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Japanese Salmon Research under the NPAFC Science Plan 2006-2010: A Review and Future Issues

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Introduction

The North Pacific Anadromous Fish Commission (NPAFC) was established under the Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean, signed on February 11, 1992 and entered into force on February 16, 1993 by Canada, Japan, the Russian Federation and the United States. The primary objective of NPAFC is to promote the conservation of anadromous stocks in the North Pacific Ocean and adjacent waters.

In 1993, the Committee on Scientific Research and Statistics (CSRS) identified two critical issues for research by the parties: (1) factors affecting current trends in ocean productivity, and (2) factors affecting changes in biological characteristics such as growth, size and age at maturity, oceanic distribution, survival, and abundance of Pacific salmon. The CSRS developed the NPAFC Science Plan to address these two critical issues by three components: (1) life history of salmonids, (2) salmonid population dynamics, and (3) salmonid habitat and ecosystem. Each component has several items that identify questions relating to the two critical issues. Under the NPAFC Science Plan, the Parties make each research plan, cooperating in the scientific research.

In 2005, the five-year Science Plan (2006-2010) was reviewed by the CSRS and approved by the Commission at the fall 2005 Annual Meeting (Anon. 2005). Three major components of research were;

(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.

The purposes of this paper are to review results of Japanese salmon research related with the present Science Plan from 2006, and to propose future research for the appropriate conservation and utilization of Pacific salmon.

Review of Research

1. Juvenile Anadromous Stocks in the Ocean Ecosystems

In general, juveniles of Japanese chum salmon (*Oncorhynchus keta*) spend their early period along the coast and migrate to offshore after a decrease of prey organisms (Seki 2005, 2007). Along the Okhotsk and Pacific Coast of Hokkaido, juvenile chum salmon are abundant in the coastal waters at surface temperature 8°C, and then disappear about 13°C (Seki, 2005; Miyakoshi et al. 2007). After leaving coastal water, most Japanese chum salmon migrate to the Okhotsk Sea and spend there by autumn together with Russian stocks (Urawa et al. 2007). Juvenile chum mainly fed on amphipods in the Okhotsk Sea and migrate to the North Western Pacific in the winter (Starovoytov 2007a, b).

In coastal waters of northern Japan, survival of juvenile chum strongly determines brood-year strengths of adult salmon: fry-to-adult survival for chum salmon released from some regions along the Sea of Okhotsk and Pacific Ocean is influenced by size at release of juveniles and/or coastal SSTs (Saito and Nagasawa 2009). In some coastal research projects, spatio-temporal variability in juvenile abundance, growth and diet is successfully linked with coastal environmental conditions such as SSTs and zooplankton abundance (Miyakoshi et al. 2007; Nagata et al. 2007, Saito et al. 2009). However, these results obtained from the coastal research seem not to necessarily correspond to adult returns (Saito et al. 2007).

It is still unclear why Japanese chum salmon concentrate in the Okhotsk Sea at juvenile stage and in the Bering Sea at immature and maturing stages. Further studies are necessary to clarify relations between oceanographic conditions, productivity of food organisms, and salmonid distribution.

