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Japanese Bibliography in 2011-2012 for NPAFC Science Plan

by

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ABSTRACT

This bibliography listed original papers and documents published in 2011-2012 by Japanese scientists and their collaborators in order to review Japanese national researches for the 2011-2015 NPAFC Science Plan. The bibliography includes 34 articles with abstracts, corresponding to five research components of the NPAFC Science Plan.

BACKGROUND

In 2010, the Science Sub-Committee (SSC) of the North Pacific Anadromous Fish Commission (NPAFC) developed a new five-year Science Plan (2011-2015) (Anonymous 2010). The SSC identified an overarching research theme "Forecast of Pacific Salmon Production in the Ocean Ecosystems under Changing Climate" and five research components: 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; 4) Biological monitoring of key salmon populations; and 5) Development and application of stock identification methods and models for management of Pacific salmon.

The national research plan by Japan was established in March 2011 to correspond to the new NPAFC Science Plan (Fisheries Agency of Japan 2011). The primary goal is to accomplish sustainable salmon fisheries with the conservation of wild and hatchery stocks in the North Pacific ecosystems. To review Japanese national researches for the NPAFC Science Plan, the previous bibliography listed original papers and documents published in 2010-2011 by Japanese scientists and/or their collaborators (Sato et al. 2011). The current issue supplemented 34 articles published in 2011-2012. The bibliography includes abstracts for all articles.

Anonymous. 2010. North Pacific Anadromous Fish Commission Science Plan 2011-2015. NPAFC Doc. 1255. 34 pp. (Available at www.npafc.org).

Fisheries Agency of Japan. 2011. Japanese salmon research under the NPAFC Science Plan 2011-2015. NPAFC Doc. 1311. 3 pp. (Available at www.npafc.org).

Sato, S., T. Nagasawa, and S. Urawa. 2011. Japanese bibliography in 2010-2011 for NPAFC Science Plan. NPAFC Doc. 1346. 14 pp. (Available at www.npafc.org).

BIBLIOGRAPHY

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

Miyakoshi, Y. and S. Saitoh. 2011. Effects of smolt size and timing of migration on recovery rate of wild masu salmon *Oncorhynchus masou*. Fisheries Science 77 (6): 939-944.

Little is known about the survival rate of wild masu salmon. To examine the effects of smolt length and migration timing on the recovery rate of wild masu salmon, we reanalyzed past tagging and recovery data (1993-1994). The tagging study was conducted in the Shokanbetsu River, northern Japan; 863 wild masu salmon smolts were captured, tagged, and released in a downstream site, and a total of 19 fish were recovered in coastal fisheries and in the natal river the following year. The data were analyzed by a logistic regression analysis with recapture as a response variable and tagging date and smolt length as explanatory variables; the tagging date had a significant effect on the recapture rate, whereas the effect of smolt size was not significant. Despite the small number of recaptures, this study indicates that migration timing is a factor affecting the marine survival of wild masu salmon smolts, although this conclusion has been repeatedly documented for other species of Pacific salmon.

Hasegawa, K., T. Sato, and K. Sasaki. 2012. Body size variation of juvenile chum salmon collected from three coastal areas of Hokkaido, northern Japan. NPAFC Technical Report 8: 81.

For Pacific salmon, growth during coastal residency (the first few weeks after juvenile salmon enter the sea) is a critical factor for juvenile survival (Bradford 1995). Thus, many researchers have studied the growth of juveniles. Although individual growth rates can be estimated using scale and otolith analyses, body size is often used as a simple index of growth rate (e.g. LaCroix et al. 2009; Duffy and Beauchamp 2011). In some instances, such as when using historical data, the only available measure of growth may be body size. However, the size of juvenile salmon in a given area may not accurately reflect the growth rate because individuals that originate from rivers outside the area may migrate into it and be captured. Juvenile chum salmon increase in size throughout their oceanic migration (Mayama and Ishida 2003). Therefore, individuals growing outside an area and that had a longer coastal residency can immigrate into the area and cause an overestimation of chum salmon growth rate. To evaluate the relationship between juvenile chum salmon body size and the river of origin, we compared the size of fish in samples collected from three areas off the coast of Hokkaido, northern Japan. We analyzed data from surface trawl surveys of chum salmon conducted in three coastal areas (Atsuta, Konbumori and Shari) from late March to mid-July, 1999-2010. Results showed the sizes of juveniles in the Konbumori area (annual mean fork length ranged 8-12 cm) were larger than fish collected in the Atsuta and Shari areas (annual mean fork length ranged 5-6 cm). Otolith analysis suggested that the large size of juveniles in Konbumori was due to immigration of large individuals originating from rivers located outside the area. Our results highlight the need to consider the migratory behaviour of individuals when considering the cause of body size variation in juvenile chum salmon.

Kasugai, K., M. Torao, H. Kakizaki, H. Adachi, H. Shinhama, Y. Ogasawara, S. Kawahara, T. Arauchi, and M. Nagata. 2011. Distribution and abundance of juvenile chum salmon (*Oncorhynchus keta*) in Nemuro Bay, eastern Hokkaido, Japan. NPAFC Technical Report 8: 58-61.

We examined the distribution and abundance of juvenile chum salmon and their

environments in Nemuro Bay, eastern Hokkaido, Japan, between 2007 and 2010 to determine a better release timing for hatchery-reared fish. For four years, we released juvenile chum salmon marked with fluorescent alizarine complexone and recaptured them in coastal waters between late April and mid-July. Juvenile chum salmon were caught more frequently when the sea surface temperature (SST) ranged between 8°C and 13°C, as previously reported. Juvenile chum salmon were relatively more abundant in the littoral zone in 2008 and 2010 when the SSTs gradually increased to above 8°C in nearshore areas. Chum salmon were less abundant in the littoral zone in 2007 and 2009 when the SST rapidly increased to 8°C in nearshore areas. Therefore, migration of juvenile chum salmon out of the littoral zone may be restricted by low SSTs in nearshore areas. The number of marked fish recaptured in the littoral zone increased when their release timing was delayed, whereas the number of marked fish recaptured in nearshore areas increased when SSTs in nearshore areas rapidly increased to above 8°C. These results suggest that high mortality might occur in the river and/or the littoral zone before juvenile chum salmon migrate to nearshore areas. In conclusion, the SSTs in nearshore areas strongly influence the distribution and abundance of juvenile chum salmon in Nemuro Bay, and delayed migration from the river and the littoral zone to nearshore areas might result in high mortality. Therefore, the release timing of chum salmon in Nemuro Bay should be shifted from late March-late May to late April-mid-May to obtain higher survival.

