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North Pacific Anadromous Fish Commission

Science Plan 2011-2015

Submitted to the

NORTH PACIFIC ANADROMOUS FISH COMMISSION

by

CANADA, JAPAN, KOREA, RUSSIA, and the UNITED STATES

Committee on Scientific Research and Statistics (CSRS)

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EXECUTIVE SUMMARY

In 2010, the Science Sub-Committee (SSC) of the North Pacific Anadromous Fish Commission (NPAFC) was charged with developing a new five-year Science Plan (2011-2015).

The vision of the Convention is conservation of anadromous populations in the North Pacific Ocean. To achieve this vision, the Commission needs the best available scientific information on the condition of anadromous populations, ecologically related species, and their marine ecosystems. Thus, the Commission's mission in scientific research is to promote the acquisition, analysis, and dissemination of scientific information pertaining to anadromous populations and ecologically related species in the ocean; to coordinate efforts to conserve anadromous populations in the ocean; and to establish an effective mechanism of international cooperation to promote the conservation of anadromous populations in the ocean.

Over the past several decades, there have been significant variations in the marine production of Asian and North American salmon populations that are linked to climate change. There is a strong need for new international cooperative research that provides better scientific information on the ecological mechanisms regulating production of anadromous populations, estimates climate impact on salmon populations in North Pacific marine ecosystems, and examines the extent to which salmon populations, since they return to coastal regions, can be used as indicators of conditions in North Pacific marine ecosystems.

The goal is to be able to explain and forecast the annual variation in Pacific salmon production. To provide necessary focus to cooperative research under the 2011-2015 Science Plan, the SSC identified an overarching research theme, "Forecast of Pacific Salmon Production in the Ocean Ecosystems under Changing Climate," and five research topics:

1) Migration and Survival Mechanisms of Juvenile Salmon in the Ocean Ecosystems;
2) Climate Impacts on Pacific Salmon Production in the Bering Sea (BASIS) and Adjacent Waters;
3) Winter Survival of Pacific Salmon in the North Pacific Ocean Ecosystems;
4) Biological Monitoring of Key Salmon Populations; and
5) Development and Applications of Stock Identification Methods and Models for Management of Pacific Salmon.

Accurate forecast of returning salmon abundances is of great importance for population managements in all countries. Precision monitoring of abundance and biomass in the ocean may be the most reliable method for predicting changes in production of anadromous populations. Accurate stock identification methods such as genetic and otolith mark analyses are necessary to monitor stock specific ocean distributions and abundance. Cooperative research that improves understanding of common mechanisms that regulate Pacific salmon production will increase the accuracy of forecasting. Finally we need models to explain how Pacific salmon production will change in the ocean ecosystems affected by changing climate.

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1. INTRODUCTION

In 2010, the Science Sub-Committee (SSC) of the North Pacific Anadromous Fish Commission (NPAFC) was charged with developing a new five-year Science Plan (2011-2015). The science plan developed by the SSC and described in this document will be recommended for approval by the Committee on Scientific Research and Statistics (CSRS) and the Commission at the fall 2010 Annual Meeting.

This document is intended for a broad audience who may be unfamiliar with the Commission and its scientific research activities. The following sections provide a brief summary of background information on the Commission, the Convention, the species of anadromous populations, the Convention area, the mandate for scientific research under the Convention, the vision of the Convention, the scientific mission of the Commission, and how international cooperation in scientific research is implemented by the Commission.

1.1 The North Pacific Anadromous Fish Commission

The North Pacific Anadromous Fish Commission (NPAFC) was established under the Convention for the Conservation of Anadromous Populations in the North Pacific Ocean (signed in 1992; entered into force in 1993). The member nations of the Commission are Canada, Japan, Republic of Korea, Russian Federation, and United States of America. The primary objective of the Commission is to promote the conservation of anadromous populations in the Convention Area.

1.2 The Species of Anadromous Populations

Species of anadromous populations listed in the Annex to the Convention include chum salmon (*Oncorhynchus keta*), coho salmon (*O. kisutch*), pink salmon (*O. gorbuscha*), sockeye salmon (*O. nerka*), Chinook salmon (*O. tshawytscha*), cherry salmon (*O. masu*), and steelhead trout (*O. mykiss*).

1.3 The Convention Area

Under the Convention, directed fishing for anadromous populations in international waters of the North Pacific Ocean and its adjacent seas (north of 33º North latitude, beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, Fig. 1) is prohibited; incidental taking of anadromous populations in fisheries directed at other species is strictly limited, and retention of incidental take is prohibited. The member nations can act individually or collectively to prevent unauthorized fishing activities and trafficking in illegally harvested fish, and they have the authority to board, inspect, and seize fishing vessels of other member-nations operating in violation of the Convention.

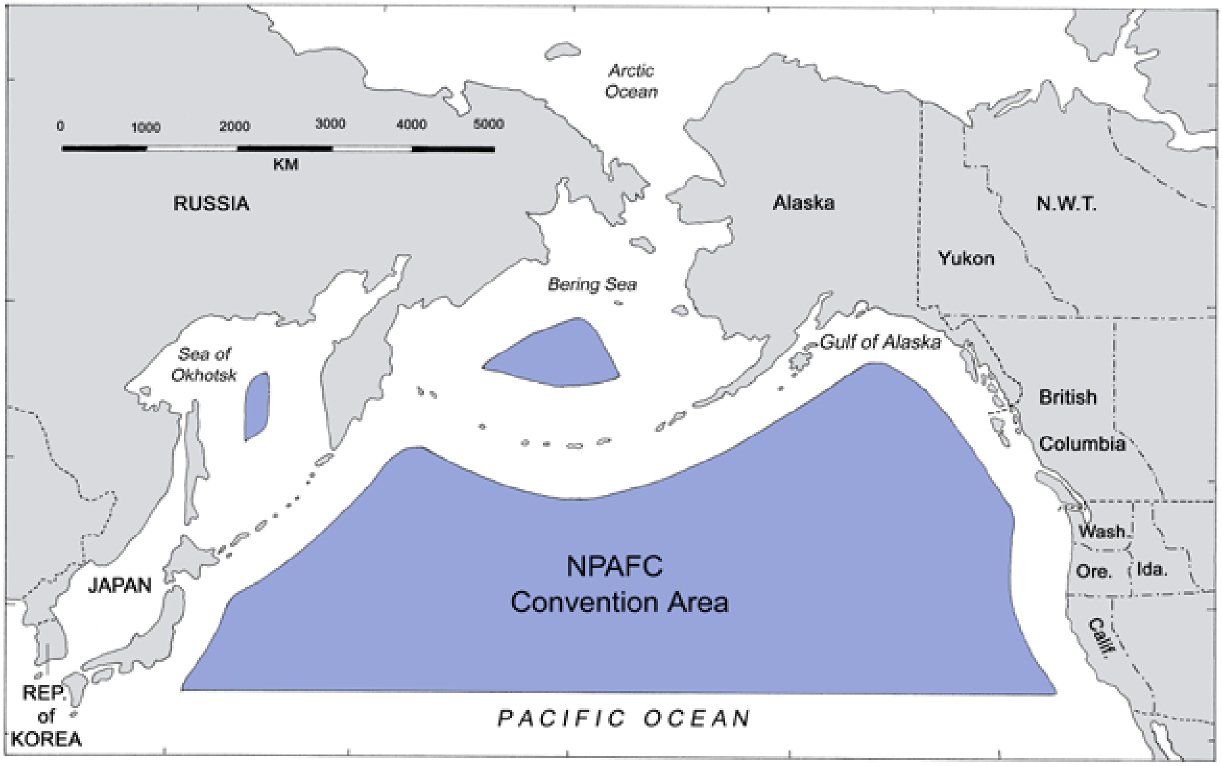

Fig. 1. Map showing the area (shaded in blue) where directed fishing for salmon is prohibited by the Convention for the Conservation of Anadromous Populations in the North Pacific Ocean, i.e., north of 33º North latitude, beyond 200-mile zones.

