 46 million pink, 3.5 million coho, 2.9 million sockeye (excluding spawning channel sockeye), and 2.2 million Chinook salmon per year. Hatchery salmon exceeded abundances of wild adult salmon in some relatively pristine habitats, e.g., Prince William Sound (pink and chum salmon) and Southeast Alaska (chum salmon). Hatchery chum salmon represented approximately 63% of total chum salmon abundance. The combined abundance of adult wild and hatchery salmon during 1990-2000 averaged approximately 656 million salmon per year (522 million wild salmon), or approximately twice as many salmon as during 1952-1975. Accuracy of wild salmon abundance estimates is low in some regions, especially where hatchery salmon intermingle with wild salmon in fisheries and on spawning grounds. The large and increasing abundances of hatchery salmon have important management implications in terms of density-dependent processes and conservation of wild salmon populations.

3-1. Migration and Distribution of Salmon (Keynote-1)

Hot and Cold Running Salmon: Lessons from BASIS on Stock-Specific Migration and Distribution Response to Climate Change

Katherine W. Myers*[1], Edward V. Farley, Jr.[2], James E. Seeb[1], Olga S. Temnykh[3], Alexander V. Bugaev[4], Tomonori Azumaya[5], and Shigehiko Urawa[6,7]

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Past research on ocean distribution of Pacific salmon established that regional stock groups of salmon migrate to specific ocean foraging areas. Is there a relation between these regional stock-specific ocean migration and distribution patterns and salmon production trends in Asia and North America? Are regional stock-specific migratory patterns influenced by climate change? Can we use this information to better understand the mechanisms of environmental and density-dependent effects on salmon carrying capacity in the ocean, as well as to improve our ability to forecast abundance trends in international and domestic salmon stocks? The potential to expand our knowledge to address these questions is limited only by the scope of our ocean field-research operations and completion of international baselines for stock identification all salmon species. BASIS was designed to provide the first synoptic seasonal information on migration and distribution patterns of regional stock groups of salmon throughout the Bering Sea. During 2002-2006, field operations coordinated by NPAFC's BASIS Working Group took place primarily in summer and fall. Stock identification methods included genetic techniques, scale pattern analysis, otolith marks, and tags. We briefly review and synthesize results of BASIS research on stock-specific distribution and migration patterns of salmon in the Bering Sea. We further discuss new models and hypotheses of climate-driven changes in migration and distribution patterns of regional stocks of salmon in the Bering Sea.

3-1. Migration and Distribution of Salmon (Oral-1)

Bering-Aleutian Salmon International Survey (BASIS): Population-Biological Researches in the Western Part of Bering Sea (Russian Economic Zone). Part 1 - Chum Salmon *Oncorhynchus keta*

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This work has represented results of identification of regional local stocks of immature chum salmon on the data of trawl surveys of the R/V “TINRO” in the Bering–Aleutian Salmon International Surveys (BASIS) in the Western Bering Sea in summer-fall periods in 2002-2003. The system of districts of the Bering Sea part of the EEZ of RF, accepted in TINRO-Center for making biocenological researches was used in this work. Scale structure was used as a criterion for differentiation. The age composition of mixed marine samples was estimated for the total sample size of 4837 chum salmon individuals, including 3877 fishes which ages were identified in particular. In the analysis there were used three age groups - 0.1, 0.2 and 0.3, taking in the total more than 99% of immature chum salmon in the trawl catches. The basis scale line consisted of 5055 chum salmon individuals from the age groups 0.3 and 0.4. The results of the identification of the complexes of local stocks are as next: three stock complexes predominated in the Western Bering Sea in September-October 2002 in the districts 1-8 - Japan (41,1 %), Sakhalin (Kuriles) + the Amur (34,8 %) and the motherland shore of the Okhotsk Sea + Kamchatka (23,4 %). In the districts 9-12 the dominants were two complexes - Sakhalin-Amur (47,5 %) and Okhotsk Sea (32,1 %). The percent of fishes originated in Japan was visibly lower (20,3 %). The occurrence of Alaskan and Chukotkan chum salmon was extremely insufficient. In July-August 2003 in the districts 1-8 the ratio between chum salmon complexes was as next: Japan – 35,4%; Sakhalin (Kuriles) + Amur – 23,5%; the motherland shore of the Okhotsk Sea + Kamchatka – 28,9%; Alaska – 10,3%; Chukotka – 1,9%. The occurrence of the complex of Alaska there was maximal for the whole observation period 2002-2003. In the districts 9-12 the part of Japan stocks was visibly lower – 9,2%. To the opposite the parts of Sakhalin-Amur (41,6%) and Okhotsk + Kamchatka (44,3%) complexes were higher. The occurrence of Alaskan and Chukotkan chum salmon was minimal – respectively 3,5 and 1,4%. In September-October the part of chum salmon of Japan increased visibly. In the districts 3-8 its’ part reached up to 56,7% and in the districts 9-12 – up to 46,8%. The occurrence of the complexes of the Okhotsk Sea +Kamchatka was also high: 38,8% in the districts 3-8 and 48,7% in the districts 9-12. The parts of the complexes of Chukotka and Alaska were low, but the occurrence of American chum salmon was little bit increased up to 2,4% in the districts 3-8 and up to 3,3% in the districts 9-12.

3-1. Migration and Distribution of Salmon (Oral-2)

Distribution and CPUE Trends of Pacific Salmon, Especially in Sockeye Salmon in the Bering Sea and Adjacent Waters

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Many populations of three abundant Pacific Salmons including pink, chum and sockeye use Bering Sea as their feeding migration waters. Two distinct patterns are apparent in CPUE fluctuation trends of five major north Pacific salmon species in the Bering Sea. The CPUE of pink and chinook salmon increased after 1988 and has remained at this level to present. Whereas, the CPUE of sockeye and chum salmon was low prior to 1977, peaked in 1980, declined until 1989, and then increased until the present. The CPUE trends of sockeye and chum salmon seem to coincide with fluctuations in Bering Sea, sea surface temperature (SST) where higher densities of sockeye and chum salmon in the Bering Sea occur during warm periods and lower densities occur during cool periods especially in sockeye salmon. These some rise or down of the CPUE seem to coincide the hypothesized regime shits at 1976/1977 or 1988/1989. The previous study showed positive correlation between sockeye CPUE and SST in the Bering Sea, but recent analysis indicates that seasonal SST rise at north western portion of the Gulf of Alaska and adjacent waters of Aleutian chain is more related to Sockeye CPUE in the central Bering Sea. Tag recoveries, genetic stock identification, parasite tags and scale analysis showed that most abundant sockeye salmon stock in central and western North Pacific in spring is the Bristol Bay sockeye. The rise of SST around the Alaska Peninsula and Aleutian chain should stimulate the immature Bristol sockeye salmon to penetrate the central Bering Sea in summer. Is the central Bering Sea suitable or not to them?

3-1. Migration and Distribution of Salmon (Oral-3)

Summer and Fall Migrations of Pink Salmon in the Western Bering Sea in 2002-2006

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The features of migrations of pink salmon in the western Bering Sea in summer and fall 2002-2006 are considered. For the first time the migrations of pink salmon of Chukchi and Koryak stocks were elucidated. Comparative analysis of juvenile pink salmon abundance during autumn period and escapement of same generation during the next year has elucidated approximate marine mortality rates of eastern Kamchatka pink salmon in early 2000-s. Whereas marine mortality of Okhotsk Sea pink salmon averaged 89 % (for October – July-August period), the respective values for eastern Kamchatka pink salmon were lower. In 2000-s the major migratory pathways of pink salmon were shifted somewhat northward as compared to 1990-s. The other distinctive feature of pink salmon migrations during the recent years is their rapid character. The major explanation of distinctiveness of 2000-s summer period mature pink salmon summer migration may be the favorable foraging and maturation conditions during the relatively "warm" period of 2002-2006 in the Bering Sea. Favorable feeding conditions may be indirectly implied by average length characteristics for June-July period. In 2000-s despite of high abundance, the average length and weight of mature pink salmon in south-eastern Bering Sea was significantly higher compared to 1990-s. The coastal catches statistics also implies tendency in growth of both abundance and size of mature pink salmon during recent years. Both for even and odd-year generations, correlation analysis revealed no statistically significant relationship between overall escapement and average body size. These results imply that growth of eastern Kamchatka pink salmon abundance, which started in 1970-s and was particularly noticeable in 1990-2000-s, did not result in lowered length characteristics due to density-dependence mechanisms. The results described above may testify for relatively favorable foraging environment of eastern Kamchatka pink salmon during 1990-s and particularly 2000-s.

3-1. Migration and Distribution of Salmon (Oral-4)

The Use of Genetic Stock Identification to Determine the Distribution, Migration, Early Marine Survival, and Relative Stock Abundance of Sockeye, Chum and Chinook Salmon in the Bering Sea

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We report the stock composition and seasonal distribution of Asian and North American salmon collected in the Bering Sea during 2002-2006 using genetic markers. This collaboration stems from seed monies from the North Pacific Research Board and extensive funding from the host agencies. We detail the BASIS stock composition research that progressively improved though genetic markers including allozymes, microsatellites, and finally single nucleotide polymorphisms (SNPs). Improvements in DNA techniques during this project were so profound that continuation support was provided for the additional development of public SNP data bases for use by NPAFC and other agencies. We report rapid advances in DNA technology for chum salmon studies using highly parallel DNA sequencing for SNP discovery. Here we focus upon the SNP database for chum salmon and provide examples for resolving proportional and individual assignment of migrating fish in Bering Sea mixtures.

3-1. Migration and Distribution of Salmon (Oral-5)

Stock-Structured Distribution and Abundance of Western Alaska Juvenile Chinook Salmon Populations in the Eastern Bering Sea, 2002-2007

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Stock-structured distribution and abundance estimates from United States BASIS surveys in the eastern Bering Sea during 2002-2007 are used to provide insight into the migratory behavior and processes impacting the production of Western Alaska Chinook salmon. Origin of juvenile Chinook is evaluated using a single nucleotide polymorphism (SNP) baseline developed and refined for Western Alaska Chinook populations by the Gene Conservation Laboratory at the Alaska Department of Fish and Game. Stock information is integrated into abundance estimates using spatial models of distribution and abundance and from expansions of average catch rate within spatial strata optimized to the estimated migration corridors of juvenile Chinook salmon. Abundance estimates are compared with escapement levels and subsequent adult returns and evaluated in terms of the production and survival of Western Alaska Chinook populations.

3-1. Migration and Distribution of Salmon (Oral-6)

Stock-Structured Distribution of Immature Sockeye Salmon Populations South of the Aleutian Arc during the Summer

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The Bering Sea and the North Pacific Ocean provide the major feeding habitats during the summer for sockeye salmon stocks originating from throughout the Pacific Rim. A better understanding of stock-specific distribution throughout these areas may clarify the mechanisms of salmon population response to recent environmental changes. Stock distribution of immature sockeye salmon in the Bering Sea during the summer has been documented using both tagging data and more recently with genetic data. The genetic data provided more detailed and more extensive coverage than the tagging data. The distribution of stocks just south of the Bering Sea, both in the Gulf of Alaska and in the eastern North Pacific has only been gleaned through tagging studies. We will use genetic data to analyze fish captured on BASIS surveys south of the Alaska Peninsula and Aleutian Arc to provide context to the previous findings of stock distributions within the Bering Sea.

3-1. Migration and Distribution of Salmon (Oral-7)

Stock-Specific Ocean Distribution and Migration of Chum Salmon in the Bering Sea and North Pacific Ocean

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Chum salmon (*Oncorhynchus keta*) is a major pelagic fish species in the Bering Sea ecosystems. The stock-specific ocean distribution of chum salmon was estimated by genetic stock identification (GSI) and otolith marks. Fish were caught by 1-h trawl at 63 stations in the Bering Sea and North Pacific Ocean during the summer (June/July) and early fall (August/September) of 2003. Tissue samples were collected from chum salmon (n=3,982), and run for 20 allozyme loci to estimate the stock composition of mixtures. In addition, otoliths were collected from chum salmon (n=3,982), and examined for mark pattern to determine the hatchery origin. The GSI-estimates combined with catch data (CPUE) indicated that the ocean distribution patterns of immature chum salmon were different among regional stocks. The Japanese stock was mainly distributed in the central Bering Sea. The distribution of the Russian stock was similar to that of Japanese chum salmon, but it also spread into the North Pacific Ocean. The northwestern Alaska stock including fall runs in the Yukon River were distributed mainly in the southern edge (40ºN) of the Gulf of Alaska. The Alaska Peninsula/Kodiak stock was widely distributed in the Bering Sea and North Pacific Ocean. The Southeast (SE) Alaska/North BC stock appeared in the northern Gulf of Alaska and southern Bering Sea. The distribution of the South BC/Washington stock was similar with that of SE Alaska/North BC stock, but expanded to the northern Bering Sea. The present samples included otolith-marked chum salmon released from Alaska (n=67), Canada (n=3), Japan (n=22), and Russia (n=6). The recovery sites of marked fish were almost consistent with the marine distribution of those regional stocks estimated by GSI. We estimated the stock-specific migration patterns of chum salmon in the Bering Sea and North Pacific Ocean from best available information including ocean conditions and winter habitats.

