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Science Plan 2006-2010

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 2005, the Science Sub-Committee (SSC) of the North Pacific Anadromous Fish Commission (NPAFC) was charged with developing a new five-year Science Plan (2006-2010). The science plan described in this document was reviewed by the Committee on Scientific Research and Statistics (CSRS) and approved by the Commission at the fall 2005 Annual Meeting.

This document is intended for a broad audience who may be unfamiliar with the Commission and its scientific research activities. A brief summary of background information on the Commission, the Convention, the species of anadromous stocks, 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 is provided in the introduction.

The vision of the Convention is conservation of anadromous stocks in the North Pacific Ocean. To achieve this vision, the Commission needs the best available scientific information on the condition of anadromous stocks, 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 stocks and ecologically related species in the ocean; to coordinate efforts to conserve anadromous stocks in the ocean; and to establish an effective mechanism of international cooperation to promote the conservation of anadromous stocks 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 stocks 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.

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 stocks 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 stocks 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 stocks, 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 stocks, and how are these trends related to population structure (spatial and temporal) and diversity of anadromous stocks in marine ecosystems of the North Pacific?
2. How will climate and climate change affect anadromous stocks, ecologically related species, and their North Pacific marine ecosystems?

Over the past decade, there have been significant variations in the marine production of Asian and North American anadromous stocks that appear to be linked to climate change. There is a strong need for new international cooperative research that provides better scientific information on the status and trends in marine production of anadromous stocks, identifies the roles of anadromous stocks in North Pacific marine ecosystems, and examines the extent to which anadromous stocks, since they return to coastal regions, can be used as indicators of conditions in North Pacific marine ecosystems.

Variation in the time, frequency, and amplitude of climate events that affect the ocean production of marine fish seems to be increasing. This has led many experts to conclude that precision monitoring of abundance and biomass in the ocean may be the only reliable method for predicting changes in production of anadromous stocks. That each species of salmon follows a life history strategy in the ocean is probable. Cooperative research that identifies the common mechanisms will improve regional forecasting. In addition, the conceptual framework for the management of fish populations has expanded from relatively simple assessments of abundance and productivity to broader needs for information on population structure (spatial and temporal) and diversity.

The SSC used a salmon ecosystem/life history conceptual framework to render a holistic understanding of the two broad questions. Under this framework, Asian and North American anadromous stocks migrating in the Convention area can be viewed as one large population that has evolved to respond successfully to natural stressors and stressor regimes at the ecosystem level. Salmon life history provides natural organization to this framework because at each maturity stage there is substantial regional and local variation in distribution and migration patterns, stressors, and stressor regimes that affect survival and growth rates. These differences may provide a buffer against climate variability and optimize the survival of the larger population. Cooperative research under this conceptual framework will provide information on abundance, biomass, vital rates, and processes essential to filling gaps in scientific information to evaluate effects of climate and climate changes in ocean ecosystems.

To provide necessary focus to cooperative research under the 5-year science plan, the SSC identified an overarching research theme, “Status and Trends in Production of Anadromous Stocks in Ocean Ecosystems,” and three major research components:

(1) Juvenile Anadromous Stocks in Ocean Ecosystems;

(2) Anadromous Stocks in the Bering Sea Ecosystem (BASIS); and

(3) Anadromous Stocks in the Western Subarctic Gyre and Gulf of Alaska Ecosystems.

Cooperative research activities under the 2006-2010 Science Plan will attempt to clarify the present status and trends in production of North Pacific anadromous stocks, to determine important stressors and stressor regimes that affect population structure and diversity, to evaluate subsequent effects of these mechanisms on the viability and performance of North Pacific anadromous stocks at critical marine life-history stages, and to evaluate effects of climate and climate changes on marine production of anadromous stocks.

Component-1: Juvenile Anadromous Stocks in the Ocean Ecosystems

In at least some species of anadromous stocks (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 stocks. Recent cooperative and national research on juvenile salmon suggests considerable interannual 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. To a greater or lesser extent, 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 stocks.