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

Chiba, S., H. Sugisaki, K. Tadokoro, and T. Nagasawa. 2011. Trophic link between Neocalanus copepods and pink salmon in the western subarctic North Pacific based on long-term nitrogen stable isotope analysis. NPAFC Technical Report 8: 19-20.

We examined the long-term change in the trophic link between *Neocalanus* copepods and pink salmon in the western subarctic North Pacific based on nitrogen stable isotope ($\delta^{15}N$) analysis. Time series of the $\delta^{15}N$ from three species of *Neocalanus*, which were extracted from the Odate Collection samples, and from pink salmon scales collected during the 1960s to 2002 were compared. $\delta^{15}N$ markedly declined (c.a. 0.2%) for both *Neocalanus* and pink salmon after 1988, roughly coinciding with the timing of the North Pacific Regime Shift. As *Neocalanus* is reported to shift its feeding strategy from herbivorous to omnivorous when phytoplankton availability is low, decline in *Neocalanus* $\delta^{15}N$ in the 1990s suggests an increase in phytoplankton availability in this region. Having observed that both *Neocalanus* biomass and pink salmon catch increased in the 1990s, *Neocalanus* production/survival likely benefitted from favorable food conditions, rich in phytoplankton, which secondarily enhanced pink salmon production. This study revealed possible bottom-up control of pink salmon production, which is driven by decadal climatic forcing over the North Pacific.

Irvine, J.R. and M. Fukuwaka. 2011. Pacific salmon abundance trends and climate change. ICES Journal of Marine Science 68 (6): 1122-1130.

Understanding reasons for historical patterns in salmon abundance could help anticipate future climate-related changes. Recent salmon abundance in the northern North Pacific Ocean, as indexed by commercial catches, has been among the highest on record, with no indication of decline; the 2009 catch was the highest to date. Although the North Pacific Ocean continues to produce large quantities of Pacific salmon, temporal abundance patterns vary among species and areas. Currently, pink and chum salmon are very abundant overall

and Chinook and coho salmon are less abundant than they were previously, whereas sockeye salmon abundance varies among areas. Analyses confirm climate-related shifts in abundance, associated with reported ecosystem regime shifts in approximately 1947, 1977, and 1989. We found little evidence to support a major shift after 1989. From 1990, generally favourable climate-related marine conditions in the western North Pacific Ocean, as well as expanding hatchery operations and improving hatchery technologies, are increasing abundances of chum and pink salmon. In the eastern North Pacific Ocean, climate-related changes are apparently playing a role in increasing chum and pink salmon abundances and declining numbers of coho and Chinook salmon.

Kaeriyama, M., H. Seo, H. Kudo, and M. Nagata. 2012. Perspectives on wild and hatchery salmon interactions at sea, potential climate effects on Japanese chum salmon, and the need for sustainable salmon fishery management reform in Japan. Environmental Biology of Fishes 94 (1): 165-177.

Pacific salmon play an important role as a keystone species and provider of ecosystem services in the North Pacific ecosystem. We review our studies on recent production trends, marine carrying capacity, climate effects and biological interactions between wild and hatchery origin populations of Pacific salmon in the open sea, with a particular focus on Japanese chum salmon. Salmon catch data indicates that the abundance of Pacific salmon increased since the 1976/77 ocean regime shift. Chum and pink salmon maintained high abundances with a sharp increase in hatchery-released populations since the late 1980s. Since the 1990s, the biomass contribution of hatchery returns to the total catch amounts to 50% for chum salmon, more than 10% for pink salmon, and less than 10% for sockeye salmon. We show evidence of density-dependence of growth and survival at sea and how it might vary across spatial scales, and we provide some new information on foraging plasticity that may offer new insight into competitive interactions. The marine carrying capacity of these three species is synchronized with long-term patterns in climate change. At the present time, global warming has positively affected growth and survival of Hokkaido populations of chum salmon. In the future, however, global warming may decrease the marine carrying capacity and the area of suitable habitat for chum salmon in the North Pacific Ocean. We outline future challenges for salmon sustainable conservation management in Japan, and recommend fishery management reform to sustain the hatchery-supported salmon fishery while conserving natural spawning populations.

Kaga, T., S. Sato, T. Azumaya, N.D. Davis, and M. Fukuwaka. 2012. Lipid content of immature chum salmon (*Oncorhyunchus keta*) affected by pink salmon (*O. gorbuscha*) abundance in the central Bering Sea. NPAFC Technical Report 8: 87.

Lipid is the principal energy storage constituent in salmonids, including chum salmon. Chum salmon migrate in the Bering Sea for foraging during the summer, and immature fish begin moving southward for overwintering in autumn. Variability of lipid content in fish can depend on foraging conditions during the growing season; therefore, lipid content during the summer can be regarded as a reliable marker for chum salmon body condition. We analyzed the lipid contents of 461 immature chum salmon collected in the central Bering Sea from 2002 to 2007. Individual variation of log-transformed lipid content was tested using generalized linear models and biological and environmental variables. A model that included fish size and pink salmon CPUE was the most effective at describing variation of lipid content in immature chum salmon. Lipid content of immature chum salmon decreased as pink salmon CPUE increased. The negative correlation between chum salmon lipid contents and pink salmon CPUE is consistent with the hypothesis of inter-specific exploitative competition for food items. The main prey of chum salmon is gelatinous plankton in

odd-numbered years and crustaceans in even-numbered years. Lipid composition of gelatinous plankton is substantially lower than that of crustaceans. Results suggest the nutritional condition of immature chum salmon may be related to the shift of prey items through inter-specific interactions, which might occur during occupation of the surface layer by large numbers of pink salmon.

Morita, K. 2012. Thermal Habitats of Pacific Salmon: Does Climate Change Benefit Pink and Chum Salmon? NPAFC Technical Report 8: 74-75.

