NPAFC
Doc. 1598
Rev. ___

Japanese Bibliography in 2014-2015 for NPAFC Science Plan

by

Shunpei Sato, Toru Nagasawa, and Shigehiko Urawa

Hokkaido National Fisheries Research Institute, Fisheries Research Agency,
2-2 Nakanoshima, Toyohira-ku, Sapporo 062-0922, Japan

submitted to the

NORTH PACIFIC ANADROMOUS FISH COMMISSION

by

Japan

April 2015

THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:
Sato, S., T. Nagasawa, and S. Urawa. 2015. Japanese bibliography in 2014-2015 for NPAFC Science Plan. NPAFC Doc. 1598. 16 pp. Hokkaido National Fisheries Research Institute, Fisheries Research Agency (Available at http://www.npafc.org).

Japanese Bibliography in 2014-2015 for NPAFC Science Plan

Shunpei Sato, Toru Nagasawa, and Shigehiko Urawa

Hokkaido National Fisheries Research Institute, Fisheries Research Agency,
2-2 Nakanoshima, Toyohira-ku, Sapporo 062-0922, Japan

Abstract: This bibliography listed original papers and documents published in 2014-2015 by Japanese scientists and their collaborators in order to review Japanese national researches for the 2011-2015 NPAFC Science Plan. The bibliography includes 37 articles with abstracts, corresponding to five research components of the NPAFC Science Plan.

Key Words: bibliography, NPAFC Science Plan, Japanese national research

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, 2011-2012, and 2012-2014 by Japanese scientists and/or their collaborators (Sato et al. 2011, 2012, 2014). The current issue has supplemented 37 articles published between April 2014 and March 2015. The bibliography includes abstracts for all articles.

References

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).

Sato, S., T. Nagasawa, and S. Urawa. 2012. Japanese bibliography in 2011-2012 for NPAFC Science Plan. NPAFC Doc. 1417. 16 pp. (Available at www.npafc.org).
Sato, S., T. Nagasawa, and S. Urawa. 2014. Japanese bibliography in 2012-2014 for NPAFC Science Plan. NPAFC Doc. 1536. 16 pp. (Available at www.npafc.org).

BIBLIOGRAPHY

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

Hasegawa, K, K. Morita, K. Ohkuma, T. Ohnuki, and Y. Okamoto. 2014. Effects of hatchery chum salmon fry on density-dependent intra- and interspecific competition between wild chum and masu salmon fry. Canadian Journal of Fisheries and Aquatic Sciences 71 (10): 1475-1482.

Stocking with hatchery fish is the principal method for harvest augmentation and, recently, restoring endangered populations. However, there is increasing concern about the negative effects of competition between hatchery and wild fish. In this study, enclosure experiments were conducted to evaluate the effects of hatchery chum salmon fry (*Oncorhynchus keta*) on wild masu (*Oncorhynchus masou*) and chum salmon fry through density-dependent competition. For masu and chum salmon, density-dependent performance (foraging rate and growth) varied depending on the presence or absence of competitor species. The negative effects on the foraging rate (evaluated by stomach content mass) and growth of wild masu salmon caused by wild conspecifics were greater than those exerted by wild and hatchery chum salmon. Wild chum salmon decreased foraging rate with increasing density of conspecifics and masu salmon and also in the presence of hatchery chum salmon. Although we could not evaluate growth under interspecific competition, wild chum salmon show body mass loss in the presence of hatchery chum salmon. These results suggest that the effects of stocking with hatchery chum salmon vary depending on the interacting species.

Kasugai, K, H. Hayano, S. Mano, T. Watanabe, T. Yoshikawa, M. Saito, R. Wakimoto, and K. Sugiwaka. 2014. Preliminary study of migration history estimated from otolith Sr:Ca ratios of masu salmon (*Oncorhynchus masou*) in Lake Kussharo. Ichthyological Research 61 (2): 178-182.

Otolith Sr:Ca ratios of 11 masu salmon (*Oncorhynchus masou*) in Lake Kussharo and its tributaries, of which outlet river has no barriers to the ocean, were analyzed to estimate their migration histories. The Sr:Ca ratios of all masu salmon generally fluctuated below 2. Masu salmon from Lake Kussharo presumably do not migrate to the ocean. However, more specimens must be analyzed to clarify the migration history of masu salmon in this lake.

Kasugai, K., H. Hayano, S. Mano, T. Watanabe, T. Yoshikawa, M. Saito, and R. Wakimoto. 2014. Upstream and downstream migration history of lacustrine sockeye salmon captured in Lake Kussharo estimated from otolith microchemistry. Scientific Reports of Hokkaido Fisheries Research Institutes 86: 145-149 (In Japanese with English abstract).

Extremely large lacustrine sockeye salmon, *Oncorhynchus nerka* (fork length: 63.6 cm), was captured in Lake Kussharo, eastern Hokkaido, Japan. Initially, the average otolith strontium:calcium (Sr:Ca) ratio of large fish was 1.10 (range: 0-4.22), which then elevated to 4, after which fluctuated about between 6-8 (mean 6.54, range 2.84-9.25), and dropped to 4 before the fish was captured in the lake. This fluctuation in the Sr:Ca ratio demonstrated that the large sockeye salmon that was captured in Lake Kussharo had migrated to the ocean.