3-1. Migration and Distribution of Salmon (Oral-8)

Pacific Rim Stock Identification of Chum Salmon (*Oncorhynchus keta*) with Microsatellites

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Variation at 14 microsatellite loci was analyzed for over 53,000 chum salmon (*Oncorhynchus keta*) sampled from over 370 locations ranging from Korea to Washington, and the variation applied to estimate stock composition in mixed-stock fishery samples. High resolution of mixed-stock samples was possible, with 1 reporting group developed for Korean populations, 7 groups for Japanese populations, 8 groups for Russian populations, 15 groups for Alaskan populations, 5 groups for Canadian Yukon River populations, 16 groups for British Columbia populations, and 5 groups for Washington populations. The number of alleles observed at a locus was related to the power of the locus in providing accurate estimates of stock composition of single-population mixtures. Approximately 700 alleles were observed across the 14 microsatellites, providing the basis for high-resolution stock identification. Analysis of known-origin samples indicated that accurate regional estimates of stock composition were obtained. Estimated stock compositions of mixed-fishery samples from coastal Japan, the Sea of Okhotsk, the northwest Pacific, the northeast Pacific, and coastal British Columbia were quite different among samples, and clearly reflected the presence of local populations. Microsatellites have provided the ability to provide accurate estimates of stock composition from many locations in the Pacific Rim distribution of chum salmon.

3-1. Migration and Distribution of Salmon (Oral-9)

Regional Stock Mixture of Juvenile Chum Salmon (*Oncorhynchus keta*) in the Western Bering Sea during Summer-Autumn 2004

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This paper reports on the ocean mixtures of regional stocks from 826 juvenile chum salmon (*Oncorhynchus keta*) specimens collected from 48 stations in the western Bering Sea during September 26 to October 23, 2004 by the Russian R/V *TINRO*. The regional origins are identified from genetic characteristics derived from fin ray specimens analyzed by the single nucleotide polymorphisms (SNP) technique, and classified against the genetic sequences of 76 known chum salmon populations from the North Pacific Rim countries. The analysis of genetic sequences from the phylogenetic trees and AMOVA tests indicate that the chum salmon specimens came from four regional groups: the Korea-Japan-Primorie region (42%), Russia (41%), Northwest Alaska (13%), and the other North American group (4%).

3-1. Migration and Distribution of Salmon (Oral-10)

Behavior of Chinook Salmon in the Bering Sea as Inferred from Archival Tag Data

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Is marine survival of Chinook salmon more affected by variability in ocean temperature than by variability in fishing mortality? Understanding the issue is complicated by a lack of information on migration and behavior of Chinook salmon. An archival tag placed on a Chinook salmon in the Bering Sea in 2002 was recovered in the Yukon River in 2004. We will analyze temperature and depth data recorded by the tag to demonstrate changes in behavior with respect to thermal and vertical habitat during the eight seasons and two maturity stages the fish was at liberty after tagging. The data from the final spring and summer will be compared with temperature and depth data from another tag on a maturing Yukon River Chinook recovered in 2005. That tag also recorded salinity data. Behavior inferred from these tags will be examined in the context of information from groundfish fishery operations and bycatch.

3-1. Migration and Distribution of Salmon (Oral-11)

Beyond BASIS – Salmon in the Arctic

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With climate change, scientists need to evaluate the possibility of Arctic waters becoming more important for Pacific salmon. The Chukchi (adjacent to and north of the Bering Sea) and Beaufort (coastal waters east of Chukchi Sea to the Mackenzie) seas are generally regarded as biologically unproductive, largely because of long periods of ice cover. With climate change, the extent and duration of ice cover is diminishing and waters are warming, which should increase the biological productivity of these areas, making them more hospitable for juvenile salmon. Significant pink and chum catches during 2007 in the Chukchi Sea highlight the possibility of expanding juvenile salmon rearing habitats in the Arctic. Chum, pink, sockeye, coho, and chinook salmon have been encountered east of the Chukchi within Canadian Arctic waters. While there is some evidence of recent increases in the frequency of occurrence of pink salmon in the western Canadian Arctic, pink salmon east of Prudhoe Bay are generally considered to be vagrants. Coho, sockeye, and chinook salmon, with apparently less tolerance for cold waters than pink and chum, are rarely encountered east of Point Hope, and chum is the only species thought to be natal to the Mackenzie River and tributaries. It is not known where in the ocean these fish rear although preliminary stable isotope results suggests they reside in an estuarine environment rather than the open ocean. Over 3300 km^3 of fresh water enters the Arctic Ocean annually, of which runoff from the Mackenzie River is a significant component. Whether the Mackenzie River plume goes west in the Beaufort Gyre, or goes east, is influenced by ice cover and winds – both of which are climate variables. In this presentation, we provide an update on the status of Pacific salmon in the Arctic, discuss the role of northern marine environments as rearing areas for young salmon, and speculate on how Pacific salmon are likely to be affected by climate change in the Arctic.

3-2. Food Production and Salmon Growth (Keynote-2)

Influence of Ocean Environment on a Reduction of Japanese Chum Salmon (*Oncorhynchus keta*) Body Size

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In the 1990s, a reduction of Japanese chum salmon (*Oncorhynchus keta*) body size was observed. In order to investigate the body size reduction of Japanese chum salmon in the North Pacific, we developed a fish bioenergetic model for chum salmon. The model was driven by SST and zooplankton density obtained from NEMURO. Although the model did not include density dependent effect (carrying capacity), this model reproduced the body size reduction of chum salmon. The model showed that the size reduction was caused by the prey density in the eastern North Pacific during winter and spring seasons. This result suggests that the carrying capacity for chum salmon in the Bering Sea is enough.

3-2. Food Production and Salmon Growth (Oral-12)

Physical Oceanographic Conditions Over the Bering Sea Shelf, 2002-2007

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We present an overview of the eastern Bering Sea shelf physical oceanography as depicted by hyrographic survey data collected on the U.S. BASIS cruises over the years 2002-2007. Differences between years include extent of the cold pool, water column heat and fresh water contents, strength of the vertical stratification and the magnitude of the cross-isobath density gradients. Spatial variations in interannual water mass property fluctuations provide a foundation for delineating robust physical subdomains. We examine the physical forcings that help control variability within these domains and the system as a whole. Environmental variables examined include wind mixing, Ekman transport, surface heat fluxes, ice cover and river discharge. Better understanding of how these controls interact with and modify the various shelf water masses will further the ultimate goal of helping to provide a better mechanistic understanding of the overall shelf dynamics and ecosystem.

3-2. Food Production and Salmon Growth (Oral-13)

Spatial and Interannual Variability in Nutrients, Phytoplankton and Zooplankton in the Eastern Bering Sea: Results from U.S. BASIS Surveys for 2002-2007

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Physical and biological oceanographic data were collected during late summer / early fall in the eastern Bering Sea on U.S. BASIS cruises during 2002-2007. We compare variations in nutrient and chlorophyll a concentrations, and zooplankton taxonomic composition in relation to physical oceanographic features for warm and cold years. Our analysis will include comparisons of spatial variations across frontal regions and between physical sub domains (e.g. Inner, Middle and Outer Domains), and across large latitudinal gradients (southern compared to northern Bering Sea) for nutrients and plankton. This analysis will provide habitat information that relates to growth, abundance and distribution of juvenile salmon and their prey, and allow us to gain an understanding of the underlying oceanographic processes affecting the eastern Bering Sea ecosystem and potential response to climate fluctuations.

3-2. Food Production and Salmon Growth (Oral-14)

Effects of Diet Changes on the Energy Content of Juvenile Pink Salmon *Oncorhynchus gorbuscha* in the Eastern Bering Sea from 2003 to 2007

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Interannual variation in juvenile pink salmon *Oncorhynchus gorbuscha* energy density was examined to assess the influence of a diet shift in the southeastern Bering Sea from 2003 to 2007. Juvenile pink salmon were collected during the United States BASIS surveys in the eastern Bering Sea to determine how ocean conditions affect the condition of these fish. Warmer spring and summer sea temperatures prevailed from 2003 to 2005 on the eastern Bering Sea shelf, whereas cooler spring and summer sea temperatures occurred from 2006 to 2007. During the same time period in the southeastern Bering Sea, a marked change in juvenile pink salmon diet occurred between the warm years and cool years; walleye pollock *Theragra chalcogramma* dominated the diet (60-75% wet mass) in warm years while euphausiids dominated the diet (45-75% wet mass) in cool years. Juvenile pink salmon energy densities were examined to determine if significant differences existed between warm years and cool years in the southeastern Bering Sea. These results can provide insights into how climate change and diet affect pink salmon survival in the subarctic.

3-2. Food Production and Salmon Growth (Oral-15)

Forage Base of Pacific Salmon in the Western Bering Sea and Adjacent Pacific Waters in 2002-2006

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The study was based on data collected as part of Bering-Aleutian Salmon International Survey (BASIS) by TINRO-Centre in the upper epipelagic zone of the western Bering Sea and adjacent Pacific waters in summer and fall 2002-2006. Zooplankton was sampled under unified approach, accepted in TINRO-Centre (Volkov 1996). Nektonic part of Pacific salmon forage base was estimated using a mathematic model of selective feeding (Sukhanov and Zavolokin 2006). Input data of the model consisted of: (1) feeding spectrum of pink, chum, sockeye, chinook and coho salmon; (2) zooplankton composition (large fraction – items >3 mm); (3) initial value of estimated parameters. Output data contained estimation of electivities and unknown fractions of squid and fish from the total zooplankton biomass. In 2002-2006 total density of salmon forage base (plankton + nekton) varied from 690 to 1590 mg/m^3. It was the lowest in fall 2004 and the highest in fall 2002. Copepods and chaetognaths dominated the potential forage base. The proportion of squids and fish was 15-42 % (in average 27 %) of the overall biomass. The part of fish was the highest in shelf (Anadir Bay). Squids were more abundant in deep-water regions of Bering Sea and adjacent Pacific waters. *Theragra chalcogramma, Clupea pallasii and Mallotus villosus* were dominant nektonic species in shelf. *Gonatus kamtschaticus*, *Gonatopsis borealis, Pleurogrammus monopterygius* and myctophids were prevalent item of salmon forage base in deep-water areas.

3-2. Food Production and Salmon Growth (Oral-16)

Alaska Sockeye Salmon Scale Patterns as Indicators for Climatic and Oceanic Shifts and Anomalies in the North Pacific Ocean

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Climate change is expected to have a dramatic affect on marine ecosystems in Subarctic regions. Our ability to detect and forecast changes in offshore climatic and oceanic conditions will assist in preparing society for changes in availability of resources for harvest in the commercial, subsistent, personal use, and sport fisheries. Pacific salmon are a highly migratory species in their marine phase and record their abiotic and biotic experiences in the growth patterns on their scales. Scale pattern analysis is a prime candidate for detecting changes in the climatic and oceanic conditions in the marine environment. In this study we use time series and state space modeling approaches to determine whether we can detect major shifts and anomalies (e.g. regime changes, El Nino and La Nina events) in the climatic and oceanic conditions in the eastern and central North Pacific Ocean from measurements of the annual marine growth patterns on the scales of sockeye salmon that returned to Karluk River on Kodiak Island in the Gulf of Alaska over an 80 year time period, 1924-2003.

3-2. Food Production and Salmon Growth (Oral-17)

Bias-Corrected Size Trend of Chum Salmon in the Central Bering Sea and North Pacific

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Since 1972, Japanese research vessels have monitored salmon stock condition in the Bering Sea and North Pacific by catching fish using a research gillnet consisting of ten different mesh sizes. Mean fork lengths of chum caught by research gillnet decreased from the 1970s to the 1990s, but recently the trend has been for increasing chum salmon body size. Although the catch efficiency of research gillnets was considered to be relatively constant over a wide range of fish size, recent studies have shown that fish size is biased in catches from multi-mesh research gillnets due to size selectivity of this fishing gear. Surface trawls were the standard fishing gear used to collect salmon in BASIS surveys. We conducted trawl and gillnet operations at the same locations and over a short time interval in the central Bering Sea using the research vessels *Kaiyo maru* and *Wakatake maru* to compare fish sizes caught by the two fishing gears. A bias-correction coefficient for chum salmon size was obtained from an estimation of size selectivity based on the two gear types. We will apply the coefficient to correct the bias in fork length data collected from gillnet catches, and will test whether temporal trends of corrected and uncorrected chum salmon mean fork lengths are similar.

3-2. Food Production and Salmon Growth (Oral-18)

Juvenile Pink and Chum Salmon Foraging Conditions, Growth Potential, and Distribution in Response to the Loss of Arctic Sea-Ice

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Climate models predict the arctic to be ice-free by 2030. The loss of Arctic sea-ice will have a profound influence on Arctic ecosystems and marine resources dependent on them. Insight is provided into the potential increased utilization of the Arctic by juvenile salmon associated with the loss of sea ice by examining the foraging conditions, growth potential, and distribution of juvenile pink and chum salmon in the Chukchi Sea during the significant retreat of sea ice that occurred in 2007. Juvenile salmon were sampled in the northern Bering and Chukchi Sea as part of the United States BASIS survey with the objective of investigating implications of climate change on salmon ecology. Juvenile pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon growth histories were reconstructed from scale circuli patterns, food habits were identified through diet analyses, and growth potential modeling simulations were run to quantify spatial differences in marine habitat. Large catches of juvenile pink and chum in the Chukchi Sea during early autumn 2007 reflected significant utilization of Arctic habitat and was likely in response to warm surface sea temperatures and the extensive loss of sea-ice during the summer. Growth rate was significantly higher for fish inhabiting the Chukchi Sea than those inhabiting the Bering Sea. Larval prickleback (*Lumpenus fabricii*) were heavily preyed upon in the central Chukchi Sea and zooplankton was primarily consumed in the southern Chukchi and northern Bering Sea. The Chukchi Sea is assessed through habitat-specific growth potential models in an effort to increase our understanding of how the loss of sea-ice will impact the growth and survival of salmon.