Because most physiological processes of ectotherms are controlled by temperature, climate warming could affect a variety of population processes in Pacific salmon. In the ocean, Pacific salmon actively move to preferred thermal habitats by migration. Generally, Pacific salmon migrate northward during summer and southward during winter (e.g., Yatsu and Kaeriyama 2005). For example, Japanese chum salmon move to the Bering Sea during the summer (sea surface temperature, ~6–11°C), and then move to the eastern North Pacific during winter (sea surface temperature, ~5–7°C; Fukuwaka et al. 2007). In addition, chum salmon control their body temperature using vertical migrations across the thermocline during summer in the Bering Sea (Azumaya and Ishida 2005; Morita 2011). Active migrations throughout their ocean lifespan allow salmon to narrow their habitat choices to their preferred temperatures. By contrast, Pacific salmon spend their juvenile and spawning stages in freshwater, where they are passively affected by ambient temperature. For example, river water temperatures in Hokkaido, Japan, vary from ~0–2°C during winter to over 20°C during summer; thus juvenile masu salmon, which spend more than one year in freshwater before seaward migration, have to adapt to this broad temperature range (Morita and Nagasawa 2010; Morita et al. 2011). Therefore, active control of thermal habitat mitigates the impact of seasonal and annual change in temperature during the ocean life stage, whereas passive control of thermal habitat operates during the freshwater life stage. These observed behavioral patterns lead to the hypothesis that climate warming would have a severe negative effect on species with long freshwater stages (e.g., masu, coho, Chinook, and sockeye salmon) and populations originating from southern populations, in particular. Moreover, preferred temperature ranges differ by species and age (body size) because older, larger fishes generally inhabit deeper and colder waters than younger, smaller fishes (Bergmann's rule). Similarly, pink salmon and small chum salmon tend to inhabit warmer waters than sockeye and large chum salmon (Morita et al. 2010a). Therefore, fish with a smaller body size (e.g., pink salmon) or shorter freshwater life (e.g., pink and chum salmon) may experience reduced or even beneficial effects from climate warming. In addition, rising temperatures involve reductions in the body size of many organisms (Gardner et al. 2011). The negative effect of rising temperature on growth is hypothesized to be more severe for large chum than for small chum salmon (Morita et al. 2010b).

Morita, K., S. Sato, T. Sato, and T. Ohnuki. 2011. The summer 2011 Japanese salmon research cruise of the R/V Hokko maru. NPAFC Doc. 1348. 14 pp. (Available at www.npafc.org).

A summer high-seas research cruise to investigate the biology of Pacific salmon was conducted from July 20 to August 9 in the Bering Sea aboard the Japanese research vessel *Hokko maru*. Research cruise activities included the collection of data on oceanography, zooplankton, micronekton, salmonid fishes, and other organisms. A total of 3,662 salmonids were caught by trawls and angling. Chum salmon was the most abundant species (92.1%), followed by sockeye salmon (5.5%), chinook salmon (1.8%), pink salmon (0.6%), coho salmon (0.1%), and Dolly Varden (0.03%). Salmonids were measured with respect to fork length and body and gonad weights, they were sexed, and the scales were removed for age

determination. Isotope, genetic, otolith, and lipid samples were obtained for future study. There were 49 chum salmon tagged with disk tags and released in the Bering Sea. From among fish released with disk-tags, 30 small chum salmon were released carrying archival tags. Age-specific catch per surface trawl (CPUE) from 17 fixed fishing stations from 2007 to 2011 are documented here.

Nagasawa, T. and T. Azumaya. 2012. Fluctuation of Japanese chum salmon returning rate related to sea surface temperatures along the spawning migration route. NPAFC Technical Report 8: 28.

Asian chum salmon catches, including Japanese stocks, increased following the 1977 regime shift and have maintained a high level of catch since then. A large portion of Japanese chum salmon stocks originate in hatcheries, and the number of chum salmon smolt releases has been almost constant (1,817-2,094 million) since 1980. Although there has been a constant enhancement effort, the number of returning chum salmon has fluctuated (44-89 million) after 1990. Before 1993, the average release size of chum salmon from hatcheries in Hokkaido was positively related to the return rate of Hokkaido chum salmon. After 1994, when the average release size was over 1.0 g, sea surface temperatures (SSTs) along the migration route from the Bering Sea to natal rivers in Hokkaido during September have been negatively related to the return rate of chum salmon. Archival tag data indicated that maturing chum salmon avoid warm waters (higher than 16°C) in both their horizontal and vertical movements. We have supposed the survival rate during the early sea life period was connected to year-class strength and return rate of Japanese chum salmon. We propose the additional working hypothesis that water temperatures along the spawning migration route in the northwestern Pacific affects the number of returning Japanese chum salmon.

Ohwada, M., K. Sakaoka, N. Hoshi, T. Abe, K. Imai, and S. Takagi. 2012. Results of 2011 Salmon Research by the Oshoro-maru. NPAFC Doc. 1383. 17 pp.

In order to accumulate oceanographic and biological data (including salmonids) and to clarify the oceanic structure and marine ecosystem, the T/V Oshoro maru conducted oceanographic observations and fishing surveys in the western North Pacific (along the 155°E longitude line). The survey was conducted during the Cruise #228 in May, and the Cruise #229-Leg5 from late July to early August, 2011. 10 oceanographic observations and four drift gillnet surveys were conducted along the 155°E during the Cruise #228 in May. The Polar Front was observed in the vicinity of 44°N. The Subarctic Boundary observed in surface (0-100 db) at nearby 42°-15'N and deeper at 40°-30'N. Pink salmon was dominant species at 43°-22.1'N, 43°-57.3'N and 41°-45.0'N, and abundant at 43°-22.1'N. Chum salmon was collected at 43°-22.1'N and 41°-45.0'N. The fork lengths (F.L.) of chum salmon collected by C-gear gillnet ranged between 480-620 mm, and those of pink salmon ranged between 330-470 mm, 76.9% of chum salmon were adult fish. 14 oceanographic observations and four drift gillnet surveys were conducted along the 155°E during the Cruise #229-Leg5 from late July to early August. Seasonal thermocline was observed in 25 m depth and, thereunder the Polar Front was observed in the vicinity of 43°N. The Subarctic Boundary was observed at 41°-15'N, deeper than 140 m at 40°-15'N clearly. Four pink salmon were collected by drift gillnet survey only at 43°-43.4'N. F.L. of pink salmon collected by C-gear gillnet ranged between 430-490 mm. To collect salmon samples extensively and to collect fresh salmon blood and various tissues, three surface long-line and five hook-and-line gear samplings were conducted during the Cruise #228 and #229-Leg5. A total of 82 chum and 253 pink salmon were collected during the two cruises.

Saito, T., K. Watanabe, K. Sasaki, S. Kogarumai, and S.H. Morita. 2012. Cyclic

fluctuations in chum salmon abundance along the Pacific coast of Hokkaido, Japan. NPAFC Technical Report 8: 36-37.