McKinnell, S., E. Curchitser, K. Groot, M. Kaeriyama, and M. Trudel. 2014. Oceanic and atmospheric extremes motivate a new hypothesis for variable marine survival of Fraser River sockeye salmon. Fisheries Oceanography 23 (4): 322-341.

In spite of a relatively optimistic pre-season forecast, the total return of adult sockeye salmon (*Oncorhynchus nerka*) to the Fraser River (British Columbia, Canada) in 2009 was the lowest recorded since quantitative records began in the late 1940s. A plausible mechanism is proposed that links a sequence of extreme oceanic and climatic events to poor marine survival. It began with record-setting snow packs in the coastal mountain range during the winter of 2007 that led to the development of unprecedented oceanographic conditions in the spring of 2007 from Queen Charlotte Strait in central British Columbia to Southeast Alaska. When combined with equally extreme atmospheric anomalies in the region in the spring of 2007, with a winter wind regime persisting through July, a coastal surface ocean with characteristics that are known to be associated with lower marine survival was established. Most of the sockeye salmon that were expected to return to the Fraser River as adults in 2009 passed through this atypical ocean as juveniles on their migration to the open ocean in 2007. A trophic gauntlet hypothesis is proposed as a new paradigm to describe the oceanic environment faced by sockeye salmon after they emigrate northward from the Strait of Georgia. The hypothesis identifies a new type of high nutrient low chlorophyll region that can explain how oceanographic extremes at critical locations along the migration route beyond the Strait of Georgia can reduce marine survival in some years.

Shin, H. S., Y. J. Choi, N. N. Kim, J. Lee, H. Ueda, and C. Y. Choi. 2014. Effects of exogenous cortisol and seawater adaptation on thyroid hormone receptors in the smolt stage of the sockeye salmon, *Oncorhynchus nerka*. Ichthyological Research 61 (1): 9-16.

The objective of this investigation was to quantify how thyroid hormone receptors of the sockeye salmon, *Oncorhynchus nerka*, respond to salinity changes from freshwater (FW) to seawater (SW) conditions. Thyroid hormone receptors (TRs) mRNA and protein expressions levels significantly increased when the fish were transferred from FW to SW, and the plasma T_3 and T_4 levels were significantly highest at 50 % SW and then maintained as control. Moreover, these parameters were significantly lower in the cortisol-injected groups than in the control. Hence, TRs, T_3, and T_4 may play a role in SW adaptation, when the fish migrate from FW to SW environments. We showed a negative correlation between cortisol and thyroid hormone levels, and a significant increase in plasma K^+ levels in the kidney when the fish were transferred to SW, with levels being significantly lower in the cortisol-injected group. Hence, cortisol appears to be a stress hormone, and the plasma Na^+ and Cl^- levels significantly increased when the fish were transferred to SW, with levels being significantly lower in the cortisol-injected group. These results indicate that cortisol modulates ion transportation in the plasma.

Torao, M., M. Miyamoto, H. Saneyoshi, and M. Kobayashi. 2014. Development of schooling behavior in the juveniles of chum salmon *Oncorhynchus keta*. Nippon Suisan Gakkaishi 80 (4): 613-615 (In Japanese, no abstract).

Urawa, S. 2015. Ocean distribution and migration of Japanese chum salmon. Bulletin of Fisheries Research Agency 39: 9-19 (In Japanese with English abstract).

The migration route of Japanese chum salmon (*Oncorhynchus keta*) has been estimated using recent information on fish abundance, otolith marks and genetic stock identification (GSI) of mixtures sampled on the high seas. Japanese chum salmon globally shift their marine distribution depending on the life stage and season. Juvenile chum salmon leave from the coastal areas in the

spring and early summer, and inhabit in the Okhotsk Sea during the summer and fall. With the decrease of surface seawater temperature (SST) in November, juveniles move to the western North Pacific Ocean, where they are distributed in a narrow area of SST 4-6ºC during the first winter. After the first wintering, young chum salmon (ocean age 1) migrate to the Bering Sea by the next summer for feeding. In the late fall, immature chum salmon move southeast to the Gulf of Alaska for their second wintering. They migrate between the summer feeding ground in the Bering Sea and the winter habitat in the Gulf of Alaska until they return to natal rivers in Japan through the Bering Sea for spawning. Intensive research on the survival mechanism of juvenile chum salmon migrating to the Okhotsk Sea and the long-term monitoring of salmon stocks in the major feeding waters in the Okhotsk Sea and Bering Sea are indispensable for the sustainable salmon fishery management in Japan.

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

Hoshi, N., K. Sakaoka, T. Abe, M. Ohwada, K. Imai, and S. Takagi. 2015. Results of 2014 Salmon Research by the *Oshoro maru.* NPAFC Doc. 1584. 10 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 #269 in May 2013. Twelve oceanographic observations and one drift gillnet survey were conducted along the 155°E during the Cruise #269 in May. The Polar Front was observed in the vicinity of 43°N which were shifted south slightly and not clear than the location in previous years. A total of 515 salmonids was caught by gillnet surveys, including 488 Pink and 27 Chum salmon. Pink salmon was the dominant species. The fork lengths (F.L.) of chum salmon collected by C-gear gillnet ranged between 474-648 mm F.L., and those of pink salmon ranged between 297-470 mm F.L.. 88.6% of chum salmon caught along 155°E were adult fish. To collect salmon samples extensively and to collect fresh salmon blood and various tissues, three surface long-line and three hook-and-line gear samplings were conducted during the Cruise #269. Almost all of caught by these gears were Pink salmon but restricted the north point (OSSL1401), caught one Sockeye salmon and Chum salmon was the dominant species. A total of one Sockeye, fourteen Chum, and 48 Pink salmon were collected during the Cruise #269.