2. Anadromous Stocks in the Bering Sea Ecosystem (BASIS)

Populations of chum salmon from Asia and North America co-migrate in the North Pacific Ocean and the Bering Sea. The Bering Sea is a major feeding habitat for chum salmon during the summer season. Japanese scientists had participated in the Bering/Aleutian Salmon International Survey (BASIS) program to clarify the effect of environmental factors on the distribution of Pacific Salmon in the Bering Sea during 2002-2003. After BASIS phase I programs, we have conducted to monitoring operations of biological and oceanographic surveys of Pacific salmon in the summer Bering Sea by R/V *Hokko maru* since 2007 (Morita et al. 2007, 2008, 2009). Main catches in the three years included sockeye salmon (*O. nerka*), chum salmon, Chinook salmon (*O. tshawytscha*), pink salmon (*O. gorbuscha),* coho salmon (*O. kisutch*), steelhead trout (*O. mykiss*), Atka mackerel (*Pleurogrammus monopterygius*) and other fishes. Sockeye salmon were distributed mainly in the central and eastern Bering Sea. CPUE (catch per unit effort) of sockeye salmon was also highest in the eastern Bering Sea. Chum salmon is widely distributed in the summer Bering Sea during 2007-2009, and they were relatively abundant in the central Bering Sea. The CPUE of chum salmon was the highest salmon species in the survey period of summer Bering Sea. Chinook salmon is widely distributed in the survey areas of Bering Sea, although the CPUE of Chinook salmon was lower than that of sockeye and chum salmon in each year. The CPUEs of pink and coho salmon were very low through the three years. In 2008, one steelhead trout was collected in the southwestern Bering Sea (Morita et al. 2008). Atka mackerel was the most abundant non-salmonid species in the Bering Sea. This fish were distributed mainly offshore of the southwestern and southcentral of the survey area of Bering Sea. Distribution of Atka mackerel differed from distribution of salmon.

In 2009, we conducted to explore the northern limit of offshore distribution of Pacific salmon in the northern Bering Sea and the Chukchi Sea (Morita et al. 2009). The northern limit of salmon catches during 2009 *Hokko maru* cruise was fishing station in the Chukchi Sea (68°46’N, 167°49’W). At this fishing station, four large chum salmon were caught, all of which were large and maturing males. The fork length of chum salmon tended to increase with increasing latitude, whereas the number of individuals caught at each fishing station tended to decrease with increasing latitude (Morita et al. 2009).

Genetic stock identification (GSI) analysis and otolith mark/recovery experiments have provided significant useful stock-specific information on the offshore ocean distribution. GSI analysis were performed using allozyme and mitochondrial DNA (mtDNA) markers, and the results showed that Japanese and Russian chum salmon stocks are predominant in the central Bering Sea during summer and fall (Urawa et al. 2009; Moriya et al. 2007, 2009). Other GSI result using mtDNA also demonstrated that the distribution pattern and abundance of chum salmon CPUE in the Bering Sea was different among years and seasons, while those changes were not significantly related to the favorable sea surface temperature range in the Bering Sea (Sato et al. 2009a). Results of otolith-marked fish recovery from the Bering Sea and North Pacific Ocean during spring and summer indicated that otolith-marked chum salmon released from NPAFC countries are detectable in the Bering Sea and North Pacific Ocean, while about 90% of the marked salmon were released from Japanese hatcheries (Sato et al. 2009b).

Addition to these the BASIS Symposium in 2008, horizontal and vertical distribution patterns of pacific salmon were revealed (Azumaya and Nagasawa 2009, Nagasawa and Azumaya 2009).

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

Asian Pacific salmon other than chum salmon mainly distribute in the western North Pacific. T/V *Oshoro maru* has continued to monitor abundances of salmon and other pelagic fishes using a research gillnet on the 155°E transect in May (Meguro et al. 2007, Kamei et al. 2008, Sakaoka et al. 2009, Hoshi et al. 2010). At the other hand, chum salmon migrate in a broad area of the North Pacific. R/V *Kaiyo maru* conducted a winter and a spring salmon researches in the North Pacific 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. 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 (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. in print). Onuma et al. (2009, 2010) found the onset of sexual maturity of Japanese chum salmon occurred at the Gulf of Alaska in the winter one year before the spawning, which should motivate the homing migration through the Bering Sea to Japan.

Contribution to NPAFC science plan

Japan has maintained the high sea salmon monitoring using research drift-net since 1972. This time series data have been helpful to detect the climate change effect on the Pacific salmon populations in the Bering Sea Ecosystem (Nagasawa and Azumaya 2009). In 2006, winter research survey in the north western Pacific was conducted by Japanese party. The researchers of other parties were invited to this cruise and throughout this cruise, knowledge on the over wintering nature of anadromous Stocks in the Western Subarctic Gyre was advanced (Fukuwaka et al. 2007). Other research cruises based on Japanese national research plans (e.g. R/V *Hokko maru* cruise in 2009; see Morita et al. 2009) were also provided useful information to our knowledge.