3-2. Food Production and Salmon Growth (Oral-19)

The Relations of Food Availability and Oceanic Region to Growth of Coho Salmon: Perspectives from the Northern California Current

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Levels of the hormone insulin-like growth factor I (IGF-I) were measured to index growth of post-smolt coho salmon in a series of research cruises off the Oregon-Washington coast. Significant differences in mean June IGF-I level have been found between years, suggesting that ocean growth differs among these same years (2000 – 2007). A positive relation was found between plasma IGF-I levels and an index of relative food abundance, with increasing food related to higher IGF-I levels. A positive relation was subsequently found between mean June IGF-I level and survival of adult Oregon Production Index coho 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. In 2007 an extended survey, from Central Oregon to Southern Alaska (44.6 - 56.3°N), was accomplished. Data from these cruises show that juvenile coho salmon growth was higher in the Alaska Coastal Current and Transition domains than in the California Current System, suggesting that ocean conditions were more favorable for growth at these northern latitudes. Together, these data demonstrate both inter- and intra-annual variation in juvenile salmon growth occurs, that at least some of this variation can be linked to varying food supply and that variations in growth can be linked to subsequent performance (survival). Acknowledgements: NOAA Fisheries, CDFO, Bonneville Power and the Pacific Salmon Commission supported this work.

3-3. Feeding Habits and Trophic Interaction (Keynote-3)

Review of BASIS Food Habits Studies and Considerations on Continuing and New Research Directions

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An overall BASIS goal is to incorporate oceanographic, salmon migration, growth, feeding, and mortality process in models "to advance our understanding of changes in productivity of salmon populations in the Bering Sea" against a backdrop of forecasted climate-ocean and ecosystem state changes. Studies of feeding habits and species interactions are an important component of future model development as these studies provide a method by which changes in salmon condition and species interactions can be observed. To synoptically review the current state of BASIS food habits studies, we will summarize seasonal mean SCI and prey composition by species and body size for 2002-2006 for northern and southern portions of the western, central, and eastern Bering Sea. Trends in feeding habits and species interactions by geographical area and salmon species and size will be discussed. The possibility of particular prey items that might be an indicator of salmon feeding condition will be examined. One example might be the pteropod *Limacina*. This shelled animal is important to salmon at particular points of their life history and may be sensitive to levels of ocean acidification and thereby also indicate changes in salmon ocean habitat. In addition, we will discuss those prey species that may confound future modeling approaches because, from a salmon perspective, they fit more than one ecological role. For example, prey species that are both prey and competitors of salmon, or prey that are both prey and predators of salmon.

3-3. Feeding Habits and Trophic Interaction (Oral-20)

Changes of Zooplankton Structure and Bioproductivity in the Bering Sea at the Beginning of the 21st Century

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The Bering Sea is highly productive region of the World Ocean and its living resources have great significance for the fishery. The estimation of distribution, structure and production of zooplankton species, which are food resources of pelagic fishes, are of great importance as every year high numbers of pelagic fishes undertake feeding migrations to this sea from other region of the Northwestern Pacific. Six cruises were carried out in the western part of the Bering Sea during 2001-2006 periods in order to study fish and zooplankton communities (species composition, distribution, abundance) in relation to the physical environment. The data obtained also used for functional division of the sampled animals by trophic groups such as "predatory" and "non-predatory" taxa. Trophic and production characteristics of the zooplankton communities were analyzed for the western Bering Sea in the inner shelf, outer shelf and deep water regions for summer and fall. Environmental conditions and zooplankton productivity were highly variable during that time. In the different landscape zones productivity of "non-predatory" zooplankton (herbivorous and omnivorous species) ranged 56-222 g/m^2 in fall and 61-656 g/m^2 in summer period. Productivity of "predatory" zooplankton (mainly sagittas) vary over a wide range too (12-66 g/m^2 in fall and 21-168 g/m^2 in summer period). In whole higher value of zooplankton productivity were observed in deep water region. An analysis of the ice conditions and weather situation on the Bering Sea at the beginning of the 21st century allow to describe as "warm" years (Glebova 2005). Increased inflow of warm Pacific Ocean waters into the Bering Sea has effected growth rates of all plankton species. It was a fact in 2003, when such oceanological situation took place in the Bering Sea (Glebova 2005). In 2000-ies the average weighted value of P/B-ratio was higher compared to that in 1990-ies. The results of this are considerably high values of dominant taxonomic groups' production and "real" (i.e. production is available for fishes) zooplankton production. In the eastern Bering Sea size and taxonomic structure of zooplankton are different from that in the western part. The production characteristic of the zooplankton communities are known to reflect its structural features. An increase in the abundance of small and medium-size copepods with high growth rate may positively affect the P/B ratio of non-predatory zooplankton in eastern part of Sea.

3-3. Feeding Habits and Trophic Interaction (Oral-21)

Zooplankton Species Composition, Abundance and Biomass on the Southeastern Bering Sea Shelf during Summer: the Potential Role of Water Column Stability in Structuring the Zooplankton Community and Influencing the Survival of Planktivorous Fishes

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The southeastern Bering Sea sustains one of the largest fisheries in the nation, as well as wildlife resources supporting valuable tourist and subsistence economies. The fish and wildlife populations in turn are sustained by a complex food web linking primary producers to apex predators through the zooplankton community. Recent shifts in climate toward warmer conditions may threaten these resources by altering trophic relationships in the ecosystem on the southeastern Bering Sea shelf. We examined the zooplankton community on the middle shelf of the southeastern Bering Sea in summer of 1999 and 2004 for any significant differences in species composition, abundance or biomass by region and year. Between August 1999 and August 2004, the summer zooplankton community of the middle shelf shifted from large to small species. Significant declines were observed in the biomass of large scyphozoans (*Chrysaora melanaster*), large copepods (*Calanus marshallae*), arrow worms (*Sagitta elegans*) and euphausiids (*Thysanoessa raschii, T. inermis*) between 1999 and 2004. In contrast, significantly higher densities of the small copepods (*Pseudocalanus* spp., *Oithon similis*) and small hydromedusae were observed in 2004 relative to 1999. The shift in the zooplankton community was accompanied by a three fold increase in water column stability in 2004 relative to 1999, primarily due to warmer water above the thermocline, with a mean temperature of 7.3^{o}C in 1999 and 12.6^{o}C in 2004. The elevated water column stability and warmer conditions may have influenced the zooplankton composition by lowering summer primary production and altering the metabolism of the planktonic invertebrates, thus selecting for species more tolerant of a warm environment supported by recycled nutrients. Stomach analysis of zero-class pollock from the middle shelf indicated a dietary shift from large to small copepods in 1999 relative to 2004. Winter survival of zero-age pollock was higher by six times in 1999 relative to 2004. This research suggests that if climate on the Bering Sea shelf continues to warm, the zooplankton community may shift from large to small taxa, thus altering energy transfer to commercial fish species, and potentially impacting the fisheries and the economies they support.

3-3. Feeding Habits and Trophic Interaction (Oral-22)

The Role of Pacific Salmon in Trophic Structure of the Upper Epipelagic Layer in the Western Bering Sea during Summer-Autumn 2002–2006

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Results of 6 surveys conducted by TINRO-Centre in frames of international BASIS program in the upper epipelagic layer of the western Bering Sea in summer and autumn 2002–2006 are summarized. Food relationships of nekton are determined and consumption of forage resources by nekton organisms is estimated. The overall amount of forage resources consumed by nekton in the upper epipelagic layer of the western Bering Sea was 9.7 million tons in the period of high abundance of juvenile walleye pollock in 2002–2003 and 3–5 times less in the period of low walleye pollock abundance in 2004–2006. In 2002–2003 the main consumers of forage resources was walleye pollock, in 2004–2006 — were Pacific salmon, squids, and sometimes Atka mackerel (yearlings), herring and capelin. Pacific salmon utilized 2.3 million tons of different zooplankton and nekton forage organisms during summer and 1.3 million tons during autumn (note that in autumn biomass of juvenile salmon in the western Bering Sea was relatively low). The main part of forage resources was consumed (by nekton) in deep-water areas (Commander Basin and western Aleutian Basin) in summer. In autumn (especially 2002–2003 when pollock juveniles were abundant) the area of maximal consumption shifted to Olyutorsky and Anadyr Bays, and Navarin shelf. In such a away, the carrying capacity of the western Bering Sea for producing Pacific salmon varies with changing environmental factors (in this case with changing of abundance the main consumers of forage resources). Spatio-temporal differences of consumption due to feeding migrations of main consumers is very important for trophic structure of western Bering Sea ecosystem because it allows to avoid overexploitation of forage resources in the upper epipelagic layer during summer–autumn feeding period and at the same time it provides their more complete utilization.

3-3. Feeding Habits and Trophic Interaction (Oral-23)

Feeding Behavior of Pacific Salmon in the Bering Sea and Status of Their Forage Base during 2003-2007 Period

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During the period of BASIS implementation the diverse information on Pacific salmon feeding behavior and plankton community structure was obtained for entire Bering Sea and northern Pacific Ocean. During the period of 1984-2008 over 9000 plankton stations were carried out within Russian EEZ. In addition, approximately 600 plankton stations were carried out during 2003-2007 as the result of BASIS comprehensive international program in the eastern and central Bering Sea. The obtained information allowed to map quantitative distribution of major zooplankton taxa and species over the large regional scale. Distinct spatial and temporal features of plankton communities were elucidated. It has been elucidated that deep-water areas are dominated by large-size plankton fraction (65-95%), whereas shallow zone – by small-size and medium-size fractions (90-55%). However, in 2006 the increase of large-size plankton fraction was observed and resulting decrease of other size-fractions. In 2006 western Bering Sea experienced stably high copepod biomasses, whereas euphausiids and hyperiids biomasses increased to the highs of 2003-2004 (biomass minimum was observed in 2005). In 2006-2007 eastern Bering Sea experienced sharp growth in large-size fraction biomass due to increase abundance od copepods, chaetognaths, and, in a lesser extent, euphausiids. Spatial differences in plankton communities composition influenced peculiarities of Pacific salmon feeding behavior. In pink, chum and sockeye salmon, despite of overall similarity in feeding behavior, species-specific and regional differences in food composition were observed. Among these species, it was only chum salmon that preferred gelatinous zooplankton species (small jellyfishes and ctenophores) and gelatinous zooplankters (appendicularians and *Clione* spp. of Pteropoda). Eastern Bering Sea is noted for a relatively low biomass of forage zooplankton species, as compared to other parts of the Bering Sea. This results in Pacific salmon switching their diets from zooplankton to fish larvae and juveniles and to decapod larvae. In addition, it has been found out that pink, chum, sockeye, coho and chinook salmon (both immature and mature individuals) are characterized by similar diel feeding cycle.

3-3. Feeding Habits and Trophic Interaction (Oral-24)

A Comparison of Jellyfish Distribution to Oceanographic Characteristics and Salmon Distributions during a Warm Year (2004) and a Cold Year (2006) in the Eastern Bering Sea

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On the eastern Bering Sea shelf, spring SST was lower, ice retreat was later and the cold pool was located further south in 2006 (cold year) compared to 2004 (warm year). Overall, fall forage fish catches were also lower in 2006 compared to 2004. A group that may be especially responsive to this climatic variation is jellyfish. The BASIS (Bering Aleutian Salmon International Survey) survey was used as a platform for estimating biomass, distribution, and size frequency of large medusae caught in surface trawls during late summer/early fall. Six species were identified from the surface trawls; *Aequorea sp*., *Chrysaora melanaster*, *Cyanea capillata*, *Staurophora mertensi*, *Aurelia labiata*, and *Phallocephora camstichatica*. Each species was compared to water mass characteristics (salinity, temperature, chlorophyll at 5 m, and water column stability) and fish catches (juvenile and adult chum salmon, *Oncorhynchus keta*, and sockeye salmon, *O. nerka*) using cumulative frequency distribution plots which look at frequency of association to different parameters in terms of percent catch of jellyfish species. A clear difference is observed in the distributions and biomass of the six jellyfish species in response to the various conditions in the warm year verses cold year. All but one jellyfish species had lower biomass in the cold compared to the warm year.