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
- Population size, survival rate and survival mechanism of juvenile salmon

Component 2: Anadromous Stocks in the Bering Sea Ecosystem (BASIS)

The centerpiece of NPAFC's marine ecosystem research to date is BASIS. Under the 2001-2005 Science Plan, BASIS research has progressed and evolved to more complex research issues, and has become an integral part of ecosystem research planned by other international, national, and regional conservation, management, and research organizations (e.g., PICES, North Pacific Research Board). 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 stocks. The results of cooperative BASIS ecosystem monitoring research in 2002-2004 indicated a very high density of Asian and North American anadromous stocks 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 stocks 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 stocks 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 stocks to climate and climate change.

Cooperative research may focus on the following critical issues:

- Distribution, migration route/timing, production, and health of anadromous stocks and ecologically related species
- Multi-year trends (regimes) in physical and biological factors that influence long-term changes in Bering Sea food production and fluctuations in salmon production and growth rates
- Hydrological characteristics, primary production, and prey resources in the habitats
- Trophic linkages, growth changes, and predation rate of anadromous stocks
- Interactions between species, between stocks, and between life-history stages
- Changes in carrying capacity of anadromous stocks

Component 3: Anadromous Stocks in the Western Subarctic Gyre and Gulf of Alaska Ecosystems

Anadromous stocks 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. Recent research vessel surveys by Canada, Japan, Russia, and the USA have collected a considerable amount of new data on anadromous stocks, 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. Anadromous stocks consume a substantial quantity and biomass of prey organisms in these ecosystems, and play an important role as a higher trophic level predator. Changes marine tropic relations in these ecosystems influence the productivity of salmon populations returning to different reproduction regions in Asia and North America.

The Western Subarctic Gyre and Gulf of Alaska ecosystems provide major wintering habitats for various anadromous stocks. While previous research has identified this as a critical period that defines the biological characteristics and biomass of anadromous stocks, 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 marine production in the Western Subarctic Gyre and Gulf of Alaska ecosystems is needed for conservation of anadromous stocks resources in Asia and North America. In addition, more accurate forecasts of adult salmon returns will benefit salmon industries around the Pacific Rim.

Cooperative research may focus on the following issues:

- Seasonal distribution, production, and health of anadromous stocks and ecologically related species
- Seasonal changes in feeding, growth, and habitat condition
- Winter survival strategies of anadromous stocks
- Effects of climate change on population size and survival rate
- Multi-year trends (regimes) in physical and biological factors that influence long-term changes in food production and fluctuations in salmon production and growth rates
- Interactions between species, between stocks, and between life-history stages
- Changes in carrying capacity of anadromous stocks

Relevant approaches to cooperative research under the 2006-2010 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 3.3), 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 timely publication by NPAFC of research results presented at workshops and symposia is an important part of this process.

As in the case of the 2001-2006 BASIS research plan, 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. Implementation of cooperative research plans approved by the CSRS and the Commission under the 2006-2010 Science Plan will follow the same procedures that were approved by CSRS for the BASIS research program.

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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1.0 INTRODUCTION

In 2005, the Science Sub-Committee (SSC) of the North Pacific Anadromous Fish Commission (NPAFC) was charged with developing a new five-year Science Plan (2006-2010). The science plan developed by the SSC and described in this document was recommended for approval by the Committee on Scientific Research and Statistics (CSRS) and approved by the Commission at the fall 2005 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 stocks, 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 Stocks 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 stocks in the Convention Area.

1.2 The Species of Anadromous Stocks

Species of anadromous stocks 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 stocks 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 stocks 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.