Kaeriyama, M., H. Seo, and Y. X. Qin. 2014. Effect of global warming on the life history and population dynamics of Japanese chum salmon. Fisheries Science 80 (2): 251-260.

We have reviewed the effects of long-term climatic/oceanic conditions on the growth, survival, production dynamics, and distribution of Hokkaido chum salmon Oncorhynchus keta in Japan during the period 1945-2005 using path analysis, back-calculation, and scale analyses, and applied a prediction method based on the SRES-A1B scenario of the intergovernmental panel on climate change. The populations of Hokkaido chum salmon were found to have had high growth rates at age 1 year since the late 1980s. Path analysis indicated that the growth at age 1 year in the Okhotsk Sea was directly affected by warm sea surface temperature associated with global warming, with the increased growth at age 1 year resulting in higher rates of survival and large population sizes. Predictions on the global warming effects on the chum salmon were (1)

decreased carrying capacity and distribution area, (2) occurrence of a strong density-dependent effect, and (3) loss of migration route to the Sea of Okhotsk, especially for Hokkaido chum salmon. We have also outlined the future challenges of establishing a sustainable conservation management scheme for salmon that include adaptive management and precautionary principles, as well as conservation of natural spawning populations and recovery of natural river ecosystems in Japan despite the warming climate.

Morita, K., T. Tamate, M. Kuroki, and T. Nagasawa. 2014. Temperature-dependent variation in alternative migratory tactics and its implications for fitness and population dynamics in a salmonid fish. Journal of Animal Ecology 83 (6): 1268-1278.

Temperature-driven life-history modifications by adaptation occur in ectotherms, and therefore, life-history modifications by adaptation need to be taken into consideration when predicting population responses to the climate change. Partial migration is a common form of life-history diversity in which a population contains both migratory and resident behaviours. Salmonid fish exhibit a wide range of life-history diversity and, in particular, partial migration. We evaluated the effect of temperature-driven life-history modifications on population dynamics in partially migratory masu salmon (*Oncorhynchus masou*) by field observations and theoretical models. Field observations revealed that spatial patterns of alternative migratory tactics were associated with temperature gradients. The occurrence of resident males increased, whereas the proportion of migrant males and the proportion of delayed migrants including both sexes decreased with increasing temperature and, thereby, with improved early growth conditions. The expected fitness for each migratory tactic was computed in a life-history model with early growth conditions as a function. Individual fitness was maximized by adopting resident tactics under favourable early growth conditions, early migrant tactics under intermediate early growth conditions and delayed migrant tactics under unfavourable early growth conditions. The results suggest that individuals exhibited a status-dependent conditional strategy, that is, the adoption of alternative migratory tactics is influenced by the status of individuals to make the best of a situation. A simulation model suggests that increased residency by males to increased temperature leads to a substantial decrease in the number of migrants. Moreover, the decrease in the number of delayed (older) migrants with increasing temperature magnified fluctuations in abundance. Our findings indicate the importance of temperature-driven life-history modifications for predicting dynamics of natural populations under climate warming.

Sato, S., T. Sato, T. Nakamura, A. Seitz, and K. Suzuki. 2015. The Summer 2014 Japanese Salmon Research Cruise of the R/V *Hokko maru*. NPAFC Doc. 1583. 22 pp.

A summer high-seas research cruise to investigate the biology of Pacific salmon was conducted from July 23 to August 13, 2014 in the Bering Sea aboard the Japanese research vessel *Hokko maru*. Research cruise activities included the collection of data on oceanography, zooplankton, micronekton, salmonids, and other organisms. In addition, seawater samples were collected for environmental DNA analysis. The mean SST at 17 monitoring stations was 11.1 °C, which was highest in the past survey years since 2007. A total of 2,142 salmonids were caught by trawls, live-box, and hook-and line. Chum salmon was the most abundant species (80.3%), followed by sockeye salmon (13.8%), Chinook salmon (5.2%), pink salmon (0.37%), and coho salmon (0.28%). The CPUE of ocean age 1 chum salmon was much lower than in other years. Salmonids were measured with respect to fork length and body and gonad weights by sex, and the scales were removed for age determination. Isotope, genetic, otolith, stomach, brain and

pituitary of chum and sockeye salmon, and seawater samples were obtained for future studies. One hundred chum salmon and nine Chinook salmon were tagged with disk tags and released in the Bering Sea. Among the tagged fish, 18 large chum salmon and seven large Chinook salmon were equipped with DST magnetic tags and pop-up satellite archival tags, respectively.

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., S. Sato, Y. Shinriki, R. Yasutomi, N. Aruga, and M. Nakajima. 2014. Relationship between vertebral number and body size in naturally spawning chum salmon in the Kotonihassamu River. Fish Genetics and Breeding Science 43 (1): 29-33 (In Japanese with English abstract).