3-3. Feeding Habits and Trophic Interaction (Oral-25)

Diets and Appetites of Hatchery-Reared and Wild Coho Salmon in the Strait of Georgia

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Wild and hatchery-reared coho salmon (*Oncorhynchus kisutch*) have now co-existed in the Pacific northwest for 30 years. Wild coho salmon in the Strait of Georgia have consistently exhibited marine survivals greater than those of hatchery coho. This superior survival occurs despite the larger average size of hatchery coho compared to their wild counterparts, a characteristic that has been shown to be directly related to marine survival. One method to achieve this is via differences in feeding: either how much is consumed ("appetite"), and/or what is consumed ("diet"). This study will be the first to examine long-term dietary comparisons of juvenile hatchery and wild coho salmon in the marine environment, namely the Strait of Georgia, British Columbia, Canada. In the Strait of Georgia from 1997-2007, hatchery coho in July were, on average, 11.6% larger than wild coho, whereas by September this difference was generally < 5%. This suggests that the initial disparity in size between hatchery and wild coho salmon decreases over the first year of marine residence. There were no significant differences between hatchery and wild coho in either appetite (volume of prey in the stomach) or in diet (analysis of stomach contents) in either July or September surveys from 1998-2007. Shifts in diet did occur annually and seasonally, but both hatchery and wild coho salmon shared the overall trends. In all years, diets in July surveys were dominated by decapods and teleosts, primarily crab megalops and herring, respectively. In September, euphausiids and amphipods dominated. Variability between hatchery and wild coho diet choices were larger in September surveys than in July surveys. Stomach volume, stomach fullness and fork length were significantly correlated between hatchery and wild coho in both July and September surveys. The data indicates that the superior marine survival of wild coho salmon in the Strait of Georgia is not due to differences in appetite or diet.

3-3. Feeding Habits and Trophic Interaction (Oral-26)

Lipid Content of Immature Chum Salmon in the North Pacific Ocean and Bering Sea

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Prey amount and climate change would affect the trophic status of salmon in the marine stage of their life history. Trophic status of salmon may be useful to understand the state of organisms and populations. In this study the total lipid contents of immature chum salmon were measured for estimating their trophic status. Total lipid contents were decided using Torry fish fat meter (Distel Co.) which is non-destructive microwave fat: water content meter and the Bligh Dryer method with chloroform and methanol. The lipid contents of 4,746 immature chum salmon were measured. The salmon were captured in the Bering Sea and North Pacific Ocean in the summer of 1998-2007, the fall of 2002-2003, the winter of 1998, 2006, and the spring of 2006. It was shown that the total lipid content increased in both of summer and fall and considerably decreased in winter. In same season, the total lipid content showed a difference between places and years. These results were the same regardless of the method. Their trophic status could be variable according to their ocean habitats related with ocean climate change. Total lipid content can be used as their condition marker and long-term trophic monitoring should be valuable in salmon research.

3-3. Feeding Habits and Trophic Interaction (Oral-27)

GIS Analysis of Potential Trophic Interactions between Pacific Salmon and Their Predators during Marine Life Period

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Correct estimates of predator-related Pacific salmon mortality should take into account total abundance estimates of Pacific salmon and their predators, as well as degree of predator-prey spatio-temporal overlap. Variability in degree of predator-prey spatio-temporal overlap is important for understanding interannual differences in Pacific salmon survival. In this study different GIS techniques were employed to quantify and interrelate carnivorous fish and Pacific salmon distribution and total abundance over the range of spatio-temporal scales. Only fish species, which typically prey upon Pacific salmon, were analyzed. BASIS surveys data for 2002-2007 period (including information on observed injuries), as well as TINRO-Center trawl surveys archival data (over 20 thousand research trawl stations covering entire Russian EEZ) for 1980-2007 period were utilized. GIS analysis was employed to quantify Pacific salmon and their predators total and relative abundance estimates for every season, large-scale geographic domain (Bering, Chukchi, Okhotsk and Japan Seas and adjacent waters off North Pacific), small-scale geographic domain (shelf, continental slope, deep-water basins) and water strata (upper epipelagic, lower epipelagic and mesopelagic layers). Discussion on methodology of GIS techniques for estimating local and total abundance of Pacific salmon and their predators was provided. Different spatio-temporal domains of Russian EEZ were ranked in relation to Pacific salmon and their predators' species composition, abundance and degree of predator-prey spatial overlap. Pacific salmon predators distribution patterns were related to those of salmon and species-specific inferences on resulting spatio-temporal variability in salmon mortality were made. The predation intensity is likely to increase during the periods of lowered Pacific salmon abundance, accompanied by increased abundance and geographic range expansion of their predators. Ratio of total abundance of Pacific salmon species to that of certain predator at a given time period and location may serve as indirect measure of resulting predation intensity. Predator spatial distribution pattern is often a tradeoff between selection of optimal abiotic environment and better feeding conditions. Therefore, density-dependent habitat selection processes and climate-induced changes in spatial distribution of Pacific salmon and their predators should be regarded as important sources of interannual variability in Pacific salmon mortality as the predator-prey spatial overlap might become significantly altered. In many instances spatial distribution of injured Pacific salmon was not a good indicator of spatial allocation of predation intensity (presumably, due to the dispersal of injured individuals), which implies that spatial occurrence of injured Pacific salmon should be treated carefully in the context of predator-prey relationship.

3-4. Production Trends and Carrying Capacity of Salmon (Keynote-4)

Perspective on Production Trends and Carrying Capacity of Pacific Salmon in the North Pacific

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Pacific salmon (*Oncorhynchus* spp.) play an important role as keystone species and ecosystem service in the North Pacific ecosystems. The object of this presentation is to understand the trends and causes of variation in production and carrying capacity of Pacific salmon, and to predict their production dynamics in future. Salmon catch data (NPAFC historical data 1993-2004 yearly) points that abundance of Pacific salmon may fall into decline since the end of twenty century despite numerically healthy. In the initial 21 century, chum (*O. keta*) and pink salmon (*O. gorbuscha*) keep high abundance with sharp increase in hatchery-released populations. However, sockeye salmon (*O. nerka*) shifted to reduction trend since the late 1990s. Abundance of coho (*O. kisutch*) and Chinook salmon (*O. tshawytscha*), and masu salmon *(O. masou*), which live in freshwater over one year, sharply declined since the 1990s and the 1980s, respectively, due to different causes such as environmental condition in the freshwater (e.g., habitat loss, urbanization, and river channelization). Significant positive correlation (r=0.838***) between carrying capacity (K) of three species (sockeye, chum, and pink salmon) defined as the replacement level of Ricker's recruitment curve and the Aleutian Low Pressure Index (ALPI) indicate that their carrying capacity would be synchronized with the long-term climate change. Residual carrying capacity (RCC) defined as a proportion (K – Biomass) K-1 of Hokkaido chum salmon was positively correlated with mean fork length (r=0.979***) and negatively correlated with mean age at maturity (r=-0.879***). This reduction in somatic growth with increase in population size is caused by the population density-dependent effect. The result of growth pattern of Ishikari River chum salmon in 1946-2004 using back-calculation and scale analyses suggests that the global warming has positively affected their growth and survival in the Sea of Okhotsk. Namely, their growth in the first year and survival was negatively correlated with the sea ice concentration in winter, and positively correlated with the sea surface temperature (SST) during summer and fall seasons, despite the lack of a relation between SST and zooplankton biomass, in the Sea of Okhotsk. Prediction about the global warming effect on chum salmon based on the SRES-A1B scenario of the IPCC and their optimal temperature resulted that (1) the global warming will affect decrease in their carrying capacity for reducing distribution area, (2) strong density-dependent effect will occur in populations, and (3) Hokkaido chum salmon will lose migration route to the Sea of Okhotsk. In conclusion, Pacific salmon should be protected and used as healthy harvests for the foreseeable future by a framework of the sustainable conservation management based on the ecosystem approach, including the adaptive management and the precautionary principle.

3-4. Production Trends and Carrying Capacity of Salmon (Oral-28)

Cyclic Climate Changes and Salmon Production in the Bering-Aleutian Region

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The main part of feeding oceanic area of salmon population originating from Bering Sea basin is located south of the Aleutian archipelago. At the same time the feeding area of Asian chum and pink salmon occupy considerable part of the Bering Sea. The main climatic indices of the North Pacific including the Bering Sea is PDO and ALPI. The PDO index reflects the mean annual ocean surface temperature in the North Pacific and shows 60-65 year fluctuations. Unlike the global temperature dynamics the secular PDO upward trend is absent. The same dynamics (without ascending age-long trend) demonstrate surface temperature in the North Atlantic and in whole Arctic region. Then, ascending age-long temperature trend associated with "global warming" has not been observed in the recent century in the North Pacific, North Atlantic and Arctic Ocean. The total catch of Pacific salmon for the recent century follows the cyclic PDO and ALPI dynamics: maximum in 1920-1940s, depression in 1950-1970s and new ascent from 1970s to maximum of 1990s – early 2000s. The curve of total Pacific salmon catch passed the deflection point in the late 1990s-early 2000s according to PDO dynamics. A simple stochastic model of approximate 60-65 year cyclic climate changes is suggested that makes it possible to predict trends of basic climatic indices and populations of Pacific salmon for several decades ahead. According to modeling it is possible to project a probable downward trend in the total Pacific salmon population for the upcoming 5-10 years.

3-4. Production Trends and Carrying Capacity of Salmon (Oral-29)

Climate, Growth and Population Dynamics of Western Alaska Chinook Salmon

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Chinook salmon returning to western Alaska represent a major proportion of wild Chinook salmon in North America and Asia. Abundance indices of Yukon, Kuskokwim, and Nushagak Chinook salmon increased after the mid-1970s climate regime shift, but declined markedly after the 1997/98 El Nino, which affected many species in the eastern Bering Sea. Growth is often an important factor affecting salmon survival; therefore, we developed growth indices of age-1.3 and age-1.4 Yukon and Kuskokwim Chinook salmon during each year and life stage in freshwater and the ocean, 1964-2004, using measurements of scale growth. Chinook scale growth during each stage at sea was not closely linked to climate shifts (in contrast to Bristol Bay sockeye salmon). However, we discovered several unique Chinook growth patterns that were consistent among age groups and stocks. Chinook scale growth was dependent on previous-year growth during all life stages except for the homeward migration, e.g., growth during the first year at sea was correlated with growth in freshwater. This pattern may reflect the importance to Chinook salmon of large prey, such as forage fishes and squid, and the greater ability of larger Chinook salmon to capture larger prey and grow faster. Chinook scale growth during the second year at sea was consistently greater during odd-numbered years, leading to greater length of adult age-1.3 Chinook salmon during odd-numbered years. This finding may reflect a cascading trophic link between abundant odd-year pink salmon and Chinook salmon. Unexpectedly, adult female Chinook salmon (age-1.3 and age-1.4) were significantly longer than male salmon. Greater growth of age-1.3 female Chinook salmon began in freshwater (Yukon) or during the second year at sea (Kuskokwim), then continued during each remaining life stage, whereas growth of age-1.4 female Chinook salmon was not significantly greater until the last year at sea and during homeward migration. This finding is opposite of that for sockeye and chum salmon and suggests that growth may be especially important to female Chinook salmon. Growth of age-1.3 Chinook salmon began to exceed that of age-1.4 salmon during freshwater (Yukon) or during the first year at sea (Kuskokwim) and was significantly greater than that of age-1.4 Chinook salmon during each subsequent life stage except for spring plus growth. This investigation provides new information about growth and life history patterns of western Alaska Chinook salmon and highlights the need to better understand salmon trophic dynamics of salmon in the Bering Sea.

3-4. Production Trends and Carrying Capacity of Salmon (Oral-30)

Population Dynamics of Asian Chum Salmon in Relation to Climate Change during 1943-2005

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To clarify the effect of climate change to the population dynamics of chum salmon (*Oncorhynchus keta*) in the North Pacific, we examined the causal linkage between growth and survival of Asian chum salmon in relation to climate change index (PDO; Pacific Decadal Oscillation) in past 6 decades. Variability in growth at age-1 to -4 of chum salmon was estimated by back-calculation method using scales of age-4 adult returning to the Ishikari River (Kaeriyama et al. 2007) in Japan during 1943-2005 and the Namdae River (Seo et al. 2006) in Korea during 1984-1998. Japanese chum salmon migrates to the Okhotsk Sea after short residing in coastal waters of Japan. Their survival rate would be decided by body size at the seaward migration and growth in the Okhotsk Sea (Kaeriyama et al. 2007). They stay in the Bering Sea during summer and fall, from age-2 until maturation age (Urawa 2000). Growth anomaly at age-1 of Japanese population had negative values during periods of the mid-1940s and the 1970s, but positive values during period of the 1980-1990s. Growth anomalies at age-2 and -3 in the Bering Sea showed opposite trends to that of age-1. Their population size was positively correlated with growth at age-1 (r=0.54**), and negatively with growth at age-2 (r=-0.48**) and -3 (r=-0.61**). However, fork length of adult was negatively correlated with growth at age-1 (r=-0.39*), and positively with growth at age-2 (r=0.64**) and -3 (r=0.78**). The PDO was correlated with growth at age-1 (cross-correlation; r=0.43**) and -3 (r=-0.43**) without time-lag, but not correlated with growth at age-2 significantly (r=-0.05NS). Results of the multiple regression analysis, however, indicated that the survival rate was affected by growth at age-1 (partial regression coefficient: 0.2*) relating to the size-related mortality (Beamish and Mahnken 2001) despite irrelevance with the PDO (-0.03NS). On the contrary, their growth at age-3 was influenced by population size (partial regression coefficient; -0.06**) relating to the survival, but not affected by PDO (-0.25NS), indicating density-dependent effect (Kaeriyama 1998, Kaeriyama et al. 2007). In age-3, Japanese chum salmon had less growth than Korean population, despite no differences in growth at age-1, -2, and -4. Namely, Japanese chum salmon showed stronger population density-dependent effect than Korean salmon did. The survival of Asian chum salmon, therefore, will be affected by climate change in the first marine life period, and the subsequent growth may be influenced by population density-dependent effect in the Bering Sea.