Future Salmon Research

The major purpose of Japanese salmon research is to accomplish sustainable fisheries, balancing the conservation and use of salmon stocks in the North Pacific ecosystem. Thus, we should concentrate future salmon studies to population dynamics and ocean ecosystems in specific waters. These researches are (1) population ecology of Japanese salmon stocks, (2) salmon studies in the Bering Sea and other waters, and (3) monitoring of major salmon stocks. These issues may be incorporated into a revised new NPAFC Science Plan.

1. Population ecology of Japanese salmon stocks

1-1. Coastal Sea Juvenile Salmon Studies

Major mortality of chum and pink salmon may occur during the initial coastal life. Thus, coastal life history studies are important to understand the survival mechanisms of salmon. To clarify mechanisms controlling population dynamics of juvenile salmon, we conduct juvenile salmon studies in Japanese coastal waters.

1-2. Studies on returning stock dynamics under environmental changes

Salmon stocks are valuable human food resources. For sustainable exploitation of salmon stocks under environmental changes, we study on the relationship between stock dynamics of returning salmon adults and environmental changes using field surveys and modelling studies.

2. Salmon Studies in the Bering Sea and Other Waters

2-1. Bering Sea Salmon Ecology Studies

Recent studies suggested that ocean growth has been recovered in the 2000s from a low level in the 1980s in many salmon stocks of the North Pacific. A major portion of ocean growth occurs in the Bering Sea, when many salmon migrate in the waters for their feeding and growth in summer. To clarify relations between the growth and mortality of salmon and the carrying capacity in the Bering Sea, we conduct monitoring surveys using trawl nets.

2-2. Monitoring of Salmon and Environment in the North Pacific Ocean

To assess the status of salmon population, Japanese salmon research vessels are continuing monitoring of salmon and their environment in the western subarctic Gyre in summer. We monitor status of salmon and pelagic fish abundances, and their environment using gillnets.

3. Monitoring of Major Salmon Stocks

A monitoring program is continued to assess the status of major salmon stocks in Japan for their proper management.

References

Anonymous (Canada, Japan, Korea, Russia, and United States). 2005. North Pacific Anadromous Fish Commission Science Plan 2006-2010. (NPAFC Doc. 921) 19 p. Committee on Scientific Research and Statistics (CSRS), North Pacific Anadromous Fish Commission, Vancouver, B.C., Canada. (Available at www.npafc.org).

Azumaya, T. and T. Nagasawa. 2009. Reproduction of short-term vertical movements observed using archival tags on chum salmon (*Oncorhynchus keta*) by a simple model. N. Pac. Anadr. Fish Comm. Bull. 5: 61-69.

Fukuwaka, M., S. Sato, S. Takahashi, T. Onuma, N. Davis, J. Moss, A. Volkov, K-B. Seong, O. Sakai, N. Tanimata, and K. Makino. 2006. International salmon research aboard the R/V *Kaiyo maru* in the North Pacific Ocean during the winter of 2006. (NPAFC Doc. 957). 12 p. Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Kushiro, Japan. (Available at www.npafc.org).

Fukuwaka, M., S. Sato, S. Takahashi, T.A. Onuma, O. Sakai, N. Tanimata, K. makino, N.D. Davis, A.F. Volkov, K.B. Seong, and J.H. Moss. 2007. Winter distribution of chum salmon related to environmental variables in the North Pacific. NPAFC Tech. Rep. 7: 29-30.

Hoshi N., Sakaoka K., Abe T., Kamei Y., Takagi S. 2010. Results of 2009 salmon research cruises of the *Oshoro maru*. (NPAFC Doc. 1226) 20 p. Graduate School of Fisheries Sciences & Faculty of Fisheries, Hokkaido University, Hakodate, Japan. (Available at www.npafc.org).