Some chum salmon stocks are known to exhibit a two-year cyclic variation in their biological parameters such as age at maturity, size, marine survival, and abundance. Previous studies suggest this variation appears to be associated with pink salmon, which have a prominent two-year cyclic pattern of abundance. In Hokkaido, brood-year abundance of adult chum salmon returning to the Pacific coast (based on coastal and river catches) shows odd- and even-year fluctuations after the 1998 brood year. A similar fluctuation is also observed in chum salmon caught around the southern region of the Sea of Okhotsk, near Nemuro Strait (Nemuro region: NE). To clarify the characteristics of this cyclic fluctuation, we examined river catches of brood years 1998-2004 for 48 river stocks extending from the Okhotsk coast to the Pacific coast of Hokkaido: 13 river stocks from the Okhotsk (OH) region, 10 river stocks from the NE region, 5 river stocks from the East Hokkaido Pacific (EP) region, and 20 river stocks from the West Hokkaido Pacific (WP) region. Correlation analyses revealed no river stocks from the NE region were associated with NE chum salmon brood-year abundance (based on coastal and river catches) even though the latter showed a two-year cyclic pattern. Neither EP nor WP chum salmon brood-year abundance was correlated with any of these river stocks. A similar result was true of the river stocks from the OH region. These findings indicate that the river stocks from the OH and NE regions did not contribute to generating the observed cyclic pattern. On the other hand, four river stocks from the EP region and eight river stocks from the WP region were positively correlated with at least one of the NE, EP, and WP chum salmon brood-year abundances. This suggests brood-year abundance of some river stocks from the EP and WP regions played a significant role in causing the recent cyclic fluctuation. Because no big spawning stocks of pink salmon exist in rivers on the Pacific coast of Hokkaido (i.e., EP and WP regions), no interaction between chum and pink salmon takes place during the freshwater and early ocean phases. Therefore, we speculate the marine survival of chum salmon originating from rivers on the Pacific coast of Hokkaido may be affected by the presence of pink salmon during their ocean residency. Our future research will continue to examine this possibility.

Sakai, O., O. Yamamura, Y. Sakurai, and T. Azumaya. 2012. Temporal variation in chum salmon, *Oncorhynchus keta*, diets in the central Bering Sea in summer and early autumn. Environmental Biology of Fishes 93 (3): 319-331.

Seasonal, ontogenetic, and diel variations in the diets of chum salmon were examined by analyzing the stomach contents of 1398 fish (300-755 mm fork length) collected in the Bering Sea during summer and early autumn of 2002. Whereas mesozooplankton, including euphausiids, hyperiids, and gastropods, constituted the greatest portion of the stomach contents during the summer, forage fishes (*Stenobrachius leucopsarus* and Atka mackerel, *Pleurogrammus monopterygius*) were the most important items during early autumn. Although no apparent diel trend was found in feeding intensity, distinct diel differences in prey composition were observed. Chum salmon caught in the morning contained *Stenobrachius leucopsarus*, whereas those caught in the afternoon had mainly fed on euphausiids. Thus, chum salmon diets change temporally because of changes in prey availability that result from differences in the annual life cycles and diurnal vertical migrations of prey species.

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

No publication

Component 4: Biological Monitoring of Key Salmon Population

Ando, D., Y. Shinriki, Y. Miyakoshi, H. Urabe, R. Yasutomi, T. Aoyama, Y. Sasaki, and M. Nakajima. 2011. Seasonal variations in and effect of incubation water temperature on vertebral number in naturally spawning chum salmon *Oncorhynchus keta*. Fisheries Science 77 (5): 799-807.

Seasonal variations and reaction norms for vertebral number (V_N) in response to incubation water temperature were estimated in adult and juvenile naturally spawning chum salmon. The mean V_N of adults varied according to spawning time; the early-spawning population had higher V_N values than the late-spawning population. Moreover, the mean V_N values in the early-spawning population decreased with seasonal changes, whereas V_N values in the late-spawning population remained stable. Chum salmon embryos in three full-sib families were incubated at five different temperatures until hatching, and the V_N values of the resulting juveniles were analyzed. The V_N reaction norm to incubation water temperature showed a V-shaped curve that was lowest at an intermediate temperature. The mean V_N at the same incubation temperature varied among the three families. These results suggest that V_N values in chum salmon are influenced by genetic components and incubation water temperatures. V_N may be a useful parameter for estimating the environmental conditions during ontogenesis and the genetic background by detecting population changes.

Hasegawa, E. 2012. Chum salmon *Oncorhynchus keta* respond to moonlight during homeward migrations. Journal of Fish Biology 81 (2):632-641.

The swimming depth of chum salmon equipped with archival tags was investigated off the Pacific Ocean coast of Hokkaido and North Honshu, Japan. As shown from movements of the fish with disc tags, chum salmon swam at shallower depths during the full-moon phase than in the other phases and their swimming speed during this phase was faster compared to other phases. In addition, the circadian rhythm suggests a biological clock. These observations are all consistent with the view that chum salmon makes use of moonlight in order to navigate at night-time during homeward migration.

Ichimura, M., T. Yanagimoto, T. Kobayashi, T. Masaoka, and M. Kaeriyama. 2011. Hybrid identification of "Sakemasu" collected in the Nemuro Strait, eastern Hokkaido, using DNA analysis. Nippon Suisan Gakkaishi 77 (5): 834-844. (In Japanese with English abstract).

"Sakemasu" collected in the Nemuro Strait was identified as a hybrid between chum salmon and pink salmon using analyses of mtDNA and nuclear DNA. The nucleotide sequences of ATPase6, NADH3 of mtDNA and ITS1, ITS2, and Aromatase B-1 of nuclear DNA of chum and pink salmon were compared to construct species specific primers (SSP). The combined results of SSP-PCR analysis of mtDNA and nuclear DNA indicated that six individuals from eleven "Sakemasu" are hybrids between chum and pink salmon. Some morphological features of crossbred "sakemasu" were mixed with parental traits.

Iida, M., T. Kato, and H. Tokuda. 2011. Natural reproduction of pink salmon in the Okhotsk coast area of Hokkaido, Japan. NPAFC Technical Report 8: 38-39.