3-4. Production Trends and Carrying Capacity of Salmon (Oral-31)

Global and Regional Elements of Ecological Capacity of the Pacific Salmon Habitat

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Not all variations in the number of animals should be related to environmental capacity. The capacity issue emerges only under extremely high abundance. The habitat capacity for each specific stock is mostly limited in the period which is the restricting one: It is early sea period of life and the first winter in the ocean. The winter temperature conditions impact the intensity of convective mixing enriching the upper layers with nutrients needed for vegetation of phytoplankton as the initial trophic link. Since the food supply in winter is the lowest the ecological habitat capacity in winter that determines the advent of salmon during the succeeding spring/summer period. This is true for the Pacific salmon in general. In the 1990-s a number of researches found relationship between the rise in most species and stocks of salmon and the decline in their length, body weight and greater maturation age. Some references linked this with regulation of density at sea at common feeding grounds of salmons from various stocks (Gritsenko at el. 2000; Ishida 1993; Bigler et al. 1996; Klovach 2003). In the 2000s this link disappeared though salmon became still more abundant. In addition, they became larger. Based on that one could assume that the capacity of habitat had increased, and food supply had gone up. The upper limit of abundance in each specific population is governed by the environmental capacity at the stage of ontogenesis where its number is most restricted. Therefore, the ecological nieches of individual Pacific salmon stocks vary; their capacities differ accordingly. Throughout the life cycle the ecological capacity is set by combined global and regional capacities in the critical periods of life; it is restricted by abiotic and biotic conditions typical of each population.

3-4. Production Trends and Carrying Capacity of Salmon (Oral-32)

Is Body Size of Maturing Chum Salmon Returning to North America and Japan Related to Population Density and/or Sea Conditions in the Eastern Bering Sea?

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Research has shown that the growth of chum salmon in the final season at sea is very important in determining body size at maturity. Research has also shown that stocks of Asian and North American chum salmon from as far south as southern British Columbia and Washington are present in the Bering Sea during their final season at sea. In addition, both ocean conditions and population density have been shown to influence body size. We plan to compare changes in the body size and abundance of maturing chum salmon with ocean conditions to understand the importance of changing ocean climate in the Bering Sea on the population dynamics of chum salmon.

3-4. Production Trends and Carrying Capacity of Salmon (Oral-33)

Role of Pacific Salmon Juveniles in the Epipelagical Ichthyocenoses of the Eastern and Western Kamchatka

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Dynamics of the ichthyofauna composition in the upper epipelagial of the Southwestern Bering Sea and East Kamchatka adjacent waters of the Pacific Ocean (Eastern Kamchatka) and of Eastern part of the Okhotsk Sea (Western Kamchatka) has been studied on the base of data of 33 trawl surveys by KamchatNIRO in September-October 1981–2005. Surveys were conducted with specialized midwater trawl (model 54.4/192 m) used for estimation of Pacific salmon juveniles abundance in 0-30 m layer (Karpenko et al, 1997). The observation period of 25 years has demonstrated over 70 species of fish presented in the trawl catches, but the basis of the ichthyocenoses in the Eastern and Western Kamchatka has been made up of several basic species. Juveniles of pink and chum salmon were dominant among Pacific salmon species (37.3% and 16.4% of total fish abundance in the catches, respectively). The total portions of sockeye, coho and chinook salmon juveniles were substantially lower (4.6%, 2.0%, 1.7%, respectively). Besides salmon juveniles, an important role in the composition of both regional shelf ichthyocenoses (in different years) played of walleye pollock juveniles (*Theragra chalcogramma*), and in the offshore waters –Atka mackerel juveniles (*Pleurogrammus monopterygius*). Also in particular years high abundance of threespine stickleback (*Gasterosteus aculeatus*) in the Eastern Kamchatka and Pacific herring (*Clupea pallasii*) in the Western Kamchatka were found. Three periods of the salmon juveniles high abundance with the maximums in 1982, 1990 and 2000 were observed in the Eastern Kamchatka. The abundance fluctuations of salmon juveniles in this area repeated every 8–10 years. The maximum of salmon juveniles abundance in the Western Kamchatka was registered in 1982, 1989, 1997 and 2003 and the fluctuations took place every 7–8 years. The successions of the ichthyocenoses revealed in the regions mentioned are almost similar to the cycles of solar activity of 11 years (it was better observed in the Eastern Kamchatka). In the both regions of Kamchatka it has been demonstrated a peak increase of salmon juveniles percent in the composition of ichthyocenoses (up to 100% of the total fish abundance) followed by an increase of the total abundance of salmon juveniles. In other words, salmon began dominate over the other species in the epipelagial during this periods. In the both regions the periods of salmon high abundance coincided with the periods of high catches of Atka mackerel, but taking place in the antiphase to the periods of walleye pollock high abundance. An increases of salmon juveniles abundance in the epipelagical communities of the Eastern and Western Kamchatka coincided with ichthyocenoses successions and possibly were one of reasons of this successions.

3-4. Production Trends and Carrying Capacity of Salmon (Oral-34)

Growth Rate Potential of Juvenile Chum Salmon on the Eastern Bering Sea Shelf: An Assessment of Salmon Carrying Capacity

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Spatial and temporal variation in growth conditions for juvenile salmon may determine the survival of salmon after their first year at sea. To assess this aspect of habitat quality, a spatially explicit bioenergetics model will be used to predict juvenile chum salmon Oncorhynchus keta growth rate potential (GRP) on the eastern Bering Sea shelf during years with cool and warm spring sea surface temperatures (SSTs). Cool spring sea temperatures occurred during 2000, 2001, and 2006, whereas warm spring sea temperatures occurred during 2002 to 2005. It is believed that higher mesozooplankton production occurs during years with warm spring ocean temperatures on the eastern Bering Sea shelf than in years when the bloom occurs in cold water at the ice edge, because warmer temperatures promote a tighter coupling between zooplankton and phytoplankton. We plan to test the hypothesis that energetic limitations negatively affect habitat quality and carrying capacity on the eastern Bering Sea shelf for juvenile chum salmon during years with cool spring SSTs.

3-4. Production Trends and Carrying Capacity of Salmon (Oral-35)

The Salmon MALBEC Project: A North Pacific Scale Study to Support Salmon Conservation Planning

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A multi-investigator team has synthesized data and expert knowledge in order to develop a simulation model--Salmon MALBEC (Model for Assessing Links Between Ecosystems)--to support Pacific salmon conservation planning at the scale of the North Pacific basin large ocean-draining river basins. MALBEC is designed to conduct risk assessments based on different conservation, hatchery policy, and/or harvest management strategies by integrating threats across the full life-cycle for major population groups. The model allows users to explore hypotheses about Pacific salmon at the North Pacific scale: the effects of competition among salmon stocks (and species) in the North Pacific, the response of salmon stocks and species to climate change, freshwater habitat change, and the possible effects of large hatchery programs on natural and hatchery stocks from other regions. The model is supported by a data base including regionalized annual run-sizes, catches, spawning escapements, and hatchery releases for 135 major pink, chum, and sockeye population groups around the North Pacific for the period 1950-2006. The model is being run with observed salmon and environmental data from 1950-2006, and with environmental (climate and habitat change) and policy scenarios for the period 2007-2050. MALBEC modeling results indicate that including time-varying and stock-specific productivity variations, which are likely related to historic climate changes, yield much improved fits to the observed abundance trends. Likewise, including density-dependent interactions in the ocean yields better fits to the observed run-size data than those simulations without density-dependent interactions in the ocean. This suggests that for any level of ocean productivity, the ocean will only support a certain biomass of fish but that this biomass could consist of different combinations of stocks, stock numbers and individual fish size. MALBEC simulations illustrate this point by showing that under scenarios of Pacific-wide reduced hatchery production the total number of wild Alaskan chum salmon increases, and that such increases are largest where density-dependent effects on survival are large and smallest where they are not. Under scenarios with reduced freshwater carrying capacities for wild stocks, the impacts of density-dependent interactions also lead to relative increases in ocean survival and growth rates for stocks using ocean habitats where density-dependence is large.

4. Discussion and Summary on BASIS 2002-2006 (Oral-36)

The SALSEA Programme – A New Initiative to Improve Understanding of the Distribution and Migration of Salmon in the North Atlantic

Presenter TBA (North Atlantic Salmon Conservation Organization)

4. Discussion and Summary on BASIS 2002-2006 (Oral-37)

Future Salmon Research: Insights from the Long-Term Research and Monitoring Project

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Abstract TBA

3-1. Migration and Distribution of Salmon (Poster-1)

Bering-Aleutian Salmon International Survey (BASIS): Population-Biological Researches in the Western Part of Bering Sea (Russian Economic Zone). Part 2 - Sockeye Salmon *Oncorhynchus nerka*

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This work has represented results of identification of regional complexes of local stocks of immature sockeye salmon on the data of trawl surveys of the R/V «TINRO» in the Bering–Aleutian Salmon International Surveys (BASIS) in the Western Bering Sea in summer-fall periods in 2002-2004. The system of districts of the Bering Sea part of the EEZ of RF, accepted in TINRO-Center for making biocenological researches, was used in this work. Scale structure was used as a criterion for differentiation. In the whole the ages of fishes in mixed marine samples were estimated for the total sample size of 3691 sockeye salmon individuals, including 2678 fishes which ages were identified in particular. In the analysis there were used four age groups - 1.1, 1.2, 2.1 and 2.2, taking in the total more than 90% of immature sockeye salmon in the trawl catches. The basis scale line consisted of 8577 sockeye salmon individuals from the age groups 1.2 + 1.3 and 2.2 + 2.3. The results of the identification were as next: in 2002 the part of North American sockeye salmon stocks in the districts 5-8 was 41,1% and in the district 12 – 23,1%. The part of sockeye salmon stocks of West Kamchatka in the districts 5-8 was 18,0% and in the district 12 - 24,7%. The occurrence of the stocks of East Kamchatka + Chukotka in the catches was 40,9 % in the districts 5-8 and 52,2 % in the district 12. In 2003 during the summer survey the part of the stocks of Alaska in the districts 3-8 was in average 43,0% and in the districts 9-12 – 34,8%. In the fall this part was respectively 39,4% and 15,1%. As for the Asian stocks, the most interesting was the mass occurrence of the stocks of West Kamchatka in this region, among these stocks the Ozernaya River sockeye salmon stock dominated in the abundance. The occurrence of the stocks of West Kamchatka in 2003 was as next: summer – 20,7% in the districts 2-8 and 29,6% in the districts 9-12; fall – 20,1% in the districts 5-8 and 52,4% in the districts 9-12. The complex of sockeye salmon stocks of East and North-East Kamchatka and of Chukotka is indigenous to the Western Bering Sea. Therefore the occurrence of sockeye salmon spawning in these regions was stably high there: summer – 36,3% in the districts 2-8 and 35,6% in the districts 9-12; fall – 40,5% in the districts 5-8 and 32,5% in the districts 9-12. In the fall of 2004 the occurrence of North American sockeye salmon stocks was 23,0% in the districts 3-8 and 16,1% in the district 12. The occurrence of sockeye salmon of West Kamchatka was the most evident (23,9%) in the district 12. To the North, in the districts 3-8 the part of these fishes was visibly reduced, up to 5,4%. The stocks of East Kamchatka and Chukotka predominated in the catches, their occurrence in the districts 3-8 was 71,6% and in the district 12- 60,0%.

3-1. Migration and Distribution of Salmon (Poster-2)

Bering-Aleutian Salmon International Survey (BASIS): Population-Biological Researches in the Western Part of Bering Sea (Russian Economic Zone). Part 3 - Chinook Salmon *Oncorhynchus tschawytscha*

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This work has represented results of identification of regional complexes of local stocks of immature chinook salmon on the data of trawl surveys of the R/V «TINRO» in the Bering–Aleutian Salmon International Surveys (BASIS) in the Western Bering Sea in summer-fall periods in 2002-2004. The system of districts of the Bering Sea part of the EEZ of RF, accepted in TINRO-Center for making biocenological researches, was used in this work. Scale structure was used as a criterion for differentiation. Scale structure was used as an instrument of the differentiation. In the whole the ages of fishes in mixed marine samples were estimated for the total sample size of 756 chinook salmon individuals, including 480 fishes which ages were identified in particular. In the analysis there were used the age groups 1.1 + 1.2, taking in the total more than 90% of immature chinook salmon in the trawl catches. The basis scale lines of 2004-2005 consisted of 3196 chinook salmon individuals from the age groups 1.2 + 1.3 + 1.4. The result of the identification indicated predominance of the stocks of Alaska in the occurrence in the trawl catches in the Western Bering Sea in 2002-2004. The part of fishes of this complex varied in range 50,2-71,2%. The peak occurrence was in 2004. Moreover, that year a high density of fishes in the boundary area of the Bering Sea part of the EEZ of RF was displayed on the trawl catches of chinook salmon distribution. The other part of immature chinook salmon was represented by one stock of the Kamchatka River (East Kamchatka).