1.4 Mandate for Scientific Research Under the Convention

Article VII of the Convention mandates extensive cooperation among member nations in conducting scientific research for the purpose of conservation of anadromous populations. With respect to the Convention area, cooperation includes "collecting, reporting and exchanging statistics and biological information, fisheries data, including catch and fishing effort statistics, biological samples and other relevant data." Pertaining to areas adjacent to the Convention area, the member-nations can be requested to provide "catch information, enhancement information, materials such as biological samples, for example, scales and DNA material, and other technical data or information related to anadromous populations and ecologically related species." The Convention calls for the development of "appropriate cooperation programs, including scientific observer programs, to collect fishing information in the Convention Area for the purpose of scientific research on anadromous populations." Member-nations are also to cooperate in scientific exchanges such as seminars, workshops, and exchanges of scientific personnel.

1.5 The Vision of the Convention and Scientific Mission of the Commission

Anadromous populations of Pacific salmon originate in the rivers, lakes, and streams of Asia and North America and intermingle in common feeding grounds in the North Pacific Ocean and adjacent seas. The Convention recognizes that each member nation has the primary interest in and responsibility for its own anadromous populations, and that each nation makes expenditures and foregoes economic development opportunities to establish favorable conditions to conserve and manage its populations.

The vision of the Convention is conservation of anadromous populations in the North Pacific Ocean. To achieve this vision, the Commission needs the best available scientific information on the condition of anadromous populations, ecologically related species, and their marine ecosystems. The member nations of NPAFC recognize that many scientific questions about anadromous populations and their marine ecosystems can be answered by international collaboration. International cooperation of scientists within the NPAFC forum, as well as between NPAFC and other relevant international organizations, provides a strong foundation for our vision.

The Commission's mission in scientific research, therefore, is to promote the acquisition, analysis, and dissemination of scientific information pertaining to anadromous populations and ecologically related species in the ocean; to coordinate efforts to conserve anadromous populations in the ocean; and to establish an effective mechanism of international cooperation to promote the conservation of anadromous populations in the ocean.

The science plan in this document pertains only to plans for NPAFC-coordinated cooperative scientific research among its member nations and with other relevant organizations. That each member nation of the Commission has its own internal research and salmon management needs is also well recognized. Thus, not all marine research on anadromous populations in the Convention area is planned and conducted in a common and sequential manner. Each member nation also develops and reports to the Commission its own national research plan. National scientific research plans are updated annually, and are summarized in the Annual Reports of the Commission.

1.6 Implementation of Cooperation in Scientific Research by the Commission

The scientific work of the Commission is carried out by its member nations, and is coordinated by the Committee on Scientific Research and Statistics (CSRS; Fig. 2). The terms of reference for the CSRS are listed in Appendix Table 1. The CSRS meets during the fall Annual Meetings of the Commission. At the annual CSRS Meeting, each member nation submits and reviews documents reporting the statistics and data requested by the Commission, the results of national and NPAFC-coordinated cooperative research, scientific research plans, and research vessel cruise plans, and coordinates scientific meetings, workshop, symposia, publications, and other cooperative activities. A Research Planning and Coordinating Meeting (RPCM) is held each spring to bring scientists together to coordinate research vessel cruises, sample and data exchanges, and other joint research activities for the current year.

The Science Sub-Committee (SSC) was established by the CSRS to facilitate its discussions for cooperation, and is charged with formulating and reviewing the implementation of the NPAFC Science Plan. The SSC also coordinates cooperation with other international organizations, such as North Pacific Marine Science Organization (PICES), North Atlantic Salmon Conservation Organization (NASCO), and other organizations.

As necessary, the CSRS forms working groups to coordinate specific cooperative projects. At present, there are five working groups. The Working Group on Stock Assessment, established in 1995, coordinates the development of catch and escapement database for salmon, produces accurate and timely estimates of hatchery production, and studies ways of developing methods for measuring the abundance of wild salmon. The Working Group on Salmon Marking, established in 1998 on *ad hoc* basis and changed to a permanent group in 2000, carries out international coordination of marks to minimize duplication between countries and develops and updates a common database for mark releases. The *ad hoc* Working Group on Stock Identification, established in 2000, develops, standardizes, and disseminates genetic and other databases among member nations, coordinates the development of new genetic technologies and protocols, and facilitates the dissemination of statistical techniques. The Bering-Aleutian Salmon International Survey (BASIS) Working Group was established in 2001 to coordinate research plans and reports of results, survey methods, external funding, and other aspects of cooperative Bering Sea salmon research (see section 2.2). The Working Group on Salmon Tagging was established in 2007 to manage the salmon tagging and recovery database and to coordinate high seas tagging activities of the Parties.

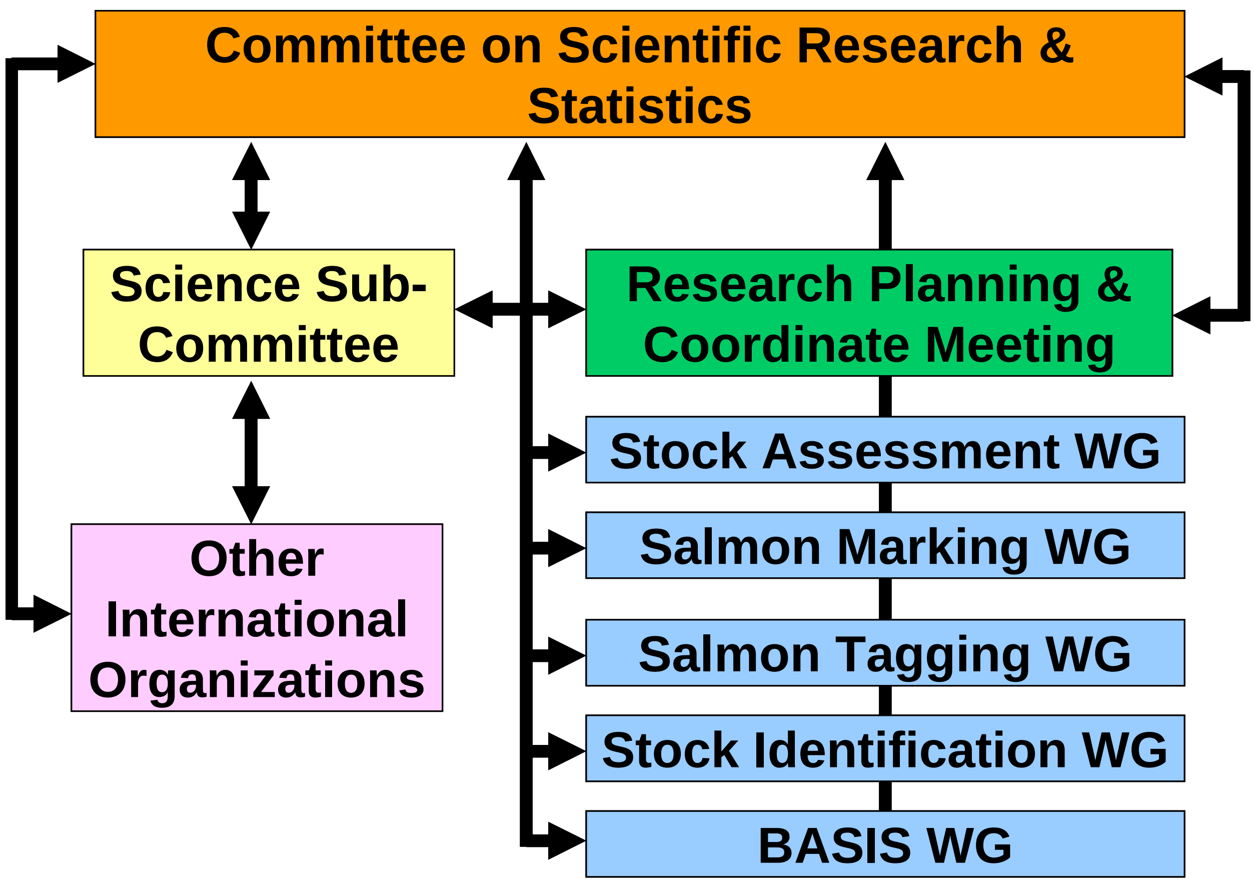

Fig. 2. Organizational chart of the NPAFC Committee on Scientific Research and Statistics CSRS). WG = Working Group; BASIS = Bering-Aleutian Salmon International Survey.

2. REVIEW OF PREVIOUS NPAFC SCIENCE PLANS

This section provides a brief review of previous NPAFC science plans, including their overarching goals, the critical issues that they addressed, the major scientific achievements and advances that resulted, and overarching hypotheses that emerged from these results.