Kamei, Y., Takagi, S., Sakaoka, K., Kajiwara, Y., Kimura J., Meguro, T., Kudo, H., Kaeriyama, M. 2008. 2007 T/V *Oshoro maru* salmon research cruises. NPAFC Doc. 1088. 25 pp. Graduate School of Fisheries Sciences & Faculty of Fisheries, Hokkaido University, Hakodate, Japan. (Available at http://www.npafc.org).

Meguro, T., Kajiwara, Y., Takagi, S., Kamei, Y., Sakaoka, K., and Kimura J. 2007. Results of 2006 salmon research cruise of the *Oshoro maru*. (NPAFC Doc. 1021) 16 p. Faculty of Fisheries, Hokkaido University, Hakodate, Japan. (Available at www.npafc.org).

Morita, K., S. Sato, T. Kaga, D. Takasaki, T. Chiba, A. F. Volkov, K. Cieciel, S. K. Kang, N. Tanimata, Y. Kamezawa, M. Katsumata, and T. Azumaya. 2006. The 2006 spring international cooperative salmon research cruise of the R/V *Kaiyo maru*. (NPAFC Doc. 958).

10 p. Hokkaido National Fisheries Research Institute, FRA, Kushiro. (Available at www.npafc.org).

Morita, K., S. Sato, M. Kagaya, Y. Goda, T. Chiba, and K. Makino. 2007. The 2007 summer Japanese salmon research cruise of the R/V *Hokko maru*. NPAFC Doc. 1044. 8pp. (Available at www.npafc.org).

Morita, K., S. Sato, H. Tokuda, M. Iida, and M. Shinto. 2008. 2008 summer Japanese salmon research cruise of the R/V *Hokko maru*. NPAFC Doc. 1116. 11 pp. (Available at www.npafc.org).

Morita, K., S. Sato, M. Kato, and J. Yamamoto. 2009. The summer 2009 Japanese salmon research cruise of the R/V *Hokko maru*: exploration of the northern limit of offshore distribution and annual survey in the Bering Sea. NPAFC Doc. 1191. 12 pp. (Available at www.npafc.org).

Morita, K., M. Fukuwaka, N. Tanimata, and O. Yamamura. In print. Size-dependent thermal preferences in a pelagic fish. Oikos.

Moriya, S., S. Sato, T. Azumaya, O. Suzuki, S. Urawa, A. Urano, and S. Abe. 2007. Genetic stock identification of chum salmon in the Bering Sea and North Pacific Ocean using mitochondrial DNA microarray. Mar. Biotechnol. 9: 179-191.

Moriya, S., S. Sato, M. Yoon, T. Azumaya, S. Urawa, A. Urano, and S. Abe. 2009. Nonrandom distribution of chum salmon stocks in the Bering Sea and the North Pacific Ocean estimated using mitochondrial DNA microarray. Fish. Sci. 75:359-367.

Miyakosho, Y., M. Fujiwara, D. Ando, H. Shimada, M. Sawada, H. Asami, and M. Nagata. 2007. Distribution and growth of juvenile chum salmon in the Abashiri Bay, eastern Hokkaido, in relation to sea surface temperature. NPAFC Tech. Rep. 7: 21-22.

Nagasawa, T. and T. Azumaya. 2009. Distribution and CPUE trends in Pacific salmon, especially sockeye salmon in the Bering Sea and adjacent waters from 1972 to the mid 2000s. N. Pac. Anadr. Fish Comm. Bull. 5:1-13.

Nagata, M., Y. Miyakoshi, D. Ando, M. Fujiwara, M. Sawada, H. Shimada, and H. Asami. 2007. Influence of coastal seawater temperature on the distribution and growth of juvenile chum salmon, with recommendations for altered release strategies. N. Pac. Anadr. Fish Comm. Bull. 4: 223-235.