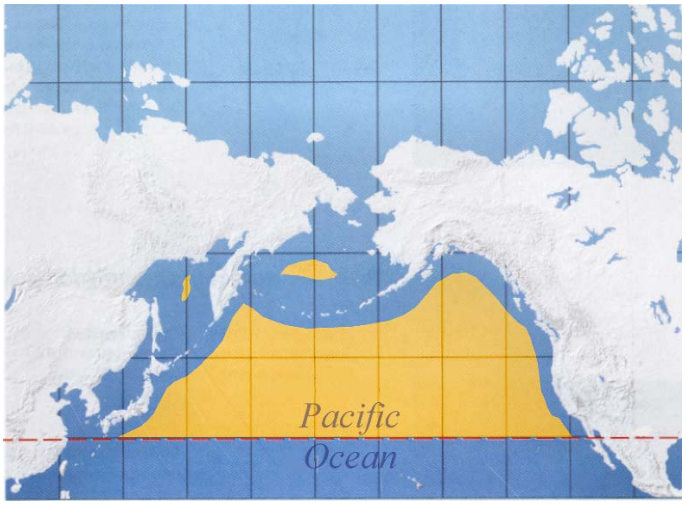

Fig. 1. Map showing the area (shaded in yellow) where directed fishing for salmon is prohibited by the Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean, i.e., north of 33º North latitude (above the dashed line), beyond 200-mile zones.

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 stocks. 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 stocks 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 stocks." 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 stocks 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 stocks, and that each nation makes expenditures and foregoes economic development opportunities to establish favourable conditions to conserve and manage its stocks.

The vision of the Convention is conservation of anadromous stocks in the North Pacific Ocean. To achieve this vision, the Commission needs the best available scientific information on the condition of anadromous stocks, ecologically related species, and their marine ecosystems. The member nations of NPAFC recognize that many scientific questions about anadromous stocks 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 stocks and ecologically related species in the ocean; to coordinate efforts to conserve anadromous stocks in the ocean; and to establish an effective mechanism of international cooperation to promote the conservation of anadromous stocks 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 stocks 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 four 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).

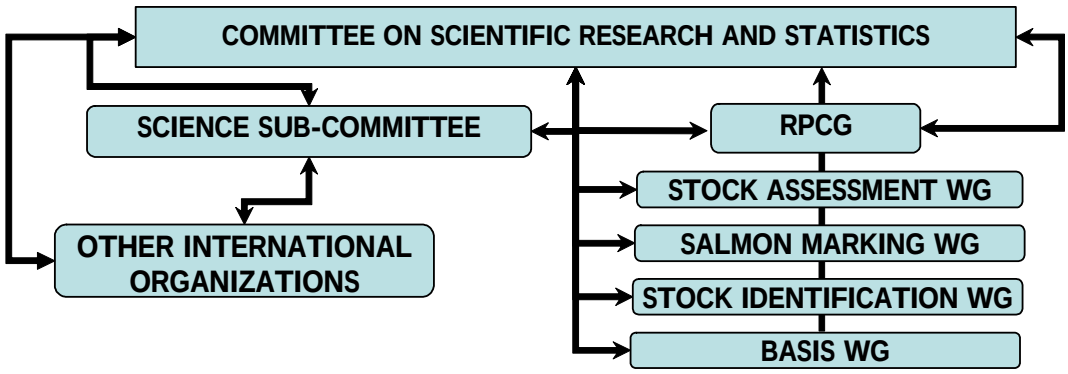

Fig. 2. Organizational chart of the NPAFC Committee on Scientific Research and Statistics. RPCG = Research Planning and Coordinating Group; WG = Working Group; BASIS = Bering-Aleutian Salmon International Survey.

2.0 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 Stocks" (NPAFC 1998b) and "Recent Changes in Ocean Production of Pacific Salmon (NPAFC 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 stocks 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 stocks 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 stocks. 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 stocks.

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 stocks. 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 (DNA) methods (NPAFC 2001, 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 2001). 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 ongoing 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 2005), and the results and recommendations from that workshop will be applied to continuing cooperative work on this issue under the new (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 2001). 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," to be held in spring 2006 is well underway. The results and recommendations from this workshop will be applied to continuing cooperative work on this issue under the new (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 stocks in the Convention area under the 2001-2005 Science Plan. Research planning and coordinating for a cooperative salmon research cruise (R/V *Kaiyo maru*) in the Convention area in winter 2006 is well underway.

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 1998). 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. The results and recommendations from this symposium will be 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 stocks 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 stocks in the open ocean; (4) the first international calibration of pelagic trawls to standardize abundance and biomass estimates of anadromous stocks 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 stocks.