2.1 The 1993-2000 Science Plan

The development of the first NPAFC science plan began in 1993. The identification of scientific issues for cooperative research under this plan was closely coordinated with the North Pacific Marine Sciences Organization (PICES). The overarching goal of this plan was to investigate the effects of changes in the productivity of the North Pacific Ocean on Pacific salmon, including two critical issues: (1) factors affecting current trends in ocean productivity and effects on carrying capacity, and (2) factors affecting changes in biological characteristics of salmon (growth, size and age at maturity, oceanic distribution, survival, and abundance). In 1995 the Commission approved a science plan that consisted of three research components: (1) salmonid life history, (2) salmonid population dynamics, and (3) salmonid habitat and ecosystem. Each component had several items that identified questions related to the two critical issues. These questions were clarified by coordinated research, and each year new questions were raised and the science plan revised accordingly. This science plan was reviewed and updated by the SSC and CSRS every two years through 2000.

The results of research under the 1993-2000 Science Plan were presented at one NPAFC-sponsored workshop, “Climate Change and Salmon Production,” (NPAFC 1998a), and two NPAFC-sponsored scientific symposia: “Assessment and Status of Pacific Rim Salmonid Populations” (NPAFC 1998b) and “Recent Changes in Ocean Production of Pacific Salmon (NPAFC 2000). A document on review of national research under the 1993-2000 Science Plan was also submitted to NPAFC (Urawa et al. 2000). Major scientific achievements and advances included: (1) recognition that salmon migrating in Convention waters are dependent on natural processes, (2) better scientific knowledge of the structural features of salmon migrations in the open ocean, (3) development and application (by Russia) of ocean trawl survey techniques to successfully forecast salmon catches and returns to spawning streams, (4) recognition that winter is a critical period for survival of salmon in the North Pacific Ocean, (5) improved understanding of intra-annual (monthly, seasonal) characteristics of salmon growth, lipids, sufficiency of food, trophic interactions, and other factors that influence their ocean survival, (6) development and first application of new (electronic) tagging technologies to study fish behavior with respect to environmental conditions, and (7) establishment and first applications of international genetic databases to identify mixtures of salmon populations in the ocean.

2.2 The 2001-2005 Science Plan

The overarching hypothesis that emerged from the results of scientific research under the 1993-2000 NPAFC Science Plan, as well as from research by other international organizations and independent scientists, is that “there is a strong relation between climate and climate change and subsequent changes in marine productivity and survival of anadromous populations in the ocean.” A growing body of scientific evidence led to general recognition among salmon experts that marine environmental conditions need to be explicitly accounted for in our assessment and management of anadromous populations. At the same time, there was relatively little or no understanding or agreement among scientists on the marine ecosystem processes leading to variation in abundance and biomass of anadromous populations.

In 2000 the NPAFC adopted a new five-year science plan (2001-2005) that focused cooperative research efforts on major gaps in our understanding of the marine life history of salmon with respect to marine ecosystem processes that affect the abundance and biomass of anadromous populations. The plan emphasized cooperative science activities in three areas where there were significant gaps in scientific information: (1) Bering Sea salmon research, (2) juvenile salmon research, and (3) winter salmon research. An important aspect of work in all three areas was to investigate the stock specific abundance, distribution, growth, and other biological characteristics of Asian and North American salmon with respect to variation in marine environmental conditions and ecosystem processes. As part of this goal, two NPAFC-sponsored international workshops focused on emerging stock identification technologies, i.e., mass marking of otoliths and genetic methods (NPAFC 2001b, 2004).

At the 2001 Annual Meeting of NPAFC, Canada, Japan, Russia, and the United States agreed to plan and coordinate a new international program of Bering Sea salmonid ecosystem research called BASIS (Bering-Aleutian Salmon International Survey; NPAFC 2001c). The goal of this NPAFC-coordinated program of cooperative research in the Bering Sea is to clarify the mechanisms of biological response by salmon to the conditions caused by climate changes. Scientific questions that provide necessary direction to the research include: (1) What are the seasonal-specific migration patterns of salmon and their relation to the Bering Sea ecosystem?; (2) What are the key biological, climatic, and oceanographic factors affecting long-term changes in Bering Sea food production and salmon growth rates?; (3) What are the similarities (or differences) in production trends between salmon populations in the Bering Sea and common factors associated with their trends in survival?; and (4) Is there an overall limit or carrying capacity of the Bering Sea ecosystem to produce salmon?

The results of this 5-year (2002-2006) BASIS research program are intended to provide necessary and vital species- and stock specific baseline data on salmon, their habitats, and their relations to other marine species in the Bering Sea ecosystem. The preliminary results of BASIS research in 2002-2003 were reviewed at an NPAFC-sponsored workshop in October 2004 (NPAFC 2005a), and the results and recommendations from that workshop will be applied to continuing cooperative work on this issue under the 2006-2010 Science Plan.

As a part of cooperative juvenile salmon research activities, an international workshop on factors affecting production of juvenile salmon was hosted by NPAFC and co-organized by NPAFC and PICES in 2000 (NPAFC 2001a). This workshop led to the publication of national review papers of research on the early marine period of Pacific Salmon, including recommendations for future studies (NPAFC 2003). Since 2001, NPAFC member nations have carried out research on juvenile salmon in the coastal waters of various oceanic regions, e.g., the Okhotsk Sea, east Kamchatka, northwest Alaska, and the Gulf of Alaska, and have accumulated substantial new information by using new techniques (e.g., rope trawl surveys, mass otolith marking, radio telemetry, etc). BASIS research has also included new cooperative field research on juvenile salmon in the Bering Sea. As a result, coordinating and planning for a workshop, "Second NPAFC International Workshop on Factors Affecting Production of Juvenile Salmon: Survival Strategy of Juvenile Salmon in the Asian and North American Oceans," was held in spring 2006 (NPAFC 2007). The results and recommendations from this workshop were applied to continuing cooperative work under the 2006-2010 Science Plan.

Historical data from winter salmon research under the previous science plan (1993-2000) was used for new computer modeling studies and retrospective analyses. However, no new winter monitoring or process studies were conducted on anadromous populations in the Convention area under the 2001-2005 Science Plan.

As a part of cooperation with other international organizations, a "Joint Meeting on Causes of Marine Mortality of Salmon in the North Pacific and North Atlantic Oceans and in the Baltic Sea" was held in Vancouver, Canada, in March 2002 with five co-sponsoring international organizations (IBSFC, ICES, NASCO, NPAFC, and PICES; NPAFC 1998a). In addition, NPAFC and PICES organized and held a joint symposium, "The status of Pacific salmon and their role in North Pacific marine ecosystems," in fall 2005 (NPAFC 2007). The results and recommendations from this symposium were used to develop specific proposals for NPAFC-coordinated research under the 2006-2010 Science Plan. Major scientific achievements and advances in cooperative research under the 2001-2005 Science Plan included: (1) the first integrated pelagic ecosystem monitoring of anadromous populations over large areas of the Bering Sea and adjacent North Pacific waters in late summer and fall; (2) the first applications of DNA stock identification techniques to determine stock composition of salmon migrating in the Convention area; (3) the first electronic data storage tag and hydroacoustic data showing vertical migratory behavior of anadromous populations in the open ocean; (4) the first international calibration of pelagic trawls to standardize abundance and biomass estimates of anadromous populations in the Convention area; (5) the first international coordination of otolith mark patterns among member countries; and (6) a greater scientific understanding of the marine ecosystem processes leading to variation in abundance and biomass of anadromous populations.

2.3 The 2006-2010 Science Plan

The 2006-2010 Science Plan was approved at the fall 2005 Annual Meeting (NPAFC 2005b). Overarching hypotheses that emerged from the results of scientific research under previous NPAFC science plans, as well as from research by other organizations and independent scientists, are that (1) anadromous populations play an important role in North Pacific marine ecosystems, and (2) there is a close relation between climate and climate change and subsequent changes in marine productivity and survival of anadromous populations in the ocean.

The SSC identified two broad scientific questions relevant to the program goals of NPAFC that would further an ecosystem-based approach to conservation of North Pacific anadromous populations, as well as contribute substantial new scientific information to the marine ecosystem research, fishery management, and conservation activities planned by relevant organizations:

1) What are the current status and trends in marine production of anadromous populations; and how are these trends related to population structure (spatial and temporal) and diversity of anadromous populations in marine ecosystems of the North Pacific?