Relationship between vertebral number and body size in naturally spawning chum salmon was surveyed in the Kotonihassamu River. There were no differences in the mean vertebral number among sampling dates and between sex. Mean body sizes of age-4 fish were compared among groups with different vertebral number. Significant difference in the mean body sizes was not observed among groups with different vertebral number, though mean body size showed a tendency to become large as vertebral number increased.

Ando, D., Y. Shinriki, K. Shimoda, R. Yasutomi, Y. Sasaki, Y. Miyakoshi, and M. Nakajima. 2014. Effects of spawning time on the variation of vertebral number in chum salmon *Oncorhynchus keta*. Nippon Suisan Gakkaishi 80 (2): 191-200 (In Japanese with English abstract).

They investigated the relationship between vertebral number variations and spawning time of chum salmon *Oncorhynchus keta* in the Chitose- and Izari Rivers, Hokkaido Island, Japan. The means of vertebral number in early-spawning populations were higher than those of late-spawning populations in both rivers. A similar trend was observed in juveniles that were derived from different spawning groups in the Chitose River and reared under common conditions. In addition, the means of vertebral number in chum salmon fry captured in the early-sampling season (January and February) were higher than those of the late-sampling season (April) in the Izari River. These results suggest that variations of vertebral number in chum salmon adults and fry are affected by spawning time, and that the variations are originally caused by genetic factors.

Aruga, N., K. Morita, T. Suzuki, N. Sato, M. Okamoto, and K. Ohkuma. 2014. Evaluation of population viability of wild chum salmon *Oncorhynchus keta* in the Toyohira River, Sapporo metropolitan watershed, Japan. Nippon Suisan Gakkaishi 80 (6): 946-955 (In Japanese with English abstract).

Natural spawning of chum salmon *Oncorhynchus keta* has been observed during the past 30 years in the Toyohira River in the Sapporo metropolitan area, an area from which they were once

exterminated. However, the population viability of wild chum salmon is still unknown as hatchery salmon from non-local broodstock have been released into the Toyohira River throughout this time. For brood years 2003-2006, all hatchery released fry from the Toyohira and Chitose hatcheries were marked within the riverine system. For these brood years, wild salmon accounted for 59.2-75.9% of the total number of spawning adults in the Toyohira River, and straying of salmon from the Chitose River hatchery was very low (0.6%). If the marine survival rates are assumed to be similar between wild and hatchery salmon, the egg to fry survival rate of naturally spawned fish is estimated to be 12.6%. This suggests that the egg-to-fry survival rate is low in the Toyohira River, possibly because of poor in-stream environmental conditions. Interestingly, the age at maturity and spawn timing differed between wild and hatchery salmon, indicating that adaptations to the environmental conditions of the Toyohira River may occur after approximately seven generations.

Gonda, Y., Y. Kondo, N. Takahashi, and K. Miya. 2014. Trials of resistivity fish counters for automatic counting of chum *Oncorhynchus keta* and masu *O. masou* salmon migrating in small rivers. Journal of Fisheries Technology 7 (1): 1-16 (In Japanese with English abstract).

Resistivity fish counters were installed on simple platforms built on the beds of two small rivers and on a fishway to count migrating chum *Oncorhynchus keta* and masu *O. masou* salmon. Counters were captured with video camera from directly above, and the accuracy of the counters was evaluated by comparison with the numbers of fish counted by video observations. Chum salmon greater than 60 cm in body length were counted with considerable accuracy when we used a fish counter equipped with electrodes shorter than 3.2 m to apply a voltage of 5 V, and when the platform was less than 20 cm below the surface. We also examined factors decreasing the accuracy of the fish counters and suggested suitable designs for riverbed platforms to improve the accuracy of the fish counters.

Iida, M., Y. Miyakoshi, T. Kato, H. Tokuda, M. Fujiwara, and D. Ando. 2014. Natural spawning of pink salmon *Oncorhynchus gorbuscha* in rivers with and without weirs on the Okhotsk side of Hokkaido. Aquaculture Science 62 (2): 129-136 (In Japanese with English abstract).

In this study, we investigated the distribution and run timing of naturally spawning pink salmon of northeastern Hokkaido, Japan in the Tokoro River system where a weir is installed, and in the Bairagi River which has no weir. In the Tokoro River, naturally spawning pink salmon were observed in 8 of 24 tributaries surveyed during 2005-2008. In visual surveys conducted in 2010, the number of pink salmon increased in early September, reached a maximum in mid-late September and subsequently decreased in early October. This pattern closely agreed with the fluctuation of the number of pink salmon captured by the weir for hatchery broodstock. In the Bairagi River, pink salmon were not observed until late September, and occurred in early October for the first time. Our study indicates that natural spawning of pink salmon may occur every year even though a weir is installed for hatchery broodstock collection, and the numbers, distribution, and timing may differ among sites and years.

Kawai, H., S. Nagayama, H. Urabe, T. Akasaka, and F. Nakamura. 2014. Combining energetic profitability and cover effects to evaluate salmonid habitat quality. Environmental Biology of Fishes 97 (5): 575-586.