Onuma, T.A., S. Sato, H. Katsumata, K. Makino, W. Hu, A. Jodo, N.D. Davis, J.T. Dickey, M. Ban, H. Ando, M. Fukuwaka, T. Azumaya, P. Swanson, and A. Urano. 2009. Activity of the pituitary-gonadal axis is increased prior to the onset of spawning migration of chum salmon. J. Exp. Biol. 212: 56-70.

Onuma, T.A., K. Makino, H. Katsumata, B.R. Beckman, M. Ban, H. Ando, M. Fukuwaka, T. Azumaya, P. Swanson, and A. Urano. 2010. Changes in the plasma levels of insulin-like growth factor-I from the onset of spawning migration through upstream migration in chum salmon. Gen. Comp. Endocrinol. 165: 237-243.

Sakaoka, K., Y. Kamei, S. Takagi, Y. Kajiwara, J. Kimura, and T. Meguro. 2009. 2008 T/V *Oshoro maru* salmon research cruises. NPAFC Doc. 1158. 17 pp. Graduate School of Fisheries Sciences & Faculty of Fisheries, Hokkaido University, Hakodate, Japan. (Available at www.npafc.org).

Saito, T., I. Shimizu, and J. Seki. 2007. Linkage between early ocean life and adult returns of chum salmon in the Strait of Nemuro, Japan. NPAFC Tech. Rep. 7: 59-60.

Saito, T., I. Shimizu, J. Seki, and K. Nagasawa. 2009. Relationship between zooplankton abundance and the early marine life history of juvenile chum salmon *Oncorhynchus keta* in eastern Hokkaido, Japan. Fish. Sci. 75: 303-316.

Saito, T., and K. Nagasawa. 2009. Regional synchrony in return rates of chum salmon (*Oncorhynchus keta*) in Japan in relation to coastal temperature and size at release. Fish. Res. 95: 14-27.

Sato, S., S. Moriya, T. Azumaya, H. Nagoya, S. Abe, and S. Urawa. 2009a. Stock distribution patterns of chum salmon in the Bering Sea and North Pacific Ocean during the summer and fall of 2002-2004. N. Pac. Anadr. Fish Comm. Bull. 5: 29-37.

Sato, S., M. Takahashi, N. Watanabe, S. Kitatsuji, D. Takasaki, T. Chiba, S. Imai, Y. Goda, Y. Katayama, M. Kagaya, M. Fukuwaka, B. A. Agler, and S. Urawa. 2009b. Preliminary records of otolith-marked chum salmon found in the Bering Sea and North Pacific Ocean in 2006 and 2007. N. Pac. Anadr. Fish Comm. Bull. 5: 99-104.

Seki, J., 2005. Study of characteristic of feeding habit of juvenile chum salmon and their food environmental in the Pacific coastal waters, central part of Hokkaido. Bull. Natl. Salmon Resources Center, (7): 1-104.

Seki, J. 2007. Overview of juvenile salmon research in Japan from 2001 to 2005. NPAFC Tech. Rep. 7: 14-16.

Starovoytov A. N. 2007a. Seasonal distribution and migration of juvenile chum salmon. NPAFC Tech. Rep. 7: 26-28.

Starovoytov A. N. 2007b. Trophic linkages of juvenile chum salmon in the Okhotsk and Bering Seas during the last decade. NPAFC Tech. Rep. 7: 92-94.

Urawa, S., S. Sato, N. Varnavskaya, P. A. Crane, and T. D. Beacham. 2007. Genetic stock identification of juvenile chum salmon caught in the Okhotsk Sea during the fall of 2003. NPAFC Tech. Rep. 7: 72-74.

Urawa, S., S. Sato, P. A. Crane, B. Agler, R. Josephson, and T. Azumaya. 2009. Stock-specific ocean distribution and migration of chum salmon in the Bering Sea and North Pacific Ocean. N. Pac. Anadr. Fish Comm. Bull. 5: 131-146.