2) How will climate and climate change affect anadromous populations, ecologically related species, and their North Pacific marine ecosystems?

To provide necessary focus to cooperative research under the 5-year science plan, three major research components are identified under a comprehensive research theme, "Status and Trends in Production of Anadromous Populations in Ocean Ecosystems."

1) Juvenile Anadromous Populations in Ocean Ecosystems;

2) Anadromous Populations in the Bering Sea Ecosystem (BASIS); and
3) Anadromous Populations in the Western Subarctic Gyre and Gulf of Alaska Ecosystems.

Results of BASIS research were presented at the International BASIS symposium hosted by NPAFC in the fall of 2008 (NPAFC 2009a). In addition, reviews of national research conducted under the 2006-2010 Science Plan were submitted by Japan (Nagasawa et al. 2010), Korea (Seong 2010), Russia (Temnykh et al. 2010) and the United States (Farley 2010).

2.3.1 Juvenile Anadromous Populations in Ocean Ecosystems

In some species of anadromous populations (e.g. pink and chum salmon), variation in adult returns may depend more on marine survival than on reproductive efficiency during the freshwater period. A common hypothesis is that the initial period of after migration to sea is the most critical phase with respect to ocean survival of anadromous populations.

Seasonal Distribution and Migration Route/Timing of Juvenile Salmon

Stock specific initial migration routes and timing were estimated for Chinook salmon (Trudel et al. 2009), coho salmon (Morris et al. 2007), sockeye salmon (Tucker et al. 2009), chum salmon (Urawa et al. 2006, 2007; Kolomeytsev 2009), and pink salmon (Tepnin 2008; Kolomeytsev 2009). Fisher et al. (2007) reviewed the distribution of juvenile Pacific salmon in the west coast of North America and found that juvenile pink, chum and sockeye salmon were abundant from Vancouver Island north into the Gulf of Alaska. Juvenile coho salmon were widespread north of northern California, and subyearling Chinook salmon were found only from central California to British Columbia.

The southern Okhotsk Sea is a major feeding habitat for Asian salmon juveniles. Sakhalin pink and chum salmon juveniles stayed in the coastal water of Aniva Bay for 1.5-2.5 months and then moved to the offshore before the end of July. Japanese juvenile chum salmon spend along the coast for 1-1.5 months and migrate into the Okhotsk Sea after a decrease of prey organisms (Seki 2005, 2007). Stock specific differences were also apparent in juvenile sockeye salmon even within a large watershed such as the Fraser River (Trudel 2009; Tucker et al. 2009).

Loss of non-seasonal sea ice and a general warming trend in the Bering Sea has altered the composition, distribution, and abundance of marine organisms inhabiting the region. The US BASIS survey indicated that juvenile pink and chum salmon utilized Arctic marine habitat (the Bering Strait and Chukchi Sea) as a feeding ground (Moss et al. 2009). The abundance of juvenile salmon increased in the western Bering Sea during cool years (2006-2009), which might be related with favorable reproduction conditions and low mortalities in the initial stage of sea life (Glebov et al. 2008).

Hydrological Characteristics, Primary Production, and Prey Resources in the Habitats

The main part of zooplankton biomass (77-87 %) in the most regions of North Pacific Ocean is comprised of macroplankton. Prey resouces are more favorable for salmon in Asian waters compared with the North America waters, because of high biomass of euphausiids, hiperiids, pteropods and appendicularia in Asian waters (Volkov 2008a,b; Shuntov et al. 2010a).

The highest plankton biomass occurred in spring and summer. Average macroplankton biomass in deep water region was 966-1202 mg/m^3 in the Okhotsk Sea (OS), 792-1055 mg/m^3 in the western Bering Sea (WBS), and 314-743 mg/m^3 in the Northwestern Pacific Ocean (NWP).

In winter, it decreased slightly: 578 mg/m^3 in OS, 314 mg/m^3 in WBS, and 258 mg/m^3 in NWP (Volkov 2008a; Shuntov et al. 2010a).

The total zooplankton biomass in the epipelagic layer of the Bering Sea, Okhotsk Sea and Northwest Pacific Ocean was 720 million tons in 1980th, 600 million tons in 1991-1995 and 590 million tons in 1996-2006. During 1980-2006 the plankton biomass decreased only in the Okhotsk Sea (Temnykh et al. 2010).

Trophic Linkages, Growth Rates and Predation Rates of Juvenile Salmon

Juvenile pink and chum salmon were most abundant in the southern Okhotsk Sea, but there was no correlation between macro zooplankton biomass and the abundance and body size of salmon juveniles because of high plankton productivity in the Okhotsk Sea (Temnykh 2009; Shuntov and Temnykh 2008; Shuntov et al. 2010c). In the western Bering Sea where the plankton productivity was relatively lower than in the Okhotsk Sea, the body size of juvenile pink salmon was influenced by density-dependent factors, but these factors did not lead to reduction of pink salmon abundance (Temnykh 2009; Shuntov et al. 2010c).

Studies on feeding selectivity showed that juvenile pink, chum and sockeye salmon selectively fed on hiperiid amphipods (mainly *Themisto pacifica*), decapods, pteropods *Limacina helicina* and euphausiids *Thysanoessa longipes*. Juvenile Chinook and coho salmon prey mainly small size nekton – fish and squid larvae and juveniles (Volkov et al. 2007; Shuntov et al. 2010b). Feeding selectivity of juvenile salmon related not only to composition and size of preys, but also to abundance and availability of preys (Naydenko 2009). High and stable feeding selectivity of juvenile salmon testified their sufficient food supply (Zavolokin et al. 2007; Shuntov and Temnykh 2008).

In the western coast of North America, higher growth rates of juvenile Chinook and coho salmon were observed in northern rather than in southern regions, while their storage energy did not exhibit a consistent trend with latitude maybe due to differences in prey quality, diet, and interspecific competition for prey resources (Trudel et al. 2007).

Population Size, Survival Rate and Survival Mechanism of Juvenile Salmon

Many papers suggested considerable interannual variation in abundance, growth, and survival rates of juvenile salmon in the ocean. These variations are related to climate-induced changes in habitat environments that operate at regional and local scales (Nagata et al. 2007; Farley and Moss 2009; Saito et al. 2009). In coastal waters of northern Japan, brood-year strengths of adult salmon were determined by survival of juvenile chum salmon which was influenced by size at release of juveniles and/or coastal SSTs (Saito and Nagasawa 2009).

In the eastern Bering Sea, size-selective predation was highest on juvenile Kuskokwim chum salmon during cold years, but that predation was not as great a factor for juvenile Yukon River chum salmon (Farley and Moss 2009). In the coastal marine waters of southeast Alaska, sablefish (*Anoplopoma fimbria*) predation on juvenile salmon occurred during strong year class of stablefish and might affect adult salmon returns (Sturdevant et al. 2009).

The early hatchery release coincided with peak abundances of wild chum salmon fry in the outer Taku Inlet, and the distribution of wild and early hatchery fry overlapped for about three weeks (Reese et al. 2009). The results suggest that the timing of release of hatchery fry may affect interactions with wild salmon fry.

The NOAA Fisheries Auke Bay Laboratories (ABL) Southeast Coastal Monitoring Project (SECM) monitored juvenile pink and chum salmon in the northern region of southeastern Alaska over 13 years (1997-2009). Using variable monthly catch data of juvenile pink salmon and associated biophysical parameters, SECM scientists developed a series of four steps for a model used to forecast commercial harvest (Heard 2009). The Canadian Program on High Seas Salmon also recently started to develop simple forecasting models for the marine survival of Pacific salmon 1-2 years prior to the return of adult salmon to their natal river (Trudel 2009).

2.3.2 Anadromous Populations in the Bering Sea Ecosystem (BASIS)

In the face of global climate change, the Bering Sea may become the most important marine ecosystem for production of Asian and North American anadromous populations. The results of cooperative BASIS ecosystem monitoring research indicated a very high density of Asian and North American anadromous populations in the Bering Sea from summer to late fall. BASIS process studies have demonstrated the important influences that various physical and biological stressors and stressor regimes may have on production of anadromous populations and ecologically related species in the Bering Sea ecosystem. While this recent research confirms the high productivity of the Bering Sea, carrying capacity, growth, and production of anadromous populations has shown a high degree of variation. These results confirm the necessity of continuing cooperative research in the Bering Sea to clarify the mechanisms of biological response of anadromous populations to climate and climate change.