Recent studies have demonstrated that the energetic profitability (net energy intake potential;

NEI potential) of a habitat, which is calculated as the gross energy gain from foraging minus the energy expenditure from swimming at a focal point, may be a useful tool for predicting the salmonid biomass. The effectiveness of the NEI potential should be tested in various systems. Even if the NEI potential is validated, its predictive accuracy and transferability could be limited if the cover habitat, which is known to be an important factor for determining salmonid abundance, is not considered. We tested whether the NEI potential is effective for predicting the salmonid biomass even in a stream with abundant cover and whether combining the NEI potential and cover effects can improve the predictability of fish biomass using a generalized linear model. Our results demonstrated that the NEI potential could generally predict the fish biomass (percent deviance explained = 79.9 %), and the model that incorporated both the NEI potential and the cover ratio improved the predictive accuracy (percent deviance explained = 88.5 %). These results suggest that energetic profitability can be an effective indicator for assessing habitat quality and is relatively transferable to other systems. Furthermore, when cover effects are considered, the habitat quality is more accurately represented; thus, combining the energetic profitability and the cover effects might improve the transferability of the assessment across habitats.

Kitada, S. 2014. Japanese chum salmon stock enhancement: current perspective and future challenges. Fisheries Science 80 (2): 237-249.

This study reviews the present status of the Japanese chum salmon *Oncorhynchus keta* stock enhancement program and considers the ecological sustainability of wild populations while providing fishery production, exemplified by the hatchery-based Kitami region set net fishery. The return rate and the number of returns have been historically high in the Sea of Okhotsk, but have decreased in other regions since 2005. Natural spawning of chum salmon occurred in at least 160 rivers in Hokkaido. The genetic diversity of Japanese chum salmon was similar to or higher than that of other Pacific Rim populations. Numbers of alleles were high at microsatellite loci, but the loss of rare haplotypes was observed in all populations. The estimated Ne /N ratio for the Kitami region was > 0.15 % including hatchery and wild fish under the present high fishing pressure. Four regional populations were inferred in Hokkaido, however, genetic differentiation was weak and some river-populations were nested. Substantial changes in run timing were observed, but it has recovered gradually owing to the recent practice of escapement. Our analyses highlight the importance of juvenile quality and the vital roles of escapements in enhanced and non-enhanced rivers. New research is needed to minimize the genetic risks associated with hatchery programs.

Miyakoshi, Y. 2014. Improvement of enhancement and conservation techniques for salmon stocks. Nippon Suisan Gakkaishi 80 (5): 674-676 (In Japanese, no abstract).

Miyoshi, K., K. Hayashida, T. Sakashita, M. Fujii, H. Nii, K. Nakao, and H. Ueda. 2014. Comparison of the swimming ability and upstream-migration behavior between chum salmon and masu salmon. Canadian Journal of Fisheries and Aquatic Sciences 71 (2): 217-225.

The spawning ground of chum salmon (*Oncorhynchus keta*) is usually located farther downriver than that of masu salmon (*Oncorhynchus masou*) in Hokkaido, Japan. To compare the swimming abilities of these two species, the relationship between swimming speed and oxygen consumption was compared using a swim tunnel in the laboratory. Then, the upstream-migration behaviors of chum salmon and masu salmon were compared using electromyogram telemetry at

fish passages in the Toyohira River, Hokkaido. In the laboratory study, the standard metabolic rate of masu salmon was lower and the critical swimming speed (U_{crit}) was faster than those of chum salmon. In the field study, the holding time needed to recover the swimming performance exceeding U_{crit} at the fish passages and the trial number needed to pass the fish passages were significantly lower for masu salmon than chum salmon. These results revealed that masu salmon are more adaptable to extended swimming in high water velocity conditions than chum salmon and that masu salmon are better equipped for a long distance upstream migration to their spawning ground than chum salmon.

Munakata, A, G. Miura, H., and Matsuda, H. 2014. Evaluation of seasonal and daily changes of plasma thyroxine and cortisol levels in wild masu salmon *Oncorhynchus masou*, sampled by a Japanese fishing method. Journal of Fish Biology 85 (4): 1253-1262.

A new fish sampling method was developed using a Japanese bait fishing rod (8-9m carbon rod and a nylon line with a small fine wire single hook), which is considered to catch wild salmonid juveniles with low sampling stress. Using this method, seasonal and daily changes of plasma thyroxine (T-4) and cortisol levels were examined in wild parr, pre-smolts and smolts of masu salmon *Oncorhynchus masou* in contiguous locations in a coastal river (Kesen River; 44 km) in northern Honshu Island, Japan, overlapping the period of smoltification and seaward migration from August to March. Plasma T-4 and cortisol were lowin 0+ and 1+ year parr caught in August and September. In March, some yearling (1+ year) fish, which were judged as pre-smolts, and smolts appeared mainly in mid and lower reaches, while parr (0+ and 1+ year parr) continued to appear in the upper and mid reaches. In March, 1+ year pre-smolts and smolts showed high plasma T-4 levels while the levels of 1+ year parr were low. During March 2008-2010, plasma T-4 levels of 1+ year pre-smolts and smolts had high levels from early to mid-March, whereas plasma cortisol levels of 1+ year smolts were low in early March and increased towardsmid-March. Based on these data, plasma cortisol increases probably occur following the increases of plasma T-4 levels to lead the 1+ year *O. masou* to the completion of smoltification and initiation of seaward migration.

Nagasawa, T. 2015. Present status of chum salmon stocks. Bulletin of Fisheries Research Agency 39: 3-7 (In Japanese with English abstract).