The number of pink salmon returning to Hokkaido, Japan, increased dramatically during the last quarter of the 20th century. Despite the constant number of hatchery fry released, the pink salmon catch shows a biennial oscillation. Because pink salmon have a

fixed 2-year life cycle, this oscillation indicates a substantial contribution of wild fish. However, there have been few efforts to quantify the natural reproduction of Japanese pink salmon. In this study, we investigated the conditions of naturally spawning pink salmon in the Tokoro River system in northeastern Hokkaido. Although many returning pink salmon were captured in the hatchery weir at the mouth of the river, pink salmon could swim over the weir during high flows. Field investigations were conducted in three tributary streams: Tokoro-horonai, Kuma, and Nikoro. Study reaches were 821 m (3,454 m^2), 317 m (998 m^2), and 1,152 m (12,909 m^2) for each stream, respectively. The number of naturally spawning pink salmon increased in early September, reached a maximum in mid-September, and subsequently decreased in late September. The number of spawning pink salmon in the streams in mid-September was 1376 in Tokoro-horonai, 20 in Kuma, and 360 in Nikoro. The number of redds also increased during September. The total number of redds was 1007 in Tokoro-horonai, 165 in Kuma, and 773 in Nikoro. The estimated total number of eggs spawned in the study streams was 2,919 thousand (168 eggs m^{-2}). To collect newly emerged fry, 0.39 m3 (1.0 m × 1.3 m, depth 0.3 m) of gravel from the Tokoro-horonai was dug up from around an individual redd on 28 February, 2011. A total of 491 pink salmon fry, 383 chum salmon fry, 6 unknown fry, and about 500 dead eggs was collected from the gravel. We concluded the number of naturally spawning pink salmon was substantial, despite the operation of a hatchery weir at the river mouth.

Koshio, Y., H. Kudo, and M. Kaeriyama. 2011. Transfer of marine-derived nutrients by pink salmon (*Oncorhynchus gorbuscha*) to terrestrial ecosystems at the Shiretoko World Natural Heritage Site, Japan. NPAFC Technical Report 8: 147-149.

Pacific salmon transport marine-derived nutrients (MDN) and material to terrestrial ecosystems and enhance biodiversity and productivity in the North Pacific Rim. At the Shiretoko World Natural Heritage Site, a number of wild chum and pink salmon return to spawn. To clarify the transfer of MDN by naturally spawning salmon to ecological communities, we analyzed carbon and nitrogen stable isotopes of organisms in freshwater and riparian ecosystems at a salmon spawning site in the Rusha River. During the salmon spawning season, carbon and nitrogen stable isotopes of biofilm, aquatic invertebrates, and fishes in the Rusha River increased 1-6 ‰ and 1-8 ‰, respectively. Thus, the MDN enrichment was 21-30 %. Stable isotope analysis of the growth section showed that brown bears (*Ursus arctos*) have four life-history patterns. Most bears fed on pink salmon for overwintering energy. Riparian vegetation was enriched 24 % with MDN. Nitrogen isotope analysis of riparian willow (*Salix* spp.) was negatively correlated with the distance from streams. Salmon carcasses were transported from the stream to the riparian area by vectors (e.g., brown bears) and flooding. Pink salmon enhanced the productivity of terrestrial ecosystems in this area. However, the MDN enrichment was equal to, or lower than, terrestrial ecosystems in North America. Despite the relatively undeveloped state of the landscape at the Shiretoko World Natural Heritage Site, the MDN enhancement from spawning salmon is unsatisfactory because of many artificial constructions, such as dams. It is essential to rehabilitate the natural ecosystems and increase wild Pacific salmon production at the Shiretoko World Natural Heritage Site during the current period of warming climate.

Kudo, H., Y. Koshino, A. Eto, M. Ichimura, and M. Kaeriyama. 2012. Cost-effective accurate estimates of adult chum salmon, *Oncorhynchus keta*, abundance in a Japanese river using a radio-controlled helicopter. Fisheries Science 119: 94-98.

This paper describes an attempt in 2008 to establish an aerial census of adult chum salmon using a small radio-controlled (RC) helicopter. The Moheji River, located in southern Hokkaido, was chosen because all the salmon in a stretch of the river between a weir

and the estuary are seine-netted every morning for artificial propagation. Aerial photographs of the river were taken from a RC helicopter equipped with a digital single-lens reflex camera and polarized filter. To quantify salmon density within the census area, the number of salmon per aerial photograph was counted using image-processing software. Salmon could be clearly identified in photographs taken from an altitude of similar to 30 m. Salmon numbers estimated by aerial census and seine-netting were significantly related. The results indicate that a small RC helicopter can be used to generate adult salmon abundance data in Japanese rivers.

Makiguchi, Y., Y. Konno, K. Konishi, K. Miyoshi, T. Sakashita, H. Nii, K. Nakao, and H. Ueda. 2011. EMG telemetry studies on upstream migration of chum salmon in the Toyohira River, Hokkaido, Japan. Fish Physiology and Biochemistry 37 (2): 273-284.

The movements of 28 adult chum salmon tagged with electromyogram (EMG) transmitters were tracked along the Toyohira river, Hokkaido, Japan, in October of 2007 and 2008 to investigate and evaluate the upstream migratory behavior through the protection bed and fishway of ground sills. The approach time of fish that ascended successfully through the protection bed and fishway was shorter than that of unsuccessful fish. The unsuccessful fish were observed to swim in currents with high water velocity and shallow water depth at swimming speeds that exceeded their critical swimming speed (U_{crit}) during the approach to these structures. In consequence, unsuccessful fish frequently alternated between burst and maximum sustained speeds without ever ascending the fishway, and eventually became exhausted. It is important that fishway are constructed to enable chum salmon to find a passage way easily, so that they can migrate upstream rapidly without wasting excessive energy.

Miyakoshi, Y., H. Urabe, H. Saneyoshi, T. Aoyama, H. Sakamoto, D. Ando, K. Kasugai, Y. Mishima, M. Takada, and M. Nagata. 2012. The occurrence and run timing of naturally spawning chum salmon in northern Japan. Environmental Biology of Fishes 94 (1): 197-206.

Since the late 20th century, the biomass of Pacific salmon has increased. Hokkaido, northern Japan, is one of the main areas of chum salmon production in the North Pacific and intensive hatchery programs support the recent high abundance. However, proper management of naturally spawning populations is necessary to conserve healthy stocks of this species. In 2008, we started a program to assess the naturally spawning chum salmon populations in Hokkaido. Of the total of approximately 1,500 rivers in Hokkaido, 238 rivers with lengths of longer than 8 km (excluding those rivers used for hatchery broodstock collection) were surveyed in 2008 and 2009. The number of non-enhanced rivers found to contain naturally reproducing chum salmon was 59 (31.4% of surveyed rivers) and 50 (37.6% of surveyed rivers) rivers in 2008 and 2009, respectively. Including the rivers where hatchery broodstock were collected and rivers shorter than 8 km that contain naturally spawning chum salmon, chum salmon ascended at least 191 and 175 rivers in Hokkaido in 2008 and 2009, respectively. Repeated foot surveys indicated that the run timings of naturally spawning chum salmon may be affected by coastal commercial fisheries. This study showed that naturally spawning chum salmon remain in many rivers in Hokkaido where hatchery programs have been intensively conducted.