Distribution, Migration Route/Timing, Production, and Health of Anadromous Populations and Ecologically Related Species

Models of salmon migration were also updated during BASIS Phase I. We now know that western Alaska sockeye salmon have extensive offshore migratory routes as juveniles during years with warm sea temperatures (Farley et al. 2007). Western Alaska immature sockeye salmon were also found in the northwestern regions of the Bering Sea during summer (Bugaev and Myers 2009). This information updates the migration and distribution models for western Alaska sockeye salmon and suggests that climate cycles and climate change may impact the migratory pathways as well as winter and summer distribution.

Several genetic and scale identification studies indicated Asian populations of chum salmon are dominant in the western and central Bering Sea during summer/fall feeding period (Urawa et al. 2005a,b, 2009; Bugaev et al. 2009; Sato et al. 2009). A migration model of Japanese chum salmon suggests that they migrate between the Bering Sea and North Pacific Ocean depending on seasonal sea temperature changes (Urawa et al. 2009).

Extensions of BASIS research into Chukchi Sea during 2007 also revealed that large numbers of juvenile chum salmon were located within the Bering Strait and Chukchi Sea and that genetic analyses of these salmon suggested they were from the Anadyr-Kanchalan region, Kamchatcka Peninsula and northwestern Alaska (Kondzela et al. 2009). Knowledge of these range extensions, shifts in migratory pathways, and distributional patterns for Pacific salmon are important components to understand as they suggest salmon may be distributing themselves further north or colonizing northern regions as the sea and air temperatures become warmer.

Diseases and parasites may be an important factor causing marine mortalities of Pacific salmon, but there have been few studies to evaluate those impacts in natural waters. Russian scientists started to examine impacts of diseases and parasites on salmon health in the marine waters (Rudakova et al. 2007; Rudakova 2008; Shvetsova et al. 2009).

Multi-Year Trends (Regime) in Physical and Bilogical Factors that Influence Long-Term Changes in Bering Sea Food Production and Fluctuations in Salmon Production

The BASIS research indicated that climate cycles can have profound effects on Bering Sea marine ecosystems. Shifts in the position the Far Eastern Low and Aleutian Low pressure systems can determine whether or not the Bering Sea experiences warming or cooling and also affect velocity of ocean currents. The position of these atmospheric low pressure systems (NE and W respectively) during 2002 to 2005 brought warmer air to the Bering Sea during winter and was related to decreased storm activity during summer. The position of these low pressure systems shifted again (SW and E respectively) during 2006; as a result, colder arctic air covered much of the Bering Sea during winter and summer storm activity increased. This climate cycle has persisted into 2008, with cold sea temperatures and record spring sea ice extent on the eastern Bering Sea shelf being recorded (http://www.arctic.noaa.gov/reportcard/seaice.html).

The impacts of these climate cycles (cool versus warm) on physical and biological parameters in the eastern Bering Sea were presented in Danielson et al. (2008), Eisner et al. (2008), Andrews et al. (2009), Murphy et al. (2009), Coyle et al. (2008), Cieciel et al. (2009), and Farley and Moss (2009). These papers suggested pelagic productivity was highest during years with warm SSTs, as abundance levels of juvenile salmon and age 0 pollock were much higher than during years with cool SSTs. However, the zooplankton community shifted from large to small taxa during warm SSTs years (Coyle et al. 2008), altering energy transfer to pelagic fish and negatively impacting fish energy density prior to winter (Moss et al. 2009; Andrews et al. 2009). This finding may explain why recruitment of some commercial fish species in the eastern Bering Sea was low during warm SST years, as fish with low energy reserves prior to winter would be expected to have higher mortality during winter.

Trophic Linkages, Growth Rates and Predation Rates of Juvenile Salmon

The BASIS food habits studies significantly increased the available information on salmon food habits during the fall in the western, central, and eastern regions (Davis et al. 2009). Within the western Bering Sea, climate cycles of warm and cool also resulted in shifting food webs and abundance of pelagic consumers. Naydenko (2009) showed that juvenile walleye pollock consumed a large portion of the forage resource during 2002 and 2003 and Pacific salmon, squids, Atka mackerel , herring, and capelin were the dominate consumers of the available forage during 2004 to 2006. Zavolokin (2009) indicated that cumulative values for relative biomass estimates of the Pacific salmon forage base in the western Bering Sea varied significantly during 2002-2006: the lowest during fall 2004 and the highest in fall 2002 and summer 2003. Volkov and Naydenko (2008) noted that copepods dominated the zooplankton biomass in the western Bering Sea during 2006, whereas euphausiids and hyperiids dominated the zooplankton biomass during 2003 and 2005. Koval (2008) connected 11 year cyclic solar activity to shifts in biomass of dominant pelagic fish species in the western Bering Sea (between salmon and Atka mackerel to walleye Pollock).

Changes in Carrying Capacity of Anadromous Populations

During BASIS Phase I research (2002 to 2006), salmon biomass in the Bering Sea increased and salmon returns to western Alaska climbed to all time highs despite the fact that brood year escapements for these returning salmon were low. The BASIS research indicated the shift to higher abundance was related to increased carrying capacity for juvenile salmon in the eastern and western Bering Sea (Farley and Moss 2009; Farley and Trudel 2009). In addition, salmon carrying capacity in offshore regions of the Bering Sea remained sufficient for growth of immature salmon in the offshore regions, despite the significant increase in salmon abundance (Azumaya et al. 2008; Shuntov and Temnykh 2009). Fukuwaka et al. (2010) estimated that the biomass of immature chum salmon in the Bering Sea basin, which was much less than the historical biomass of walleye pollock in the pelagic Bering Sea. The carrying capacity of pink, chum and sockeye salmon is synchronous with long-term trends in climate change (Kaeriyama et al. 2009).

BASIS Phase II Plan

Parties within NPAFC agreed to continue BASIS into Phase II (2009–2013). The Phase II plan (NPAFC 2009b), approved at 2009 NPAFC Annual Meeting, will focus on the following research questions:

1) How will climate change and climate cycles affect anadromous populations, ecologically related species, and the Bering Sea ecosystems?
2) What are the key climatic factors affecting cyclical changes in Bering Sea food production and pelagic fish communities?
3) How will climate change and climate cycles impact the available salmon habitat in the Bering Sea?
4) How will climate change and climate cycles affect Pacific salmon carrying capacity within the Bering Sea?

During BASIS phase II, the NPAFC has an unprecedented chance to continue the time series of biological and oceanographic data to focus on how climate change and cycles affect the Bering Sea ecosystem. The primary methodological approach is to conduct an international survey of salmon, associated pelagic nekton, and their ecosystem in the Bering Sea, deploying survey vessels at key times and regions to provide, among other things, a picture of the migration and ecology of salmon inhabiting the Bering Sea. BASIS phase II is intended to be a 5-year (2009-2013) program of field, laboratory, and computer modeling research would enable us to combine previous field efforts to track at least two cohorts of the longer-lived salmon species (sockeye, chum, and Chinook salmon) through a complete Bering Sea production cycle. Through this research plan, we hope that a clear understanding of salmon carrying capacity in the Bering Sea will result: from their first entry into the marine environment, to their departure from coastal to offshore waters where they develop and migrate extensively, and then their return back to home streams.

2.3.3 Anadromous Populations in the Western Subarctic Gyre and Gulf of Alaska Ecosystems

Anadromous populations play a very important role in the Western Subarctic Gyre and Gulf of Alaska ecosystems. Immature and maturing salmon originating from Asia and North America intermingle in both of these ecosystems (Myers et al. 2007, Beacham et al. 2009, Urawa et al. 2009). Recent research vessel monitoring surveys by Canada, Japan, Russia, and the USA have collected a considerable amount of new data on anadromous populations, ecologically related species, and environmental conditions in the Western Subarctic Gyre and Gulf of Alaska ecosystems. In particular, three species – pink, chum, and sockeye salmon – occur in high abundance in Western Subarctic Gyre and Gulf of Alaska ecosystems during all seasons (Nagasawa and Azumaya 2009). Otolith mark and genetic analysis confirmed that North American populations were dominant among chum salmon in the Gulf of Alaska (Urawa et al. 2009). Anadromous populations consume a substantial quantity and biomass of prey organisms in these ecosystems, and play an important role as a higher trophic level predator. Changes in marine tropic relations in these ecosystems influence the productivity of salmon populations returning to different reproduction regions in Asia and North America.