Among species of Pacific salmon, chum salmon rank second only to Chinook salmon in having the largest adult body size and second to pink salmon in highest abundance. Chum salmon also have the widest geographic distribution of all Pacific salmon species. Two major seasonal groups, summer chum and autumn chum, are recognized in Asia and North America. In Asia, summer chum salmon are native to Kamchatka, northern Okhotsk coast, northeastern Sakhalin, and the Amur River regions. Autumn chum salmon are native to Japan, the southern coast of Sakhalin, Korea, and the Amur River. The coastal commercial catches of chum salmon have remained at historically high levels of abundance in the North Pacific since the 1990s. The relative abundance of chum salmon varies decreases from north to south in both Asian and North America. Favorable ocean conditions and improved hatchery programs have supported overall high abundance levels of Asian chum salmon, but in some southern regions adult returns have decreased since the mid 2000s. Hatchery releases of chum salmon have been constant in Japan since the mid 1980s. In contrast, hatchery releases have increased in Russia since the mid 2000s.

Sahashi, G., and K. Morita. 2014. Fall-winter collection of two salmonid species: seasonal changes in population densities in four tributaries of the Kushiro river system.

Ichthyological Research 61 (2): 189-192 (No abstract).

Saito T., Y. Okamoto, and K. Sasaki. 2015. Biological characteristics of chum salmon in Japan. Bulletin of Fisheries Research Agency 39: 85-120 (In Japanese with English abstract).

To clarify the regional differences in biological characteristics of chum salmon, *Oncorhynchus keta*, inhabiting the northern Japan, the number of adult returns (coastal and river catches), peak of upriver migration (PUM), coastal sea surface temperature at the PUM, fork length of age 4 adults, age at maturity, egg diameter and fecundity of age 4 females were examined, on the basis of data collected in seven regions of northern Japan during the summer-winter of fiscal year 1994-2008. All biological characteristics showed clear differences among the regions or between some pairs of the ones, and some characteristics of river stocks appeared to change along latitudinal gradients. Particularly, the PUM, fork length, age at maturity, and egg diameter in river stocks along the Sea of Japan coast exhibited an abrupt change at the boundary of the Tsugaru Strait. In Hokkaido, the PUM was earlier as compared with previous observations made before 1960s, which probably resulted from artificial alterations of the run timing in many stocks. Consequently, the advanced PUM enforced fish to experience higher sea temperatures during their spawning migration. Egg diameter, standardized by grand mean of fish length of each stock, demonstrated a decreasing trend over the study period, although it was undeniable that a problem of the dataset might cause an apparent trend. Although some artificial alterations were recognized in biological characteristics of chum salmon stocks, this study demonstrated that regionally distinguishable traits are still present over the wide range of stocks in Japan.

Takahashi, M. 2015. Status of hatchery production of chum salmon populations in Japan. Bulletin of Fisheries Research Agency 39: 49-84 (In Japanese with English abstract).

This review paper compared trends of artificial enhancement activities (timing of spawning operations, effective population size, timing of fry releases and body size of released fry) among seven regional populations of chum salmon (Okhotsk, Hokkaido Sea of Japan, Nemuro, East Hokkaido Pacific, West Hokkaido Pacific, Honshu Pacific, and Honshu Sea of Japan) in northern Japan. Seasonal changes of coastal sea surface temperature (SST) in each region were also compared. In 2010, a total of 246 chum salmon hatcheries was operated in northern Japan, and the mean number of fry releases per facility was 7,527 thousand fish. Relatively small hatcheries were abundant in the west Hokkaido Pacific and Honshu Sea of Japan regions. The timing of taking eggs peaked in late October for the Okhotsk and east Hokkaido Pacific populations, and late November for the Honshu Pacific population. The recent effective population size (Ne) exceeded 10,000 adults/year in five river populations (Tokushibetsu, Ishikari, Nishibetsu, Tokachi, and Yurappu) representing each regional population in Hokkaido. Patterns of coastal SST changes during juvenile salmon migration varied among regions: SST increased faster in the Sea of Japan regions than in the Pacific regions. The peak of fry releases was almost stable in late March for the Honshu Sea of Japan population, and in late May for the Okhotsk population, but it fluctuated in other regional populations. The mean body size of released fry increased in three regional populations (Okhotsk, Hokkaido Sea of Japan, and East Hokkaido Pacific), but did not change in other regional populations since 1990s. Future issues to maintain Japanese chum salmon populations are: 1) well understanding the features of each regional population, 2) conserving the diversity of each population, and 3) identifying the best timing of fry releases and their body size in each population to maximize their survival in the ocean.

Tomida, Y., T. Suzuki, T. Yamada, R. Asami, H. Yaegashi, Y. Iryu, and T. Otake. 2014. Differences in oxygen and carbon stable isotope ratios between hatchery and wild pink salmon fry. Fisheries Science 80 (2): 273-280.