3.0 THE 2006-2010 SCIENCE PLAN

3.1 Broad Scientific Questions

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 stocks 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 stocks 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 stocks, 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 stocks; and how are these trends related to population structure (spatial and temporal) and diversity of anadromous stocks in marine ecosystems of the North Pacific?
2. How will climate and climate change affect anadromous stocks, ecologically related species, and their North Pacific marine ecosystems?

Over the past decade, there have been significant variations in the marine production of Asian and North American anadromous stocks that appear to be linked to climate change. There is a strong need for new international cooperative research that provides better scientific information on the status and trends in marine production of anadromous stocks, identifies the roles of anadromous stocks in North Pacific marine ecosystems, and examines the extent to which anadromous stocks, since they return to coastal regions, can be used as indicators of conditions in North Pacific marine ecosystems.

Variation in the time, frequency, and amplitude of climate events that affect the ocean production of marine fish seems to be increasing. This has led many experts to conclude that precision monitoring of abundance and biomass in the ocean may be the only reliable method for predicting changes in production of anadromous stocks. That each species of salmon follows a life history strategy in the ocean is probable. Cooperative research that identifies the common mechanisms will improve regional forecasting. In addition, the conceptual framework for the management of fish populations has expanded from relatively simple assessments of abundance and productivity to broader needs for information on population structure (spatial and temporal) and diversity.

3.2 Conceptual Model

The SSC used a salmon ecosystem/life history conceptual framework to render a holistic understanding of the two broad questions. Under this framework, Asian and North American anadromous stocks migrating in the Convention area can be viewed as one large population that has evolved to respond successfully to natural stressors and stressor regimes at the ecosystem level. Salmon life history provides natural organization to this framework because at each maturity stage there is substantial regional and local variation in distribution and migration patterns, stressors, and stressor regimes that affect survival and growth rates. These differences may provide a buffer against climate variability and optimize the survival of the larger population. Cooperative research within this conceptual framework will provide information on abundance, biomass, vital rates, and processes essential to filling gaps in scientific information to evaluate effects of climate and climate changes in ocean ecosystems.

3.3 Research Theme: Status and Trends in Production of Anadromous Stocks in Ocean Ecosystems

The influence of regional and local environmental stressors on the status of different salmon species and stocks at initial and subsequent life history stages is varied. These stressors may affect the quantity and biomass of juvenile salmon migrating to the sea, immature and maturing salmon migrating in the open ocean, and adult salmon returning to coastal and freshwater fisheries. Obtaining reliable abundance estimates is essential to understanding survival at each marine life history stage. For conservation of anadromous stocks, better scientific information is needed on the effects of climate and climate change on anadromous stocks, ecologically related species, and their North Pacific marine ecosystems.

Cooperative research activities will attempt to clarify the present status and trends in production of North Pacific anadromous stocks, to determine important stressors and stressor regimes that affect population structure and diversity, to evaluate subsequent effects of these mechanisms on the viability and performance of North Pacific anadromous stocks at critical marine life-history stages, and to evaluate effects of climate and climate changes on marine production of anadromous stocks.

3.3.1 Component-1: Juvenile Anadromous Stocks in Ocean Ecosystems

In at least some species of anadromous stocks (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 stocks. Recent cooperative and national research on juvenile salmon suggests considerable interannual 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. To a greater or lesser extent, 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 stocks.

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
- Population size, survival rate and survival mechanism of juvenile salmon

3.3.2 Component 2: Anadromous Stocks in the Bering Sea Ecosystem (BASIS)

The centerpiece of NPAFC's marine ecosystem research to date is BASIS. Under the 2001-2005 Science Plan, BASIS research has progressed and evolved to more complex research issues, and has become an integral part of ecosystem research planned by other international, national, and regional conservation, management, and research organizations (e.g., PICES, North Pacific Research Board). 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 stocks. The results of cooperative BASIS ecosystem monitoring research in 2002-2004 indicated a very high density of Asian and North American anadromous stocks 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 stocks 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 stocks 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 stocks to climate and climate change.