Both ecosystems provide major wintering habitats for various anadromous populations. While previous research has identified this as a critical period that defines the biological characteristics and biomass of anadromous populations, a few open ocean field research and monitoring programs have been carried out during the winter and early spring periods in the past. Japan conducted a winter and a spring salmon researches in the North Pacific Ocean in 2006 (Fukuwaka et al. 2006, Morita et al. 2006). Objectives of these researches were to study the stock condition of salmon and their environment in the winter and to explore the biology of salmonids in the offshore areas. Various populations of Asian and North American chum salmon inhabit in the central Gulf of Alaska (145°W) during winter, but there was a nonrandom distribution that North American populations were distributed in the northerly regions (51°-53°N) and conversely Asian chum salmon were more prevalent in the southern regions (48°-50°N) (Beacham et al. 2009). North-to-south distribution of chum salmon in the winter was further to south than the summer and thermal preferences of chum salmon was different between the western and eastern North Pacific Ocean (Fukuwaka et al. 2007). In the spring, larger sockeye, chum, and pink salmon inhabited colder waters than smaller fish, which may maximize growth performance of individual fish (Morita et al. 2009, 2010).

Russia conducted two winter and four summer surveys in the central and western North Pacific Ocean during 2006-2010. High pink and chum salmon concentrations were observed in the western Subarctic Gyre which was less favorable for wintering salmon due to high SST gradients (Temnykh et al. 2010). In winter, salmon inhabit in deeper layer of water as compared with their summer habitats (Starovoytov et al. 2010a, b). The estimated abundance of Okhotsk Sea populations of pink salmon in the western part of North Pacific Ocean was only 30% lower than in the southern Okhotsk Sea in the previous autumn. Perhaps, low mortality of pink salmon of this generation in winter relates to favorable habitat conditions. In particular, the low number of pelagic fish predators was noted in the central and western parts of Subarctic Gyre in winter. The low fish predation might cause high marine survival of pink salmon (Temnykh et al. 2010). The estimated zooplankton biomass in the western North Pacific Ocean during winter and spring was relatively higher than past winter research estimates (Nagasawa 1999), and suggested favorable feeding conditions for Pacific salmon (Temnykh et al. 2010).

3. LONG-TERM RESEACH AND MONITORING PLAN (LRMP) FOR PACIFIC SALMON IN THE NORTH PACIFIC OCEAN

This project is designed to advance the scientific understanding of Pacific Salmon ocean ecology by drawing on the considerable expertise of scientists associated with the North Pacific Anadromous Fish Commission (NPAFC). The output of this project was a Long-term Research and Monitoring Plan (LRMP) that synthesized past research, identify critical areas for new research to understand impacts of future climate and ocean changes on the population dynamics of Pacific salmon (NPAFC 2009c).

Each of the Pacific salmon producing countries conducts research and monitors its salmon fisheries to protect and utilize a resource that provides food and economic opportunities. Effective management requires an understanding of the mechanisms that regulate the production of Pacific salmon in fresh water and in the ocean. Each country can study Pacific salmon within their own jurisdiction, but international cooperation is needed to understand the processes that influence Pacific salmon on the high seas.

The NPAFC is a trusted organization where researchers can share their data and interpretations to determine how to forecast the effects of a changing ocean ecosystem on Pacific salmon production. The authors of this report agree that it is now possible to use new technologies and a new spirit of international cooperation to identify the fundamental processes that influence Pacific salmon survival in the ocean. This Long-term Research and Monitoring Plan represents a consensus of a large group of researchers from all Pacific salmon producing countries that the approaches identified in the plan will improve the ability of each country to forecast how their salmon populations will respond to the changing freshwater and marine ecosystems.

Development of LRMP began with the first meeting on April 7-9, 2008 in Sokcho, Korea where over 30 experts from all member countries met to identify their own country visions of future research needs in addition to reaching agreement on key areas of research. From the ideas compiled at the meeting in Korea, the members created the first drafts of LRMP and the synthesis of knowledge (bibliography), which were presented to a smaller panel at the second meeting held on September 29 – October 2, 2008 in Nanaimo, Canada. The final drafts of LRMP and synthesis were released on May 29, 2009, and approved at the Steering Committee Meeting, held in Shiogama, Japan on June 18-20, 2009. The bibliography (Beamish et al. 2010) contains over 500 papers on climate impacts on Pacific salmon by authors from all countries in a format that summarizes most papers. The brief summary of LRMP is followed:

It is known that there is a large mortality of juvenile Pacific salmon in the early marine period. In addition, the conditions in the winter can also determine brood year strength. Comprehensive winter ecosystem surveys are needed to determine the distribution and condition of Pacific salmon from all countries to identify the sources and magnitude of the winter mortalities. Linking this information with biotic and abiotic factors will improve forecasts of brood year strength as well as improve the understanding of how the capacity of the ocean to produce salmon will be affected by climate.

Each country also identified key areas of ocean research and long-term monitoring requirements. Surveys of juvenile salmon are needed to determine the factors affecting early marine survival. Pink salmon were identified as a key species for monitoring because they are the most abundant Pacific salmon species and because their life history characteristics make them an ideal ecological indicator of marine ecosystems. Consensus on genetic baselines for sockeye, Chinook and chum salmon and the development of genetic baselines for pink salmon are necessary to monitor stock specific ocean distributions and abundance. This information is needed to produce more accurate estimates of the timing and abundance of adults that are returning to coastal rivers.

Research and monitoring programs in the ocean will also identify the capacity of the ocean to produce the various species of Pacific salmon. The continued development of a North Pacific marking strategy is necessary to study hatchery production and to monitor the proportions of hatchery fish in the ocean and within total returns to coastal communities. International, integrated studies need to include specialists that are familiar with physical, chemical and climatological processes as well as experienced modelers.

As strategic plans are developed to address our primary objective, each of the boxes in Figure 3 could be considered in our research and monitoring plans. The process of developing the plan should also create an international team of scientists that will continue to find ways to integrate research to make optimal use of funds, vessel time and data. BASIS is an example of such a team. Although NPAFC has discussed the need to establish a fully shared data system, data management and communication issues are frequently not fully considered in the implementation of programs. In summary, it is important to create a team, optimize the use of scientific resources and make data available.