Miyakoshi, Y. and M. Nagata. 2011. Recent patterns in return rate of chum salmon to different regions of Hokkaido. NPAFC Technical Report 8: 29-31.

Japanese chum salmon has contributed substantially to the recent high abundance of chum salmon in the North Pacific, representing more than 60% of total commercial chum

salmon catches during 2003-2007. Hokkaido is the principal area of salmon production in Japan. Hokkaido chum salmon stocks have been supported by intensive hatchery programs and currently an annual total of ~one billion hatchery-reared chum salmon juveniles are stocked in 140 rivers and 80 net-pen sites in Hokkaido. The number of chum salmon returning to Hokkaido has been at historical levels since the 1990s. However, the large difference in recent return rates has been remarkable among regions; the recent return rates are historically high in the Okhotsk Sea region, relatively low in the Sea of Japan region, and highly variable in the Pacific Ocean region. In the last few years, declines of returning chum salmon to the Pacific Ocean and Nemuro Strait regions were remarkable. Innovations in hatchery technology are represented by improved fish quality and release timing by feeding fry after the 1960s. Release size has been increased by improvement of rearing techniques and expanded rearing facilities; mean size was 0.8 g in 1987, exceeded 1.0 g in 1991, and attained 1.3 g in 2009. Release size of hatchery-reared juveniles differs among regions, and the effects of increased release size on return rates are not distinct when release size is over 1 g. As for release timing, it has been recommended that hatchery-reared juveniles be released when coastal sea water temperatures range from 5° to 10°C. The timing when coastal sea water temperatures are within this range has been gradually changing. Also, the proportion of hatchery-reared fish that were released from net-pens increased in the last decade, although the annual number of fish released has been constant. These recent changes in hatchery stocking and conditions of the coastal environment may affect the pattern of return rates of chum salmon to different regions of Hokkaido.

Morita, K., S.H. Morita, and T. Nagasawa. 2012. Seasonal changes in stream salmonid population densities in two tributaries of a boreal river in northern Japan. Ichthyological Research 58 (2): 134-142.

We examined seasonal changes in population densities of stream salmonids (masu salmon, white-spotted charr *Salvelinus leucomaenis*, and rainbow trout) in two tributaries of the Shoro River, eastern Hokkaido, Japan. In one small tributary, water temperature was relatively high during the winter, and populations of salmon and trout increased through immigration at this time of the year, becoming dominant components of the salmonid assemblage; the density of charr in this stream decreased during the winter, but charr was dominant during the summer. In another medium-sized tributary, the water temperature fell to close to 0 °C during the winter, and densities of salmon and charr decreased in this season, through emigration; trout were very rare in this stream. Seasonal patterns of stream salmonid densities vary among species and between localities, resulting in seasonal changes in species composition. For a comprehensive understanding of population processes, a whole-river survey across seasons will be necessary.

Nagata, M., Y. Miyakoshi, H. Urabe, M. Fujiwara, Y. Sasaki, K. Kasugai, M. Torao, D. Ando, and M. Kaeriyama. 2012. An overview of salmon enhancement and the need to manage and monitor natural spawning in Hokkaido, Japan. Environmental Biology of Fishes 94 (1): 311-323.

The chum and pink salmon catches in Hokkaido, Japan have increased dramatically since the 1970s and the 1990s, respectively. In contrast, masu salmon catches have been steadily decreasing. Despite intensive hatchery development in Hokkaido, naturally spawning salmon populations persist based on results from a recent river survey. This paper focuses on the challenges of maintaining hatchery salmon populations while protecting natural chum, pink and masu salmon populations in Hokkaido. Two important initiatives related to meeting this ambitious goal are managing hatcheries in a way that minimizes negative interactions between natural and hatchery salmon populations, and initiating new

efforts at restoring and rehabilitating degraded freshwater habitats. In addition, in order to maintain a balance of demand and supply in the domestic market through the exportation of extra salmon, Hokkaido has decided to enter full assessment to gain Marine Stewardship Council (MSC) certification of the Hokkaido chum salmon trap net fishery. This would involve a fundamental shift in fisheries management as practiced in Japan, specifically elevating the importance of managing the fishery in a way that conserves natural salmon populations. A key component of a new salmon management strategy is the establishment of a zone management framework based on the designation of stream units to spatially separate natural salmon from hatchery salmon to minimize negative effects of hatchery fish and to utilize effectively hatchery salmon for commercial fisheries. This effort is allied with similar initiatives in other Pacific Rim countries that are focusing on management reform to restore natural ecosystem function and maintain the coexistence of wild and hatchery salmon.

Tamate, T. 2012. A concise review of geographic variation in adult body size in anadromous masu salmon, *Oncorhynchus masou*. Environmental Biology of Fishes 94 (3): 527-532.

Adult body size (size at maturity) is one of the key life history traits and is well known to sometimes correlate with latitude in anadromous salmonids. However, it is poorly understood whether geographic size patterns except for latitudinal trends occur or why such patterns have been shaped. The present paper briefly reviewed body size variation between anadromous returns of masu salmon in the Okhotsk group (10 populations along the Sea of Okhotsk coast), the Pacific group (2 populations along the Pacific Ocean coast) and the Sea of Japan group (24 populations along the Sea of Japan coast). The Okhotsk group was smaller than the Sea of Japan group. Although the statistical analysis detected no differences among the remaining combinations, the Okhotsk group was possibly smaller than the other groups because the size of the Pacific group seemed to be within range of the Sea of Japan group but tended to be larger than that of the Okhotsk group. Future research should first test whether size at maturity genetically differs between the Okhotsk group and the other two groups to explore further evolutionary factors shaping geographic size variation.

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

Kishi, M.J., K. Awa, T. Miwa, H. Ueno, and T. Nagasawa. 2011. Ecosystem approach for management of artificial release of chum salmon from Japan based on a bioenergetic model coupled with NEMURO. NPAFC Technical Report 8: 117-120.