We examined differences in otolith oxygen ($\delta^{18}O_{otolith}$) and carbon ($\delta^{13}C_{otolith}$) stable isotope ratios between hatchery and wild pink salmon fry. The $\delta^{18}O_{otolith}$ values of hatchery and wild fry were -7.7 ± 0.2 ‰ and -8.3 ± 0.3 ‰ (1σ), respectively. This difference reflected differences in temperature conditions experienced by each fry. The $\delta^{13}C_{otolith}$ values of hatchery and wild fry were -19.2 ± 0.3 ‰ and -11.1 ± 1.8 ‰ (1σ), respectively. The lower $\delta^{13}C_{otolith}$ values of hatchery fry were probably related to their intake of artificial diets. Discriminant analysis of $\delta^{18}O_{otolith}$ and $\delta^{13}C_{otolith}$ values demonstrated a highly significant difference between hatchery and wild fry with 95.8 % classification accuracy. Therefore, analysis of $\delta^{18}O_{otolith}$ and $\delta^{13}C_{otolith}$ precipitated in the fry stage may be useful for discriminating the origin of returning adult pink salmon. The discrimination method for returning adult fish would provide important information for evaluating the effect of hatchery release and their impact on the wild population.

Torao, M. 2014. Instance of small pink salmon, *Oncorhynchus gorbuscha* in rivers at the Nemuro Strait, eastern Hokkaido, Japan. Scientific Reports of Hokkaido Fisheries Research Institutes 86: 151-154 (In Japanese with English abstract).

I examined the body size, maturity and age of "small pink salmon" caught in the rivers at Nemuro Strait, Eastern Hokkaido, Japan. On September 28, 2009 a male pink salmon with a fork length of 31.5 cm and weight of 381.4 g was caught in Shibetsu River. The Gonad Somatic Index (GSI) was 7.86. This mature male had scales indicating 1−year old fish (i.e., "jack"). A female pink salmon caught in Furen River on 20 November 2010 had a fork length of 26.5 cm and weight of 156.8 g, indicating it was an immature (GSI 0.77) 1-year old fish. An immature female (28.5 cm in fork length) caught in Kunbetsu River on 10 September 2013 had otoliths marked by the Alizarin Complexone (ALC). Marked pink salmon were released from the Shibetsu Hatchery during May in 2012. Therefore this fish was a 2-year-old fish. "Small pink salmon" are likely of contain mixed age, sex and maturity, and the ocean conditions (e.g., water temperature and nutritional conditions) affecting the growth of juvenile pink salmon during their first year at sea may have some influence on the appearance of small pink salmon.

Ueda, H. 2015. The current propagation systems and physiological studies of Japanese chum salmon. Fisheries Science 81 (2): 219-228.

In Japan, chum salmon *Oncorhynchus keta* is mainly propagated via artificial insemination, the release of juveniles from their natal river to the ocean, and the recapture of homing adults along the coast and within the natal river. The biomass of Japanese chum salmon increased steadily from 1970 to 1996 because of the successful improvement of propagation systems. However, the returning rate of homing adults has become unstable, and the aftermath of the 2011 Tohoku earthquake and tsunami caused a major decrease in the number of juveniles released in the Tohoku area. It is now widely accepted that specific factors in the natal stream are imprinted on the nervous system of juvenile chum salmon during downstream migration and that adults use these factors to recognize the natal stream during their upstream homing migration. Recent physiological studies from behavioral to molecular biological approaches to elucidate mechanisms of imprinting and homing migration in chum salmon are useful for developing new chum salmon propagation systems to enhance the survival rates of juveniles in coastal areas and stabilize the returning rate of homing adults. This review introduces a semi-closed recirculating aquaculture system to estimate the health condition and improve the olfactory imprinting

capability of juvenile chum salmon.

Urabe, H., M. Nakajima, M. Torao, and T. Aoyama. 2014. Application of a bioenergetics model to estimate the influence of habitat degradation by check dams and potential recovery of masu salmon populations. Environmental Biology of Fishes 97 (5): 587-598.

Using a bioenergetics model, we examined how check dams negatively effect masu salmon (*Oncorhynchus masou*) populations by causing habitat loss in upstream areas and habitat degradation in downstream areas. The potential recovery of masu salmon populations in the upstream area was estimated based on the expected biomass and potential recovery area. We also determined if and how fish carrying capacity is affected by degradation of substrate conditions (armoring and compaction) in the downstream area. Recovery of upstream areas was considered to be effective in enhancing and conserving masu salmon populations. We demonstrated that the dam-induced altered substrate conditions and habitat degradation in the downstream area resulted in a considerable reduction of drifting prey. Simulation analysis revealed that a 40 % increase in the abundance of masu salmon juveniles in the downstream area could be expected if substrate conditions were restored. We concluded that both improvement of migration barriers and restoring the sediment regime would be important in enhancing and conserving wild masu salmon populations.

Yamamoto, S, T. Yokoduka, K. Fujimoto, K. Takagi, and T. Ono. 2014. Radiocaesium concentrations in the muscle and eggs of salmonids from Lake Chuzenji, Japan, after the Fukushima fallout. Journal of Fish Biology 84 (5): 1607-1613.

Approximately 18 months (September to December 2012) after the Fukushima Dai-ichi Nuclear Power Plant accident, elevated radiocaesium concentrations were measured in samples of muscle and eggs from masu salmon *Oncorhynchus masou*, kokanee *O. nerka*, brown trout *Salmo trutta* and lake trout *Salvelinus namaycush* from the Lake Chuzenji system, central Honshu Island, Japan (160km from the station). Mean muscle concentrations were 142.9-249.2 Bq kg^{-1} wet mass and mean concentrations in eggs were 38.7-79.0 Bq kg^{-1} wet mass. There was no relationship between fork length and muscle radiocaesium concentration in any of the species, but there were significant relationships between individual muscle and egg radiocaesium concentrations from *O. masou*, *S. trutta* and *S. namaycush*.