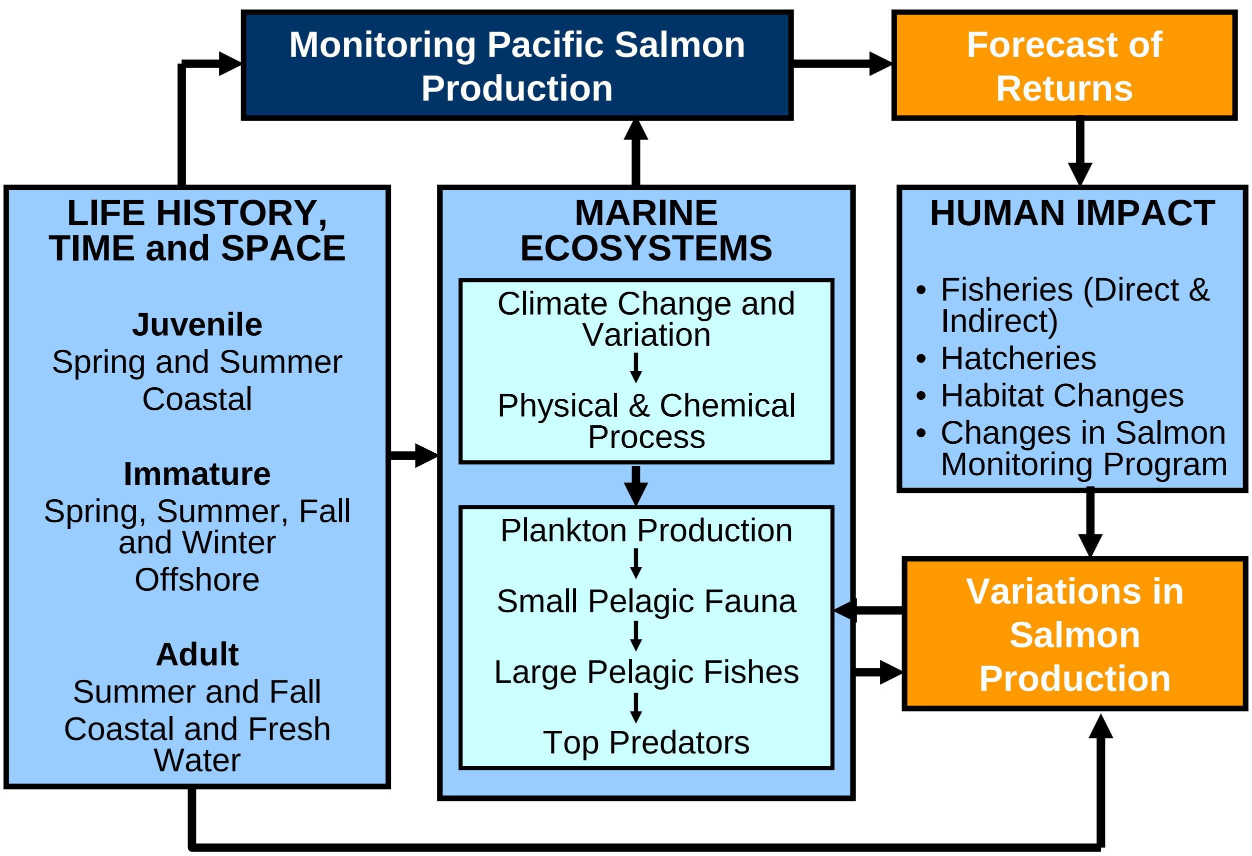

Fig. 3. A scheme of long-term research and monitoring for Pacific salmon in marine ecosystems.

4. THE 2011-2015 SCIENCE PLAN

4.1 Background

This plan identifies the major research topics relating to the management of Pacific salmon. Countries agreed that the effects of a changing climate will affect Pacific salmon production in the ocean as well as in fresh water. Future research needs to ensure that models can be developed that accurately describe how climate affects the ecological mechanisms that determine the production of Pacific salmon. Ocean sampling programs are needed that identify the major rearing areas of all species. These programs need to be integrated so that the mechanisms that link salmon production to climate are determined. Past science plans stressed the importance of sharing information. The Bering-Aleutian Salmon International Survey (BASIS) is an example of how all countries maximized their research funding through the almost immediate exchange of data. Future research plans need to integrate studies of the physical environment with biological production and with a focus on the critical periods in the life history of Pacific salmon.

It is recognized that each country will have specific scientific needs, but it is also recognized that there are common problems among researchers that can best be solved using the integration that has been established within the NPAFC. Most members recognize that small-scale and short-term studies are no longer the way to identify the processes that regulate Pacific salmon production. It is necessary to carry out large-scale research simultaneously throughout the North Pacific. Winter is a period of poor understanding of Pacific salmon dynamics and a time that is particularly difficult to study. It is desirable to have large-scale, multi-national expeditions, but it is recognized that outside funding may be necessary for such expeditions. While it is beyond the scope of this five-year plan to expect such expeditions, it would be possible to at least begin to plan how such expeditions could happen. Initial plans could focus on winter studies as this is a critical season for Pacific salmon survival.

The objectives of all research plans are to provide responsible stewardship for Pacific salmon while ensuring that fisheries are stabilized. Fishing has a major impact on the population dynamics of Pacific salmon. Accurately forecasting the returning abundances of Pacific salmon is of great importance to all countries. Accurate stock identification methods such as genetic and otolith mark analyses are necessary to monitor stock specific ocean distributions and abundance. The improved understanding of the mechanisms regulating Pacific salmon production will improve the accuracy of forecasting. Recent research is showing that there are common linkages among species and populations. Thus, it appears that the science community is improving its collective ability to understand the reasons for both the variability and the trends in production that have occurred in the past.

The Science Plans that follow are the specific needs of each country. Within each plan, are the common needs of maintaining and improving escapement monitoring. All countries have hatcheries and understanding the interaction of hatchery and wild salmon remains a priority. There is a common need to know what the balance should be between hatchery and wild production. There also is a need to understand why pink and chum salmon are doing so well in the current ocean environment. However, perhaps the most important need is to maintain a team approach among the scientists studying Pacific salmon.

4.2 Research Theme: Forecast of Pacific Salmon Production in the Ocean Ecosystems Under Changing Climate

Over the past several decades, there have been significant variations in the marine production of Asian and North American anadromous populations that are linked to climate change. There is a strong need for new international cooperative research that provides better scientific information on the ecological mechanisms regulating production of anadromous populations, estimates climate impact on salmon populations in North Pacific marine ecosystems, and examines the extent to which salmon populations, since they return to coastal regions, can be used as indicators of conditions in North Pacific marine ecosystems.

The goal is to be able to explain and forecast the annual variation in Pacific salmon production. Accurate forecast of returning salmon abundances is of great importance for stock managements in all countries. Precision monitoring of abundance and biomass in the ocean may be the most reliable method for predicting changes in production of anadromous populations. Accurate stock identification methods such as genetic and otolith mark analyses are necessary to monitor stock specific ocean distributions and abundance. Cooperative research that improves understanding of common mechanisms that regulate Pacific salmon production will increase the accuracy of short-term and long-term forecasting. Following research topics are identified.

4.2.1 Component 1: Migration and Survival Mechanisms of Juvenile Salmon in the Ocean Ecosystems

A common hypothesis is that the initial period of after migration to sea is the most critical phase with respect to ocean survival of anadromous populations. Recent cooperative and national research on juvenile salmon suggests considerable inter-annual variation in abundance, growth, and survival rates of juvenile salmon in the ocean. These variations may be related to climate-induced changes in habitat environments that operate at regional and local scales. These processes are monitored annually in marine survey areas along the coasts of Asia and North America. A better understanding of these processes is needed for conservation and management of anadromous populations.

Cooperative research may focus on the following issues:

- Seasonal distribution and migration route/timing of juvenile salmon
- Hydrological characteristics, primary production, and prey resources in the habitats
- Trophic linkages, growth rates and predation rates of juvenile salmon
- Ecological interactions between species, and between populations
- Survival rate and survival mechanism of juvenile salmon
- Population size and carrying capacity of juvenile salmon

4.2.2 Component 2: Climate Impacts on Pacific Salmon Production in the Bering Sea (BASIS) and Adjacent Waters

Climate change, and its impact on salmon carrying capacity in the Bering Sea was discussed at the BASIS Symposium held in November 2008. A current overarching hypothesis suggests that climate change will alter the current geographic distributions and behaviors of humans, marine mammals, seabirds, and fish by restructuring their habitats within the Bering Sea ecosystem (NPRB 2007). Oral presentations at the symposium highlighted evidence that increased levels of atmospheric carbon dioxide are linked to warming air and sea temperatures, reduced sea ice extent during winter, and melting of the polar cap in the Arctic region (Bond et al. 2008). However, the effect of climate change on the Bering Sea ecosystem is still debatable, with studies indicating no direct effect on the ecosystem (Shuntov and Temnykh 2009) to studies that indicate the possibility of reduced ecosystem productivity with increasing sea surface temperatures (Coyle et al. 2008).

The goal of BASIS phase II is to understand how climate change will affect productivity of Bering Sea salmon and ecologically related species. Key scientific questions are:

1. How will climate change affect anadromous populations, ecologically related species, and the Bering Sea ecosystems?
2. What are the key climatic and oceanographic factors affecting long-term changes in Bering Sea food production and salmon growth rates?
3. How will climate change impact the available salmon habitat in the Bering Sea?
4. How will climate change affect Pacific salmon carrying capacity within the Being Sea?

Cooperative research may focus on the following critical issues:

- Monitor and evaluate climate-oceanographic and biological factors related to foraging conditions, distribution, abundance and production of salmon and ecologically related species.
- Determine and understand the role of salmon in nektonic communities and their association to Bering Sea ecosystem status.
- Understand influence of climate-oceanographic conditions upon structure, status, population structure, migration, biological parameters and production processes of Pacific salmon populations.
- Understand foraging dynamics, food competition and its influence on growth and survival of salmon.
- Understand the processes that affect salmon production.
- Study the linkage between marine survival of salmon, and climate and ocean changes.
- Predict the potential impacts of global climate change on marine salmon habitats.