3-1. Migration and Distribution of Salmon (Poster-3)

Origin and Distribution Local Stocks of Sockeye Salmon *Oncorhynchus nerka* in the Western Part of the Bering Sea in August - October 2006

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This study continued the identification monitoring of local stocks of sockeye salmon on the base of scale criteria launched in 2002 as a part of BASIS (the Bering-Aleutian Salmon International Survey) in the EEZ of Russia. The basis of our study included the data from the complex pelagic survey carried out by TINRO-center in the Western Bering Sea for the summer-fall period (August-October). The mixed samples were the scale samples of immature sockeye salmon from the trawl catches of the R/V “TINRO”. The total sample size of the mixed samples was - age - 1681 fish and identification - 1290 fish. The baseline samples were collected by scientists from KamchatNIRO, ChukotTINRO, Sevvostrybvod and Alaska Department of Fish and Game (Juneau, Alaska, the USA) for the summer 2006. The scales from 3162 fishes from Kamchatka, Chukotka and Alaska were used as the scale baselines. The results obtained indicate dominant role (55,3% or 88,18 million fishes) of the complex of stocks of the Bristol Bay in forming stocks of immature sockeye salmon for the observation period. The most frequent among the Asian stocks were the fishes from the rivers Kamchatka (15,0% or 23,85 million fishes) and Ozernaya (14,5% or 23,07 million fishes). The summary contribution of the North-East Kamchatka and Chukotka minor stocks in the region was high traditionally (11,7% or 18,64 million fishes). The contribution of the West Kamchatka minor stocks was minimal (3,5% or 5,61 million fishes).

3-1. Migration and Distribution of Salmon (Poster-4)

Water Dynamics of the Southwestern Bering Sea and Its Effects in Distribution of Juvenile Pink Salmon (*Oncorhynchus gorbuscha*) on the North-East Coast of Kamchatka in September

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Maps of juvenile pink salmon *Oncorhynchus gorbuscha* distribution in the southwestern Bering Sea were built on the data of trawl surveys carried out by KamchatNIRO in 1998, 2000, 2002 and 2005. Maps of surface topography, speed and direction of geostrophic transfer were obtained with application of dynamical method on the base of concomitant hydrological observations. We also analyzed simultaneously the altimetry data averaged within the time interval of the surveys. Our comparison of satellite maps of subsurface currents to the maps built (subsatellite) has revealed a substantial difference. To continue the work we preferred the methods of the distant monitoring to escape well known shortages of the dynamic method of assessment, effects of a huge span of the survey period and not enough primary data pool. Analysis of combined maps of direction/speed of currents and of juvenile pink salmon stocks distribution brought us two principle conclusions contrasting to the results of earlier studies of this issue, which used results of figuring out the geostrophic currents or maps of general water transfer. The first one is that juvenile pink salmon distribution in September in the waters of the Southwestern Bering Sea are well concerted to prevailing (averagely for the period of the survey) direction of subsurface transfer. We also have concluded that the most dense aggregations of juvenile pink salmon are in the sites of the convergence of flows, what most likely are the places of stagnation of principle forage objects.

3-1. Migration and Distribution of Salmon (Poster-5)

Do Bering Sea Temperatures Regulate Catch Rates in the South Alaska Peninsula June Fishery?

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After departing the Bering Sea immature salmon are known to travel to the east in the well-established circulation of the Subarctic Current and Alaska Gyre. The extent of migration to the east and then north in the Gulf of Alaska during the winter could control the distance of salmon offshore in the southwest bound Alaska Stream the following spring. The hypothesis under consideration is that during colder years, immature salmon migrate from the Bering Sea through the Aleutian passes earlier in the fall and enter the Subarctic current sooner and further offshore. In migrating further east than in warmer years these immature salmon would then end up traveling further north in the Gulf of Alaska and closer to shore on their maturing southwesterly migration past the Alaska Peninsula to the Aleutian Passes.

Dramatic changes in availability of sockeye and chum salmon in a near shore coastal fishery along the South Alaska Peninsula appear to be unrelated to general abundance of stocks known to be present in the fishery. Effort was high enough in the 1980s and 1990s that the subsequent reduction of effort would have been expected to lead to increased catch per unit effort (CPUE) but catch rates declined instead. Relaxation of regulatory restrictions did not reverse the downward trend in CPUE over a 13 year period in spite of relatively large and stable stock abundance.

Local knowledge in this fishery holds that unknown forces regulate availability of salmon over decadal time scales. Between 1983 through 1993 Bering Sea surface temperatures cooled and the abundance of immature salmon in the Bering Sea declined. During this same period, the coastal fishery experienced high CPUE in seven of eleven years. The fall of 2006 was cold in Alaska and CPUE in the 2007 coastal fishery was the highest since 1999 and the second highest since 1993. While this information is consistent with the hypothesis it remains to be seen if recent temperature and immature salmon abundance from the Bering Sea supports this interpretation.

3-1. Migration and Distribution of Salmon (Poster-6)

Mixed Stock Analysis of Autumn Schools of Immature Sockeye Salmon in West Bering Sea (West Pacifics)

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At present time different genetic methods based on DNA analysis are widely used for sockeye salmon origin determination in mixed stocks, and methods based on single nucleotide polymorphism (SNP) analysis became the most popular. This approach has several advantages such as high reliability, reproducibility and unambiguous interpretation of results. Allele distribution of five sockeye SNP loci (One-mhc109, One-mhc190, One-mhc251, One-Prl2 и One-CytB26) was scored. Allele-specific PCR was applied for SNP detection. SNP-specific primers were designed based on sequences provided by Alaska Fish and Game Department. Reference genetic baseline included SNP allele frequencies for main coastal populations from nine Russian and four American lake-river systems. Tissue samples from Alaska were obtained from Alaska Fish and Game Department. Sea samples were collected in 2004, September-October, during complex trail survey on “TINRO” ship in the area between 161°E and 178°W. All the fishes caught were immature. The results of mixed stocks analysis showed that about 72 % of fishes from northwestern part of Bering Sea belonged to Asian coast populations mainly from Chukotka peninsula and Kamchatka River. These results are in accordance with previous data that the main area of mixture of Asian and American sockeye stocks during summer-fall season was located in Bering Sea between 175°E and 175°W. The present investigation was carried out in the context of international program BASIS.

3-1. Migration and Distribution of Salmon (Poster-7)

Reproduction Short-term Vertical Movements of Chum Salmon (*Oncorhynchus keta*) Using a Simple Model

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Vertical movements pattern of chum salmon (*Oncorhynchus keta*) during homing migration were examined using archival tags. Vertical movements through thermocline with a periodicity of less than 1 h were observed in day time in the North Pacific. To examine why this short-term vertical movement was caused, we developed a simple vertical movement model based on the heat budget model. It is assumed that chum salmon have an optimum body temperature and they migrate to relatively high prey density to conserve their body temperature. The model reproduced the short-term vertical movements such as observation. This shows that if the body temperature of chum salmon is in the optimum body temperature, they will be able to obtain the prey in the water which is less than the optimum body temperature.

3-1. Migration and Distribution of Salmon (Poster-8)

Some Aspects and Results of Hydroacoustic Researches of Pacific Salmon in the Bering Sea (Russian EEZ) in Summer–Autumn 2003-2007

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The structure of vertical and horizontal distribution of salmon in upper (epipelagic) layer of the western Bering Sea (Russian EEZ) and adjacent Pacific Ocean by data of acoustic measurements in summer and autumn, 2003, 2004, 2005 and 2007 are presented. Advantage of acoustic sounding in are registration of salmon echosigns during trawl survey and comparison with trawl survey data of their vertical distribution. The calibrated quantitative Simrad EK500/EK60 echosounding system with two split-beam transducers 38 and 120 kHz and FAMAS (TINRO-Center) has been used for registration and processing of acoustic data. The range of vertical distribution and migrations of most salmon were limited by layer of termocline according to acoustic measurements. The average of salmon habits depths by latitude good related with latitudinal distribution of termocline layer in the survey area. The salmon are moving in upper layer at night time and vertical distribution at day time wider. Vertical distribution of salmon in autumn time is increasing compare summer according of vertical extension of termocline layer. The distribution of young immature pink, chum, and sockeye salmon on near-surface layer are observed. The maximum range of vertical migrations have mature chum salmon, pink salmon in summer period and young pink salmon in autumn. The sockeye salmon have not significant vertical migrations in day time.

3-1. Migration and Distribution of Salmon (Poster-9)

Distribution of Otolith-Marked Chum Salmon in the Bering Sea and North Pacific Ocean in 2006 and 2007

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The techniques of otolith marking were used to determine the stock origins of chum salmon caught in the Bering Sea and North Pacific Ocean during the spring and summer. In the spring of 2006, 2,222 otolith samples were collected from chum salmon caught in the North Pacific Ocean (41˚00’-54˚00’N, 155˚00’E-160˚00’W) and Bering Sea (51˚50’-55˚50’N, 175˚00’E-170˚00’W) by surface trawl operations of R/V *Kaiyo maru*. In the summer of 2006, 949 otolith samples were collected from chum salmon caught in the central North Pacific Ocean (41˚00’-47˚30’N, 180˚00’) and Bering Sea (55˚30’-58˚30’N, 180˚00’) by gillnet operations of R/V *Wakatake maru*. In the summer of 2007, 5,175 otolith samples were collected from chum salmon caught in the central North Pacific Ocean (41˚00’-47˚30’N, 180˚00’) and Bering Sea (52˚38’-59˚23’N, 174˚55’E-170˚11’W) by R/V *Wakatake maru* (gillnet) and *Hokko maru* (surface trawl). The collected otolith samples were mounted on glass slides and ground to expose the primordia. Otolith microstructure patterns were compared to the mark patterns of voucher specimen deposited in the NPAFC website (http://npafc.taglab.org). In the spring of 2006, 12 otolith-marked chum salmon (0.64% of fish examined) and five otolith-marked chum salmon (1.49% of fish examined) were found in the North Pacific Ocean and southern Bering Sea, respectively. Eleven otolith-marked salmon (1.30% of fish examined) were collected in the central Bering Sea in the summer of 2006. In the summer of 2007, 154 otolith-marked chum salmon (3.12% of fish examined) were found in the Bering Sea. No otolith-marked chum salmon were collected in the central North Pacific Ocean in the summer of 2006 and 2007. Approximately 90% of these marked salmon were released from Japanese hatcheries. Other marked fish were originated from hatcheries in Alaska, Russia, and the Republic of Korea.

3-1. Migration and Distribution of Salmon (Poster-10)

Nonrandom Distribution of Chum Salmon Stocks in the Bering Sea and North Pacific Ocean during Summer and Fall in 2002 to 2004

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Stock origin and ocean distribution of immature chum salmon in the Bering Sea and North Pacific Ocean were estimated by genetic stock identification (GSI) using mitochondrial DNA (mtDNA) single nucleotide polymorphisms (SNPs). The samples were collected by surface trawl during the Bering/Aleutian Salmon International Survey (BASIS) research cruise of R/V *Kaiyo maru* in the summer (late June and July) and/or fall (late August to mid September) of 2002 to 2004. More than 1,700 blood samples were collected on board from chum salmon in each year. These samples were used to extract DNA, and detect mtDNA SNPs for identification of haplotypes by the DNA microarray method. Stock contributions (Japan, Russia, or North America) of immature chum salmon were estimated with the obtained mtDNA haplotype data by a conditional maximum likelihood algorithm using a mtDNA baseline data from 96 populations in the North Pacific Rim. Relationships between distribution pattern of specific stocks and sea surface temperature (SST) were examined by randomization test. The mixture samples of chum salmon were more than 97% immature fish in the fall of 2002 and 2003, whereas the occurrence of immature fish was less than 90% in the summer (80.2% in 2003 and 88.1% in 2004). Our genetic stock estimates suggested that immature fish were mostly of Asian (Japanese and Russian) origins, and were widely distributed in the surveyed areas (51º41’˜ 58º30’N, 172º30’Ē172º21’W of 2002; 52º33’˜58º24’N, 174º41’Ē170º34’W of 2003 summer; 52º30’˜57º59’N, 174º49’Ē170º17’W of 2003 fall; 52º58’Ñ57º58’N, 175º14’Ē170º01’W of 2004) of the Bering Sea during summer and fall. Particularly, the Japanese stocks were predominant in the northcentral and northeast Bering Sea, and the Russian stocks were abundant in the western and southern Bering Sea. Although the North American stocks tended to increase in the eastern Bering Sea and around the Aleutian Islands, their occurrence was generally less abundant than the Asian stocks in the Bering Sea. The randomization test showed non-significant correlation between the stock distribution and SST. The present mtDNA microarray analysis suggests that the distribution pattern of each stock showed no inter-annual variation within the three survey years (2002 to 2004), and it was not significantly related with SST.