The suitable release number of Hokkaido chum salmon was calculated based on a bioenergetic model coupled with the lower trophic level model, NEMURO, for the North Pacific. The constraint condition we used was the carrying capacity of the North Pacific Ocean, which was the prey density for salmon. The prey density was calculated by a two-way version of NEMURO; i.e., prey density (predatory zooplankton and copepods) was not calculated by the lower trophic model itself, but by decreasing grazing by fish. Consequently, prey density must be kept so the concentration was enough to provide for salmon growth. The cost function was the total income of fishermen. The cost function must be the maximum under the constraint condition. The income of fishermen was the calculated unit price multiplied by total catch. The unit price of chum salmon was determined by empirical data as a function of return ratio and wet weight. We also modeled the competition of chum and pink salmon for prey. NEMURO coupled with a physical model was used to calculate prey density and to predict wet weight of salmon. Results

showed that if the chum release number was greater, then the return number of chum salmon was greater, but the individual body weight was less. The most suitable number in our model indicated the present release number of chum salmon was the most appropriate for the model cost function, i.e., maximizing the income of fishermen.

Kitanishi, S., T. Yamamoto, K. Edo, and S. Higashi. 2012. Influences of habitat fragmentation by damming on the genetic structure of masu salmon populations in Hokkaido, Japan. Conservation Genetics 13 (4): 1017-1026.

Dam construction dramatically influences riverine ecosystems, with habitat fragmentation being one of the most serious impacts. This habitat fragmentation is particularly relevant for anadromous species such as salmonids. We examined the effects of habitat fragmentation on masu salmon populations in Hokkaido, Japan. Specifically, we sampled from 15 locations located above and below a dam region in the Uryu River system, and analyzed the genetic structure of the populations using 10 microsatellite loci. No indication of a significant reduction in genetic diversity, estimated by allelic richness and heterozygosity, was observed within the above-dam region compared to the below-dam region. However, we also found that reducing the number of alleles had occurred within the above-dam region. The analysis of molecular variance and multidimensional scaling analysis indicated significant genetic differentiation between regions and within each region. A significant relationship between genetic and geographic distance was observed in the below-dam region, while no signal of isolation by distance was detected in the above-dam region. This study suggests a possibility of ongoing loss of alleles coinciding with habitat fragmentation caused by anthropogenic environmental changes such as water-level regulation, which negatively impacts genetic structure.

Kogura, Y., J.E.Seeb, N. Azuma, H. Kudo, S. Abe, and M. Kaeriyama. 2011. The genetic population structure of lacustrine sockeye salmon, *Oncorhynchus nerka*, in Japan as the endangered species. Environmental Biology of Fishes 92 (4): 539-550.

Lacustrine sockeye salmon are listed as an endangered species in Japan despite little genetic information on their population structure. In order to clarify the genetic diversity and structure of Japanese populations for evaluating on the bottleneck effect and an endangered species, we analyzed the ND5 region of mitochondrial DNA (mtDNA) and 45 single nucleotide polymorphisms (SNPs) in 640 lacustrine sockeye salmon in Japan and 80 anadromous sockeye salmon in Iliamna Lake of Alaska. The genetic diversity of the Japanese population in both mtDNA and SNPs was significantly less than that of the Iliamna Lake population. Moreover, all Japanese populations had SNP loci deviating from the HWE. In spite of low genetic diversity, the SNP analyses resulted that the Japanese population was significantly divided into three groups. These suggest that Japanese sockeye salmon populations should be protected as an endangered species and genetically disturbed by the hatchery program and transplantations.

Sato, S., M. Kato, K. Morita, and S. Urawa. 2011. Stock-specific summer ocean distribution of immature chum salmon in the Bering Sea as inferred from SNP markers. NPAFC Technical Report 8: 50-51.

Stock-specific ocean distribution of chum salmon in the Bering Sea and Arctic Ocean during the summer of 2009 was estimated by genetic stock identification (GSI) using single nucleotide polymorphisms (SNP) markers. Cruises were conducted by the research vessel R/V Hokko maru in the Bering Sea (52°30'N-63°00'N, 174°49'E-170°05'W), Bering Strait (64°48'N-65°14'N, 169°36'W-168°40'W), and Chukuchi Sea (67°53'N-70°05'N, 167°49'W-167°23'W) during July 15 to 24 and July 30 to August 9. A total of 3,519 fish

was collected from 27 stations in the Bering Sea, and seven fish were caught at two stations in the Bering Strait and three stations in the Chukuchi Sea. Abundance of chum salmon in the central Bering Sea (56°N-58°N) was higher than the abundance in other areas of the Bering Sea. Adipose fin samples (N=2,256) were collected and fixed in 100% ethanol. Each sample was assayed for 33 SNP loci by TaqMan chemistry. The genotyping data were pooled from two or three stations nearby and used for GSI. Because most fish (96%) were immature fish, maturing fish were excluded from the genetic analysis. Stock contributions (Japan, Russia, and North America) of immature fish were estimated by a conditional maximum likelihood algorithm using a SNP baseline dataset from 146 populations from the Pacific Rim. GSI-estimated stock composition was 42-57% Japanese and 29-52% Russian in the central and northern (59°N-63°N) Bering Sea, however, the stock composition in the southern Bering Sea (52°N-55°N) was 7-38% Japanese and 57-79% Russian. In the western Bering Sea (53°N-56°N, 175°E), the stock composition was estimated to be 7-22% Japanese and 69-83% Russian. The percentages of North American stocks were 4-14% in the survey areas of the Bering Sea. The GSI-estimated CPUE (catch per unit effort) indicated the abundance of Japanese stocks increased gradually from the southern to northern areas of the Bering Sea, and they predominated in the central and northern Bering Sea. Russian stocks predominated in the southern and western Bering Sea, while North American stocks were less abundant than Asian stocks in the survey areas of the Bering Sea. Our results suggest the distribution pattern and abundance of Japanese and Russian chum salmon may differ between the southern and northern areas of the Bering Sea. In particular, Japanese chum salmon stocks utilize wide regions of the Bering Sea, including northern waters, as a summer feeding area.

Templin, W.D., C. Habicht, L.W. Seeb, S. Sato, S. Abe, K. Warcheit, J.Y. Park, and J.E. Seeb. 2012. Improved genetic stock identification of chum salmon through the PacSNP collaboration. NPAFC Technical Report 8: 49.

Understanding the distributions of chum salmon in the oceanic and near-shore waters of the North Pacific Ocean and Bering Sea has become increasingly useful for studying the effects of climate change, large-scale hatchery production, and bycatch in offshore fisheries. For more than two decades, genetics data have been used as a key tool for studying the migratory routes of the species based on extensive sets of data from spawning populations originating from across the
species' range. During this period the genetic markers applied continually improved with advances in technology. With the collaborative development of the PacSNP baseline among North American and Asian researchers, single nucleotide polymorphisms (SNPs) were demonstrated as particularly amenable for multinational applications because they are easily shared, require little inter-laboratory standardization, and can be assayed through increasingly efficient technologies. The PacSNP baseline is focused on the continued development of the database and applying it to problems of international interest. We present improvements to the PacSNP baseline to provide a more comprehensive representation of populations and greater resolution through the addition of more informative markers.