4.2.3 Component 3: Winter Survival of Pacific Salmon in the North Pacific Ocean Ecosystem

Western Subarctic Gyre and Gulf of Alaska ecosystems provide the major wintering habitats for various anadromous populations. While previous research has identified this as a critical period that defines the biological characteristics and biomass of anadromous populations, open ocean field research and monitoring programs have typically been carried out only during the late spring to early fall period. Better information on the status and trends in production and condition of Pacific salmon during the late fall to early spring period is needed for conservation and management of salmon resources. Knowledge of variation in the characteristics of winter marine production in the Western Subarctic Gyre and Gulf of Alaska ecosystems is needed for conservation of salmon population resources in Asia and North America.

Cooperative research may focus on the following issues:

- Winter distribution, production, and health status of salmon populations
- Hydrological characteristics, primary production, and prey resources in the winter habitats
- Trophic linkages, growth rate and predation of salmon at different stages
- Winter survival rate of salmon at different stages
- Winter carrying capacity of salmon populations
- Effects of climate change on salmon populations during winter
- Interactions between species, and between populations

4.2.4 Component 4: Biological Monitoring of Key Salmon Populations

Anadromous populations are an ideal ecological indicator of marine ecosystems. There is a need to maintain and improve basic monitoring of escapement, catch, smolt migration and other biological information for potential use in the forecasting of salmon return strength or ocean survival of Pacific Rim stock groups. Some of these long-term programs are disappearing for a variety of reasons. Understanding the linkages between climate and Pacific salmon production depends upon these basic data. In areas where hatcheries are present, data on hatchery fish abundance should be separated from wild fish abundance. Biological information such as age composition of a population, body size, fecundity and egg size should be included in the monitoring.

With the potential of limiting food resources in epipelagic waters of the North Pacific Ocean as a consequence of climate change, understanding the implications of habitat utilization by increasing numbers of Pacific Rim salmon populations is important. The identification of annual regional salmon production trends from hatchery and wild stock sources would enable researchers to examine the effects of ocean salmon biomass on subsequent survival, size at return, and age at return of key population groups.

Cooperative research may focus on the following issues:

- Identify key populations of each salmon species as indicators of regional and basin-scale ecosystems
- Monitor biological status of key salmon populations (abundance, age and body size at return, timing of return, fecundity, egg size, trophic condition, genetic diversity, disease and parasites)
- Identify annual regional production of hatchery and wild salmon

4.2.5 Component 5: Development and Applications of Stock Identification Methods and Models for Management of Pacific Salmon

Consensus on genetic baselines for sockeye, Chinook, coho and chum salmon and the development of genetic baselines for pink salmon are necessary to monitor stock specific ocean distributions and abundance. This information is needed to produce more accurate estimates of the timing and abundance of adults that are returning to coastal rivers. High-seas tagging and otolith mark programs are also important to examine migration behavior of specific populations. Finally we need models to explain how Pacific salmon production will change in the ocean ecosystems affected by changing climate.

Cooperative research may focus on the following issues:

- Improve genetic baselines for chum, sockeye, coho and Chinook salmon
- Develop genetic baselines for even-year and add-year pink salmon
- Integrate the database of tag recoveries
- Develop the database of otolith mark recoveries
- Improve forecast models for estimating abundance of specific salmon populations

4.3 Cooperative Research Approaches and Implementation of Science Plan

Relevant approaches to cooperative research under the 2011-2015 Science Plan will include collection and synthesis of existing data and metadata to generate and test specific hypotheses, integrated ecological monitoring research (research vessels, remote sensing), conceptual and quantitative modeling, process-oriented field and laboratory studies, and retrospective analyses. Scientific results from cooperative studies using these approaches will progressively fill in major gaps in scientific knowledge with respect to the research theme, components, and issues (sections 4.2), as well as contribute new scientific information to climate-change/ecosystem research being carried out by other relevant programs (e.g., PICES, North Pacific Research Board). NPAFC workshops and symposia serve an important purpose in the rapid exchange of significant new research results. The following workshops and symposium are temporally scheduled during 2011-2015:

2011/2012: NPAFC Workshop on Production Trends of Pink and Chum Salmon (components 2 and 4)

2012/2013: NPAFC Juvenile Salmon Workshop-III[*1] (components 1-3)

2013/2014: NPAFC Workshop on Forecasting Pacific Salmon Production (component 5)

2014/2015: NPAFC BASIS Symposium-II[*2] (component 2)

[*1] Juvenile salmon workshops were held every 6 years (I in 2000 and II in 2006). The workshop-III may cover winter salmon ecology as well as survival mechanisms of juvenile salmon.

[*2] BASIS symposium-I was held in 2008. The BASIS Phase II planed to hold a workshop in 2011 and symposium-II in 2014 or 2015 (NPAFC 2009b).

The timely publication by NPAFC of research results presented at workshops and symposia is an important part of this process. Internet-publication of NPAFC Technical Reports (including extended abstracts of workshop) may be considered to reduce the workshop costs.

A book on the marine ecology of Pacific salmon will be published from the American Fisheries Society as part of the celebration of the 20th anniversary of the NPAFC. The book, entitled “Life Histories of Pacific Salmon and Steelhead Trout in the Ocean Ecosystems,” will be a review of the ocean life histories and ecology of seven Pacific salmon species. The book will also identify standard salmon research techniques in the ocean and add relevant new information for the life history of Pacific salmon in fresh water. There has been a wealth of new scientific information about Pacific salmon in the past 20 years. It is timely that the information published in the book edited by Groot and Margolis in 1991 is updated and it is appropriate that the NPAFC scientists cooperate to publish this book. The book will introduce recent advances in knowledge of the marine life histories of each salmon species. This included stock specific distribution and migration models, feeding behavior, trophic interactions, survival mechanisms and productivity capacity. Each chapter will be written by scientists who have spent years studying a particular species. The book will be an invaluable source of information for scientists, teachers and students. Readers will be able to broaden their understanding of how Pacific salmon survive in the ocean. The information should become a standard reference for all Pacific salmon and all who are interested in Pacific salmon.

Specific proposals and approaches for new cooperative research under the NPAFC Science Plan will be developed at the CSRS working-group level, and will be subject to approval by the CSRS and the Commission. Specific policies for cooperation, identifying and addressing user needs, data quality, management and dissemination, logistics, outreach and education, and public involvement will be developed at the working-group or sub-group level, and will be subject to approval by the CSRS and the Commission.

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APPENDIX. Terms of Reference for the Committee on Scientific Research and Statistics of the North Pacific Anadromous Fish Commission.

These terms of reference for the committee are pursuant to Articles VII, VIII, and IX of the Convention, and were adopted by the Commission at the Commission's Inaugural Meeting in February 1993. Other matters may be referred to it by the Commission. In particular, the committee shall not be limited to, but on an interim basis, shall:

(1) review and coordinate the collection and exchange of scientific data and collection of specimens of anadromous species;

(2) coordinate and assess scientific studies to ensure the identification of the location of origin of anadromous populations migrating in the Convention Area and areas adjacent to it;

(3) ensure the availability of scientific information and views on ecologically-related species, including the impact of by-catches in related fisheries of species of concern designated by the Commission;

(4) develop appropriate observer programs to collect fishing information in the Convention Area for the purpose of scientific research on anadromous populations and, as appropriate ecologically-related species;

(5) coordinate scientific exchanges, seminars, workshops, field research and data analyses;

(6) make recommendations to the Commission for the conservation in the Convention Area of anadromous populations and ecologically-related species of concern designated by the Commission;

(7) make recommendations to the Commission to avoid or reduce incidental taking of anadromous fish in the Convention Area;

(8) review proposed scientific research programs in accordance with Article VI, paragraph 6 of the Convention;

(9) identify ecologically-related species which may be designated by the Commission as being of concern;

(10) create sub-committees necessary to carry out the functions of the committee;

(11) review and approve reports submitted for publication and make recommendations regarding other reports to be published;

(12) prepare a report annually for the Commission.

The Committee shall also:

(1) make recommendations to the Commission on cooperation, as appropriate, with PICES and other relevant international organizations to obtain the best available information, including scientific advice, to further the attainment of the objectives of the Convention;

(2) make recommendations to the Commission to invite any State or entity not party to the Convention to consult with respect to scientific matters relating to the conservation of anadromous populations and ecologically-related species;

(3) consider other matters as referred to it by the Commission.