3-1. Migration and Distribution of Salmon (Poster-11)

Origin of Juvenile Chum Salmon Caught on the 2007 U.S. BASIS Survey of the Bering Strait and Chukchi Sea Using Genetic Markers

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Chum salmon have a very broad distribution throughout the North Pacific Ocean and Bering Sea during their marine life history stage. They spawn in natal drainages in this area on both continents, with small populations persisting in Arctic rivers. Under the increasingly smaller and thinner Arctic ice cap conditions during summer months, chum salmon populations may expand into both the marine and fresh water environments of the Arctic region. Juvenile chum salmon were collected from the Bering and Chukchi Seas during the U.S. BASIS survey in August-September 2007. We summarize information on the origin of juvenile chum salmon captured from two areas off northwestern Alaska, in the Bering Strait and in the eastern Chukchi Sea, with a suite of microsatellite and single nucleotide polymorphism DNA markers. A genetic mixed-stock analysis with a coastwide baseline was used to identify the regions of origin. These results will provide a better understanding of juvenile chum salmon migration and Arctic habitat utilization.

3-1. Migration and Distribution of Salmon (Poster-12)

High-Resolution Stock Identification for Migratory Studies of Chinook Salmon

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While the life history and ecology of Chinook salmon in freshwater is well known, less is known of the oceanic migration patterns and relative survival of individual stocks in the marine environment. Until recently, investigation of the effects of fluctuating marine conditions on the abundance and distribution of Chinook salmon has only been approachable through the sporadic collection of tagged individuals and analysis of scale patterns. The Alaska Department of Fish and Game has developed a baseline of 53 markers based on single nucleotide polymorphisms (SNPs) surveyed in 175 populations across the species range in the North Pacific. This baseline provides the foundation for the application of genetic stock identification to the high-resolution exploration of the distribution of Chinook salmon in marine waters. We compare this method to the resolution possible from previous methods to demonstrate its utility for mixed stock analysis of high seas samples. Our results show that this baseline provides a rapid and cost effective approach to analysis of samples from complex mixtures encountered in multi-national research and fishery monitoring efforts.

3-1. Migration and Distribution of Salmon (Poster-13)

Monitoring of Viruses in Chum Salmon (*Oncorhynchus keta*) Migrating to Korea

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Migrating Pacific salmons for spawning are susceptible to many infections. Salmon fry are also susceptible to many infectious agents and the salmonid pathogens can affect the survival of salmon fry and smolts. Hence, it is important to investigate the prevalence of salmonid pathogens because the pathogens can affect the amount of release of salmon fry and the migration rate of adult salmonids. Routine surveys were conducted for investigating virus distribution in migrating adult chum salmon (*Oncorhynchus keta*) and their offsprings at the Namdae River, Korea, during 2006~2008. Anterior kidney were removed from adult chum salmon individuals and homogenized with minimal essential medium (MEM-O), then centrifuged to make supernatants for conducting RT-PCR. Five offsprings were pooled to for conducting RT-PCR. Infectious Pancreatic Necrosis Virus (IPNV), Infectious Hematopoietic Necrosis Virus (IHNV) and Viral Hemorrhagic Septicemia Virus (VHSV) were the target viruses for monitoring. In 2006, only adult salmon were investigated and 22.5% of fish (22/80) were found to be IHNV-positive by two-step PCR. In 2007, 65% of pooled fry (21/32) were IHN-positive and 9.3% (3/32) were IPNV-positive. However, only 1% of adult (1/80) was IHNV-positive. In 2008, 25 % (8/32) of pooled fry were IHNV-positive. All the samples tested were VHSV-negative. The occurrence of IHNV in chum salmon in Korea was confirmed for the first time in this study. The finding of virus in adult chum salmon raises a possibility of marine environment origin. However, relative high prevalence of viruses in fry is more likely to suggest that the virus can be originated from fresh water. More exclusive studies are needed to clarify whether these viruses are originated from fresh water or sea water. And it is also necessary to investigate that these viruses can affect the survival of smolts after migration into the sea.

3-1. Migration and Distribution of Salmon (Poster-14)

Management of Salmon Bycatch in the Eastern Bering Sea Pollock Fishery

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The Magnuson-Stevens Act emphasizes the importance of minimizing bycatch, to the extent practicable, as part of the goal to achieve sustainable fisheries. Measures to reduce Pacific salmon bycatch (*Oncorhynchus* sp.) have been developed and implemented resulting in specific closed (no-fishing) areas when established bycatch limits for Pacific salmon are reached. As a result of increased Chinook salmon bycatch in recent years, the North Pacific Fishery Management Council has been evaluating alternative management measures for the eastern Bering Sea pollock fishery, including establishing limits on the total amount of salmon that may be caught by the fleet in a given season. In order to evaluate the impacts of these management measures under consideration, the effectiveness of the previous closed-area management system is evaluated in conjunction with proposed limits on the fleet. Bycatch patterns are qualitatively characterized using fishery observer data. Results show that the spatial and temporal salmon bycatch patterns are highly variable between years. Salmon size and sex composition of the bycatch adds to the complexity of developing effective management options aimed at minimizing the bycatch impacts of the Eastern Bering Sea pollock fishery. Bycatch patterns show consistent diel patterns and on broader scales, may be impacted by oceanographic conditions.

3-2. Food Production and Salmon Growth (Poster-15)

Interannual Variation in Phytoplankton Biomass, Spatial Distribution, and Taxonomic Assemblage Structure on the Eastern Bering Sea Shelf

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Phytoplankton form the base of the pelagic food web and perform a critical role in the eastern Bering Sea ecosystem. These primary producers are grazed upon by zooplankton, which are in turn an important food source for juvenile salmon and their prey. We investigate interannual differences in phytoplankton biomass and taxonomic assemblage structure (as indicated by cell size) between frontal regions in the eastern Bering Sea, and across latitudinal gradients from the southern to the northern Bering Sea. Size-fractionated chlorophyll a samples, collected in late-summer/early-fall on BASIS cruises from 2003-2007, were utilized for this study. We relate observed spatial and temporal patterns to physical environmental parameters including temperature, salinity, mixed-layer depth, and current patterns. Potential affects of warm vs. cold year regimes on phytoplankton dynamics are discussed.

3-2. Food Production and Salmon Growth (Poster-16)

Total Abundance Estimates of Pacific Salmon Forage Base (Macroplankton and Small Nekton) within Far Eastern Seas and Adjacent North Pacific Waters

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Based upon data of TINRO-center comprehensive surveys within Far Eastern seas and adjacent northwestern Pacific waters during 1984-2006, total abundance estimates of plankton and small nekton (squids and small-size fish) are provided. Information on plankton and nekton is summarized for three time periods (1984-1990, 1991-1995 and 1996-2006) and three landscape zones (inner shelf, outer shelf with shelf break and basin areas) for each Far Eastern sea and adjacent northwestern Pacific waters. Regional specificity and interannual dynamics of plankton and nekton communities (which are major components of forage base for Pacific salmon and other epipelagic nekton species) quantitative composition are reviewed. Maximum relative abundance of plankton is observed in the Okhotsk Sea, minimum - within Pacific waters off Kamchatka Peninsula and Commander Islands. Major portion of zooplankton biomass is attributed to basin areas. However, Okhotsk Sea is noted for major share of plankton being present within out shelf and shelf break. Squids, to a certain degree, have compensated “losses” in macroplankton component of Pacific salmon forage base in the Far Eastern seas and adjacent Pacific waters during 1980-2000-s. During 1990-2000-s notable increase in cephalopods abundance in northwestern Pacific waters was observed. Share of squids biomass (from overall nekton biomass) was particularly high in vast basin area of Far Eastern Seas and adjacent northwestern Pacific waters, i.e. in areas which are noted for high Pacific salmon abundance. Peak CPUEs of small-size fishes were noted in shelf and shelf break zones, which may compensate low abundance of forage macroplankton and squid species in these areas. Small-size nekton species biomass is much lower compared to overall macroplankton biomass, but similar to that of hyperiids and pteropods, which are preferred by Pacific salmon among other macroplankton species. Within pelagic layer of northwestern Pacific waters the nekton species are well-supplied by forage resources. It has been reported previously, that at the end of previous century despite of high nekton abundance it consumed at most 10% of overall plankton production. During the last 25 years, despite of twofold-threefold decrease of plankton biomass during wintertime, forage resources were sufficient to preclude influence of density-dependence upon consumers’ abundance.

3-2. Food Production and Salmon Growth (Poster-17)

Density-Dependent Growth of Alaska Sockeye Salmon Under Varied Climate and Production Regimes in the North Pacific Ocean, 1925-1998

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In the past century, climate and salmon productivity has varied between warm and high production from the early 1900s through the mid-1940s, cool and low production from the mid 1940s through the mid-1970s, and warm and high production from the mid-1970s to 2000s. For a 76 year time series, we examine how the juvenile, immature, and mature marine scale growth of sockeye salmon related to sockeye salmon abundance based on commercial harvest to determine how intra-specific density-dependent growth has varied under these climate and production regimes. Results of the multivariate adaptive regression spline models indicate that intra-specific density-dependent growth occurred in all marine life stages and was strongest during the cool regime and at lower abundances. During the warm regimes, a positive relationship occurred between immature growth and sockeye salmon abundances, while no relationship occurred between growth and abundance for the juvenile and maturing life stages. We question whether a scenario of a cold regime or extremely warm climate at higher population levels could drastically reduce the growth and survival of salmon.

3-2. Food Production and Salmon Growth (Poster-18)

Growth and Survival of Sockeye Salmon from Karluk Lake, Alaska in Relation to Climatic and Oceanic Regimes and Indices, 1922–2000

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Alaska salmon populations fluctuate with climate and ocean conditions in the North Pacific Ocean. We examined an ocean regime hypothesis that faster growth resulted in higher that expected brood survival as a consequence of warmer ocean conditions from 1922–1946 and 1977–2000, and slower growth resulted in lower than expected brood survival during cooler conditions from 1947–1976. Freshwater and annual marine growth was measured on scales collected from age 2.2 sockeye salmon that returned to Kodiak Island, Alaska from 1924 to 2000. Growth in the first and second marine year fluctuated with climate and survival from 1947 to 2000. A possible biological mechanism linking climate to survival was faster growth in the first and second year at sea, as a consequence of warmer coastal waters, increased coastal precipitation amounts, and increased atmospheric circulation.

3-3. Feeding Habits and Trophic Interaction (Poster-19)

Feeding Selectivity of Pacific Salmon in the Western Bering Sea and Adjacent Pacific Waters

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Species-specific, size-based and seasonal prey selectivity was examined for Pacific salmon caught in the western Bering Sea and adjacent Pacific waters in summer and fall 2002-2006. Potential zooplankton preys were sampled with 0.1 m^2 Jedy net with a 0.168 mm mesh. Micronekton (small fish and squids) abundance was estimated using a mathematic model which based on salmon diet data and plankton composition. All salmon species positively selected for most conspicuous prey. In the daytime, it is hyperiid amphipods, euphausiids, pteropods, decapod larvae, the squid *Gonatus kamtschaticus*, juvenile walleye pollock *Theragra chalcogramma* and atka mackerel *Pleurogrammus monopterygius*, which have a pigmented and/or large body. In the nighttime, salmon feed mainly on myctophids and euphausiids, which have luminous photophors. In 2002-2006, pink, chum and sockeye salmon selectively preyed on the same food items. Prey selectivity rank for first three items was: the euphausiid *Thysanoessa longipes* > the hyperiid amphipod *Themisto pacifica* > the pteropod *Limacina helicina* for pink salmon, *T. pacifica* > decapod larvae > *Th. longipes* for chum and sockeye salmon. Chinook and coho salmon positively selected mostly for nektonic organisms (squids and forage fish). Seasonal variation of salmon feeding preferences was determined. Chum, sockeye and chinook salmon reduced the number of favorite prey from summer to fall. Relationship between predator and prey size was studied.

3-3. Feeding Habits and Trophic Interaction (Poster-20)

Winter Food Habits of Chinook Salmon in the Eastern Bering Sea

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Winter is a critical period for ocean survival of salmon. Although BASIS research was not conducted in winter, sampling by the U.S. North Pacific Groundfish Observer Program (NOAA Fisheries) provided the first data on winter food habits of Chinook salmon in the eastern Bering Sea. Stomach samples, scale samples, and associated catch and biological data collected by U.S. observers from January to March and July to August 2007 were analyzed. Results showed the proportion of empty stomachs was higher in winter (45%) than in summer (8%), indicating winter starvation of Chinook salmon. We discovered that some Chinook salmon feed in winter on walleye pollock offal (cut fins, bone, skin, etc.), presumably discarded by at-sea groundfish processors. The most common natural food of Chinook salmon in winter was squid. Diversity of squid species in Chinook salmon diets was higher in winter than in summer, when more fish (particularly, juvenile walleye pollock) were consumed. Additional seasonal-, spatial-, age-, size- and maturity-related patterns of prey utilization by Chinook salmon in the eastern Bering Sea will be discussed and compared to results of BASIS research.