Urawa, S., S. Sato, M. Takahashi, and T. Saito. 2011. Status of hatchery-origin chum salmon in the Bering Sea deduced from otolith mark recoveries. NPAFC Technical Report 8: 52-53.

Otolith marking is an effective tool for determining the hatchery origin of individual salmon in both high seas and coastal waters. Otolith-marked salmon are annually released from hatcheries in Canada, Japan, Korea, Russia, and the United States under the coordination of the North Pacific Anadromous Fish Commission (NPAFC). The total number of

otolith-marked chum salmon released in 2003-2009 was approximately 4.8 billion juveniles (23% of the total hatchery releases in North Pacific Rim countries). Otolith samples were collected from chum salmon caught in the central North Pacific and Bering Sea by researchers aboard Japanese research vessels (Wakatake maru and Hokko maru) in the summer of 2006-2010. The samples (n=13,279) were examined to detect otolith marks, and hatchery origins were determined by referring to the NPAFC database of otolith mark releases, which is available at http://npafc.taglab.org. A total of 372 otolith-marked chum salmon was found in the Bering Sea, of which 352 (94.6%) fish were released from 11 hatcheries in northern Japan. The Japanese marked fish showed no hatchery-specific distribution, and most fish were distributed north of 55ºN in the Bering Sea during July and early August. Distribution patterns were slightly different between young fish (ocean age-1) and older fish and between immature and maturing fish that may reflect their specific migration routes (Urawa et al. 2009). Alaskan marked chum salmon (n = 7) were found widely distributed in the Bering Sea, and all of them were released from Southeast Alaska and Prince Williams Sound. Russian marked fish (n=5) were recovered in the central Bering Sea, and they originated from the Ketkinsky and Paratunsky Hatcheries located in Eastern Kamchatka. One Korean marked chum salmon released from the Yangyang Hatchery was found in the western area (56º30'N, 176ºE) in July 2007, as already reported by Sato et al. (2009). Can high-seas otolith-mark recovery data be used for the forecast of hatchery chum salmon runs? To test this possibility, the recovery rate of chum salmon otolith marks in the Bering Sea (Bering Sea Catch Index, BSCI) during 2006-2010 surveys and the return rate of adults to the natal river were compared for the 2004-2006 brood years. Results differed among regional populations. In rivers on the Okhotsk Sea coast, a high BSCI was followed by a high return rate of chum salmon. By contract, in rivers on the Japan Sea coast, a low BSCI was followed by a low return rate. There was a positive linear relation between BSCI and return rate for brood year 2004 ($R^2 = 0.803$, $p = 0.001$), 2005 ($R^2 = 0.664$, $p = 0.004$), and 2006 ($R^2 = 0.934$, $p < 0.001$). These results suggest the possibility that high-seas otolith-mark recovery data are useful for forecast of chum salmon runs in specific populations.

Yamamoto, S., S. Kitamura, H. Sakano, and K. Morita. 2011. Genetic structure and diversity of Japanese kokanee *Oncorhynchus nerka* stocks as revealed by microsatellite and mitochondrial DNA markers. Journal of Fish Biology 79 (5): 1340-1349.

Genetic structure and diversity of nine Japanese kokanee (landlocked) *Oncorhynchus nerka* stocks and anadromous *O. nerka* from the North Pacific and the Canadian Lake Cultus population were examined using microsatellite and mitochondrial DNA. Sequence analyses of the cytochrome b region of mtDNA for Japanese kokanee *O. nerka* stocks on Honshu and Hokkaido islands revealed that most Japanese stocks were monomorphic of one major haplotype, which was also dominant in the Lake Cultus population and anadromous *O. nerka* in the North Pacific. Assignment tests using microsatellite DNA revealed that there was no clear-cut population structure in Japanese kokanee *O. nerka* stocks.

Yu, J.N., N. Azuma, and S. Abe. 2011. Genetic variation between collections of hatchery and wild masu salmon inferred from mitochondrial and microsatellite DNA analyses. NPAFC Technical Report 8: 46-48.

There has been very little effort to understand genetic divergence between wild and hatchery collections of masu salmon. In the present study, mitochondrial (mt) NADH dehydrogenase subunit 5 gene (ND5) and six polymorphic nuclear microsatellite DNA loci were used to compare the genetic variability in three hatchery broodstocks of masu with the variability in eight putative wild masu salmon populations. These populations were sampled from five rivers including one known source river for the hatchery broodstocks. Both ND5

and microsatellites showed no significant genetic divergence based on F_{ST} estimates between four annual collections from the source river population, suggesting no change in genetic diversity over this time period. The F_{ST} estimates, an analysis of molecular variance (AMOVA), and a neighbor joining tree using both DNA markers suggested significant differentiation between the three hatchery and all eight putative wild populations. We conclude that genetic diversity of hatchery populations is low relative to putative wild populations of masu salmon, and discuss the implications for conservation and fisheries management of salmon in Hokkaido, Japan.

Yu, J.N., N. Azuma, and S. Abe. 2012. Genetic differentiation between collections of hatchery and wild masu salmon (*Oncorhynchus masou*) inferred from mitochondrial and microsatellite DNA analyses. Environmental Biology of Fishes 94 (1): 259-271.

There has been very little effort to understand genetic divergence between wild and hatchery populations of masu salmon. In this study, we used mitochondrial (mt) NADH dehydrogenase subunit 5 gene (ND5) and six polymorphic nuclear microsatellite DNA loci to compare the genetic variability in three hatchery broodstocks of masu salmon with the variability in eight putative wild masu populations sampled in five rivers including one known source river for the hatchery broodstocks. Both ND5 and microsatellites showed no significant genetic divergence (based on F_{ST} estimates) between four annual collections from the source river population, suggesting no change in genetic diversity over this time period. The F_{ST} estimates, an analysis of molecular variance (AMOVA), and a neighbor-joining tree using both DNA markers suggested significant differentiation between the three hatchery and all eight putative wild populations. We conclude that genetic diversity of hatchery populations are low relative to putative wild populations of masu salmon, and we discuss the implications for conservation and fisheries management in Hokkaido.