Cooperative research may focus on the following critical issues:

- Distribution, migration route/timing, production, and health of anadromous stocks and ecologically related species
- Multi-year trends (regimes) in physical and biological factors that influence long-term changes in Bering Sea food production and fluctuations in salmon production and growth rates
- Hydrological characteristics, primary production, and prey resources in the habitats
- Trophic linkages, growth changes, and predation rate of anadromous stocks
- Interactions between species, between stocks, and between life-history stages
- Changes in carrying capacity of anadromous stocks

3.3.3 Component 3: Anadromous Stocks in the Western Subarctic Gyre and Gulf of Alaska Ecosystems

Anadromous stocks 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. Recent research vessel surveys by Canada, Japan, Russia, and the USA have collected a considerable amount of new data on anadromous stocks, 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. Anadromous stocks consume a substantial quantity and biomass of prey organisms in these ecosystems, and play an important role as a higher trophic level predator. Changes marine

tropic relations in these ecosystems influence the productivity of salmon populations returning to different reproduction regions in Asia and North America.

The both ecosystems provide the major wintering habitats for various anadromous stocks. While previous research has identified this as a critical period that defines the biological characteristics and biomass of anadromous stocks, 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 marine production in the Western Subarctic Gyre and Gulf of Alaska ecosystems is needed for conservation of anadromous stocks resources in Asia and North America. In addition, more accurate forecasts of adult salmon returns will benefit salmon industries around the Pacific Rim.

Cooperative research may focus on the following issues:

- Seasonal distribution, production, and health of anadromous stocks and ecologically related species
- Seasonal changes in feeding, growth, and habitat condition
- Winter survival strategies of anadromous stocks
- Effects of climate change on population size and survival rate
- Multi-year trends (regimes) in physical and biological factors that influence long-term changes in food production and fluctuations in salmon production and growth rates
- Interactions between species, between stocks, and between life-history stages
- Changes in carrying capacity of anadromous stocks

3.4 Cooperative Research Approaches and Implementation of Science Plan

Relevant approaches to cooperative research under the 2006-2010 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 3.3), 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 timely publication by NPAFC of research results presented at workshops and symposia is an important part of this process.

As in the case of the 2001-2006 BASIS research plan (NPAFC 2001c), 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. Implementation of cooperative research plans approved by the CSRS and the Commission under the 2006-2010 Science Plan will follow the same procedures that were approved by CSRS for the BASIS research program (Fig. 3).

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.

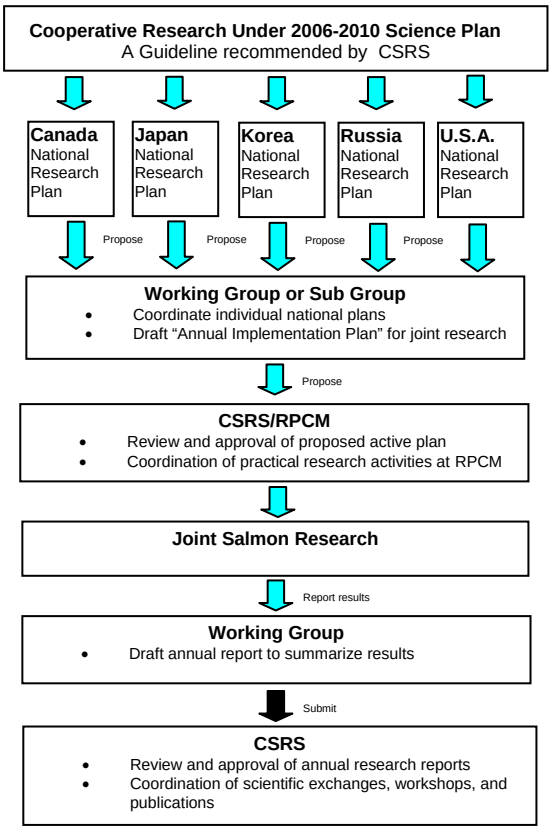

Fig. 3. Diagram showing the CSRS-approved guideline for implementation of cooperative research under the 2006-2010 Science Plan.

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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 stocks 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 stocks 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 stocks 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 stocks and ecologically-related species;

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