3-3. Feeding Habits and Trophic Interaction (Poster-21)

Pacific Salmon Feeding Behavior in the Eastern Bering Sea in the August – October of 2003–2007

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In 2003-2005 Pacific salmon fed primarily on small-sized fishes (mostly juvenile walleye pollock, as well as Pacific sandlance, capelin, flatfishes and other species). For juvenile pink salmon proportion of juvenile fishes in their diets ranged between 58 and 89 % of total stomach contents weight, whereas for juvenile chum and sockeye salmon ranges were 56-69 and 68-82 %, respectively. The share juvenile fishes in juvenile chinook and coho salmon diets reached 88-100 %. In 2006 nekton species (primarily juvenile Pacific sand lance) were major food of juvenile chum and pink salmon (68-72 %). Juvenile walleye pollock, megalopa crabs and euphausiids were dominant food items of juvenile sockeye salmon. The stomach contents of adult sockeye (30-60 cm) and pink (40-50 cm) salmon was characterized by dominance of euphausiids (44-75 % and 82 % of totals stomach contents weight, respectively). Jellyfishes, euphausiids, pteropods and juvenile walleye pollock comprised the diet of large-size chum salmon (40-90 cm) in Bristol Bay. Hyperiids and jellyfishes were observed in juvenile chum stomach stomachs (25-35 %). Significant prevalence juvenile fishes in a diets of pink, chum and sockeye salmon is related to high juvenile walleye pollock abundance and low forage zooplankton biomass during 2003-2005. The majority of zooplankton biomass was constituted by small-size and medium-size fractions. The large-size fraction of zooplankton, which is a major food component, made no more than 20-50 %. In Bristol Bay shelf proportion of large-size fraction has increased up to 60-70 % of total zooplankton biomass during 2006-2007. In 2007 majority of large-size fraction of zooplankton was constituted of chaetognaths and copepods. However, contrary to 2006, third position (in terms abundance) was taken not by jellyfishes, but by euphausiids (6, 5 % large-size fraction total biomass). In 2007 the proportion of euphausiids increased in chum, pink and sockeye salmon diets, as well as in predatory salmon species diets (chinook and coho salmon). In shallow waters of Bristol Bay euphausiids prevailed among food items of pink and sockeye salmon (57-100 %), whereas hyperiids were dominant in shelf zone (43-58 %). Nekton (primarily juvenile Pacific sand lance) occurred among food items of sockeye salmon with BL <40 cm. Euphausiids, megalopa crabs, hyperiids and pteropods dominated in juvenile chum stomach contents (up 79 %). Jellyfishes were most often observed in diets of large-size chum salmon (up to 90 %). Most intensively ate juvenile salmon.

3-3. Feeding Habits and Trophic Interaction (Poster-22)

Do Chinook Salmon (*Oncorhynchus tshawytscha*) Feed on Processing Waste from Fishing Vessels in the Bering Sea?

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Chinook salmon (*Oncorhynchus tshawytscha*) have been an increasing component in the bycatch of the walleye pollock (*Theragra chalcogramma*) fishing industry in the Bering Sea, off the coast of Alaska. Declining runs of Chinook salmon have recently caused increasing concern about such bycatch mortality. Chinook salmon and pollock typically do not share the same marine habitat, and so the reason for high Chinook bycatches in pollock trawls has yet to be established. One possibility is that salmon may be attracted to the pollock fishing vessels by offal disposal during times when the vessels process their catch at sea. Salmon do not normally feed on walleye pollock, but may feed on processing waste from fishing vessels. These salmon would then face a much greater risk of being caught in the trawling gear, and indeed this practice could account for the increasing numbers of Chinook bycatch. Here, we determined the presence of pollock in Chinook salmon stomachs by DNA sequence analyses. Between January and August 2007, stomach contents of 56 Chinook salmon caught incidentally by pollock fishers were examined; 22 of these stomachs contained remains identified morphologically as pollock. We used a DNA barcoding approach to verify this identification. The results will influence pollock fishery procedures in order to help minimize the incidental catch of Chinook salmon in pollock fishing gear.

3-4. Production Trends and Carrying Capacity of Salmon (Poster-23)

Food Supply of Pacific Salmon in the Western Bering Sea and Adjacent Pacific Waters

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We examined the food supply (provision) of Pacific salmon in the western Bering Sea using indirect characteristics (salmon daily rations, growth rate, diet overlap, trophic niche breadth etc.) and analysed the potential for feeding competition among salmon and other marine habitants. High and relatively stable salmon daily rations, feeding on few food items (mainly two or three species), pronounced feeding selectivity, low percent of dominant plankton items (copepods and chaetognaths) in salmon diet, stable diel feeding rhythm and similar growth rate every year – all these evidences indirectly testify to sufficiently high food supply of Pacific salmon in the western Bering Sea in 2002-2006. Diet overlap of salmon and dominant nektonic species (juvenile Atka mackerel, Walleye pollock, Pacific herring, Northern smooth-tongue, myctophids and gonatid squids) was low or middle. Some of these species fed mainly at night. Furthermore, all these fish and squids may be prey of salmon. Consequently, we suggested that there was a low potential for feeding competition among salmon and nektonic species in the western Bering Sea in 2002-2006. In addition to fish and squids, biomass and feeding habits of jellyfish were studied. Most of medusae fed on planktonic crustaceans (copepods, euphausiids, amphipods, pteropods, chaetognaths, ostracods, and larvae decapods). Their feeding consumption was low. But taking into account their high biomass (1800-3200 kg per square km in summer and 1900-4200 kg per square km in fall), medusae may considerably affect forage base of Pacific salmon and other planktivorous fish.

3-4. Production Trends and Carrying Capacity of Salmon (Poster-24)

Changes in Size and Growth Rate of Anadir River Chum Salmon (*Oncorhynchus keta*) in 1962-2007

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Annual changes in body size and growth rate of Anadir River chum salmon (age 0.3 and 0.4) in 1962-2007 were studied. Regression analysis showed that their fork length and mass significantly decreased from 1960s to 2000s. Body length of Anadir River chum salmon was the highest in 1972 and 1979, but the lowest in 1991 and 1994. The most pronounced decreasing of chum body size occurred from the early 1980s to the middle 1990s. In 1962-1980 and 1997-2007, their fork length and mass remained relatively stable. Growth analysis back-calculated from scales showed growth rate of Anadir River chum salmon did not change significantly during 1962-2007. Their growth reduction began from the second year and was the most intensive in the third year. Significant negative correlation was observed between annual total catches of Pacific salmon and fork lengths of Anadir River chum salmon.

3-4. Production Trends and Carrying Capacity of Salmon (Poster-25)

Can Juvenile Sockeye Salmon Research Be Utilized for Stock-Specific Forecasts of Returning Adults to Bristol Bay Alaska?

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Research cruises along the eastern Bering Sea shelf have been conducted from 2000 to 2007 to study juvenile western Alaska salmon ecology after their first summer at sea. Relative abundance of juvenile sockeye salmon was much higher during 2002 to 2005 when compared to 2000, 2001, 2006 and 2007. Bristol Bay sockeye salmon spend 2 to 3 years at sea before returning as adults to their natal lakes. Adult returns to Bristol Bay from 2004 to 2007 were also much higher than previous years, indicating that juvenile abundance may be linked to numbers of returning adults. Abundance estimates will be developed for each freshwater age group of juvenile sockeye salmon for 2000 to 2007. Mixed-stock analysis, using genetic data, will provide stock-specific information for juvenile sockeye salmon by age group and year. These results will be compared to age-specific adult returns to the major river systems in Bristol Bay. These results will also be used to compare stock-specific migration routes along the eastern Bering Sea shelf.

3-4. Production Trends and Carrying Capacity of Salmon (Poster-26)

Effect of Salmon-Derived Matter and Nutrients on Dolly Varden, Brown Bear and Vegetation in the Rusha River, Shiretoko World Natural Heritage Area

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Anadromous Pacific salmon (*Oncorhynchus* spp.) transport marine-derived nutrients (MDN) to the terrestrial ecosystem at their spawning season. The Shiretoko World Natural Heritage area (SWNHA) in the eastern Hokkaido is one of few locations where chum (*O. keta*) and pink salmon (*O. gorbusha*) naturally spawn in Japan. However, their contribution to terrestrial and aquatic ecosystems has not yet been known. The objective of this study is to clarify the influence of pink salmon on riparian ecosystem in the SWNHA. Dolly Varden (*Salvelinus malma*) dominantly distribute in the SWNHA. They mainly fed on eggs spawn by pink salmon and sea lice (*Lepeophtheirus salmonis*) parasitizing on salmon in the Rusha River (salmon-run river), but preyed on invertebrates in the Shiroi River (non-salmon river). Dolly Varden in the Rusha River had higher condition factor and trophic level (δ15N) than those in the Shiroi River. This result suggests that pink salmon eggs are useful for Dolly Varden to preserve enough energy during the wintering. According to the result of stable isotope analysis (δ13C and δ15N), fishes (e.g., Dolly Varden and masu salmon (*O. masou*)), terrestrial animals (e.g., brown bear (*Ursus arctos*)), and plants (e.g., willow (*Salix* spp) and butterbur (*Petasites japonicus*)) at the Rusha River had higher trophic level than those at the Shiroi River. These results indicate that the MDN of pink salmon is incorporated into freshwater and riparian ecosystems in the SWNHA.

3-4. Production Trends and Carrying Capacity of Salmon (Poster-27)

Salmon Distribution in the Northern Japan during the Jomon Period

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In Japan, the present southern limit for chum salmon returns is the Tone River in Chiba Prefecture on the Pacific side and the Tedori River in Ishikawa Prefecture on the Japan Sea side. Salmon distributions along the coast of Tohoku Region from Aomori to Fukushima Prefecture on the Pacific side were examined based on archeological evidence during the Jomon Period, 10,000-2,300 years ago. The oldest salmon remains were found in the northern part of the Tohoku Region, such as in Hachinohe in the Initial Jomon Period during 10,000-6,000 years ago. Thereafter, salmon remains were found in Miyako in the Early Jomon Period 6,000-5,000 years ago, in Oofunato in the Middle Jomon Period, 5,000-4,000 years ago, in Rikuzentakada in the Late omon, 4,000-3,000 years ago, and Naruse in Senda Bay in the Final Jomon, 3000-2300 years ago. These shifts of salmon remains from north to south reflect the change in salmon distribution due to decreasing temperature after the Jomon Marine Transgression, 6,000-5,000 years ago. Based on this archeological evidence, we discuss implications of these past changes on the future.

3-4. Production Trends and Carrying Capacity of Salmon (Poster-28)

Genetic Population Structure of the Yurappu River Chum Salmon *Oncorhynchus keta* Determined with the Mitochondrial DNA Analysis

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Wild chum salmon (*Oncorhynchus keta*) live in the Yurappu River located in southern Hokkaido, Japan. Hatcheries located at upper site of the river released huge amount of juvenile chum salmon transplanted around Hokkaido from 1952 to 1995. In the Yurappu River, therefore, the native population is concerned to be genetically disturbed by transplanted populations. Hatchery population is assumed to spawn at upper site near the hatcheries. In general, the run-timing of Pacific salmon is heritable (Quinn 2000). Southern populations, including Yurappu River population, have later run-timing than others in Hokkaido chum salmon (Nagata & Kaeriyama 2003). These suggest that genetic differentiation may occur among populations due to temporal and spatial barriers. The object of this presentation is to clarify the genetic population structure of the Yurappu River chum salmon using mtDNA analysis. Nucleotide sequence analysis of about 500bp in the variable portion of the 5'end of the mtDNA control region detected 8 variable sites, which defined 8 haplotypes. As a result of analysis, significant difference was detected between early-run and late-run populations ($p<0.01$) while it wasn't detected among spawning site. In the Yurappu River chum salmon, the late-run population had smaller number of haplotype and haplotype diversity than the early-run and transplanted populations. According to the pairwise estimates of Fst, the haplotype distribution of Yurappu River chum salmon indicates no difference between early-run and transplanted populations, but significant difference between late-run and transplanted populations. These results suggest that the early-run population would be genetically disturbed by transplanted populations, while that the late-run population would keep the original heritability in the Yurappu River.

3-4. Production Trends and Carrying Capacity of Salmon (Poster-29)

Dynamics of Escapement and Spawning of Pink Salmon (*Oncorhynchus gorbuscha*) at Rivers in the Shiretoko World Natural Heritage Area, 2007

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Pacific salmon (*Oncorhynchus* spp.) play as an ecosystem service for sustaing biodiversity and production in the terrestrial ecosystem because of supplying the marine-derived material to rivers at the spawning migration. Accurate estimation of their escapement and spawning dynamics is basically important for the evaluation to quantify effect of salmons on the riparian ecosystems. The objective of this paper is to establish census method of escapement and spawning dynamics of pink salmon (*O. gorbuscha*) in the Rusha River, the Shiretoko World Natural Heritage area. We studied the dynamics of escapement and spawning of pink salmon in the Rusha River in 2007. Escapement of pink salmon was estimated by the area under the curve method (AUC) and the evaluation model using maximum likelihood approach method (MLA), and was calculated standard error by Bootstrap method. The number of their escapement was estimated as 39± 8 thousands individuals. The total number of spawning redds and density was counted about 3,300 redds and 0.063 redds m-2, respectively. Namely, number of their spawning redds was extremely fewer than the adult escapement. We estimated number of pink salmon carcasses in the Rusha River based on the method of Quinn et al. (2003). The survey categorized all salmon by mode of death: “senescent” and “bear-kill”. Number of senescent pink salmon was counted as about 23 thousand individuals. The total number of bear-killed salmon was counted about 9 thousands individuals and occupied 24% of the escapement. This proportion of bear-kill salmon in the Rusha River was higher than it (9%) in Alaskan sockeye salmon case based on the estimation formula (Ruggerone et al. 2000). These results suggest that almost all of spawning redds will be re-excavated many times by more than 20 thousands pink salmon since available spawning areas are limited in the Rusha River.