Yamamoto, S., K. Mutou, H. Nakamura, K. Miyamoto, K. Uchida, K. Takagi, K. Fujimoto, H. Kaeriyama, and T. Ono. 2014. Assessment of radiocaesium accumulation by hatchery-reared salmonids after the Fukushima nuclear accident. Canadian Journal of Fisheries and Aquatic Sciences 71 (12): 1772-1775.

To understand the process of radiocaesium uptake in salmonids after the Fukushima Dai-ichi Nuclear Power Plant accident, a lake caging experiment and two captive-rearing experiments with controlled radiocaesium concentrations of water and feed were conducted in and around Lake Chuzenji, central Honshu Island, Japan (160 km from the station). Substantial accumulations of radiocaesium were confirmed in muscle of hatchery-reared kokanee (*Oncorhynchus nerka*) and masu salmon (*Oncorhynchus masou*) after release into the cages, indicating that radionuclide contamination of fish is an ongoing process, 1.5 years after the nuclear accident. Two captive experiments, controlling water and feed radiocaesium levels, showed that direct radiocaesium transfer from water (43 mBq.L-1) in Lake Chuzenji to muscle tissue was undetected, at least during the similar to 90-day experimental period, whereas a rapid increase in radiocaesium levels was observed when fish were cultured using

radiocaesium-contaminated pellets. The results revealed that radiocaesium contamination in salmonids is mainly via the food chain and that direct intake from water via the skin, gut, and (or) gills has no major direct impact on muscle tissue concentrations.

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

Kitanishi, S., and T. Yamamoto. 2015. Comparison of genetic structure between juvenile and adult masu salmon indicates relatively low reproductive success of dispersers. Environmental Biology of Fishes 98 (1): 405-411.

Delineating population genetic structure and gene flow is a critical for identifying evolutionary processes and effective conservation. In this study, we examined the genetic structure of masu salmon (*Oncorhynchus masou*) populations within the Atsuta River, Hokkaido, Japan. In addition, to infer whether dispersers contribute to next generation's gene pool, a comparison between the genetic structure of juvenile and adult masu salmon was conducted. Significant genetic differentiation and isolation by distance were observed among populations of both juveniles and adults. The degree of genetic differentiation was larger among the juvenile samples, especially among geographically distant samples, than among the adults. These results suggest that a number of relatively stable discrete populations are maintained in the river and that the reproductive success of dispersers to distant tributaries was relatively low among distant tributaries.

Miyauchi, Y., Y. Gohda, Y. Hirama, Y. Okamoto, and T. Ohnuki. 2015. Shortening of marking time to increase otolith thermal marking pattern of chum salmon (*Oncorhynchus keta*) released from hatcheries. Journal of Fisheries Technology 7 (2): 89-95 (In Japanese with English abstract).

Thermal otolith marking is an effective tool to identify the origin of anadromous salmon released from hatcheries. The otolith is thermally marked by abrupt changes in water temperature (3–4°C) during incubation. The marking time required for creating one ring is at least 24 h (cooling for 12 h and warming for 12 h). The number of available marking patterns is limited because the window of marking is less than two weeks for the eyed-egg stage. In order to increase otolith marking patterns, we conducted laboratory experiments to shorten the marking time. Our experiments confirmed that a clear marking ring was created within 12 h (cooling for 3 h and warming for 8 h at least) in the otolith of chum salmon (*Oncorhynchus keta*) during the eyed-egg stage. By using this method, various marking patterns were created in the otolith of fish, even at hatcheries where the marking period was restricted because of relatively high water temperatures during incubation.

Sato, S., and S. Urawa. 2015. Genetic structure of chum salmon populations in Japan. Bulletin of Fisheries Research Agency 39: 21-47 (In Japanese with English abstract).

We examined the genetic structure of Japanese chum salmon populations using 20 allozyme markers. A total of 2,447 individuals from 35 populations of Hokkaido and northern Honshu was used to estimate mean allelic richness, observed (H_O) and expected (H_E) heterozygosities, a neighbor-joining (N-J) phylogeny, average pairwise F_{ST} values, and to conduct analysis of molecular variance (AMOVA). Some of these parameters were compared with the average

number of alleles (A), mean effective number of alleles (Ae), and HE calculated based on allelic frequency data from microsatellite DNA marker analysis of Japanese chum salmon. In our allozyme study, HO and HE values of chum salmon populations in Honshu (H_O, 0.200; H_E, 0.199) were larger than those of Hokkaido (H_O, 0.186; H_E, 0.190). In contrast, the A, Ae, and HE values calculated with the reported microsatellite data were larger in the populations of Hokkaido (A, 27.5; Ae, 15.7; H_E, 0.917) than those of Honshu (A, 24.2; Ae, 14.2; H_E, 0.908). Both the N-J tree and AMOVA analysis with the allozyme data suggested seven regional groups, five in Hokkaido and two in Honshu. Furthermore, F_{ST} estimates demonstrated genetic differentiation between Hokkaido and Honshu regions (0.014-0.034). Similar genetic population structure was suggested by the N-J tree and F_{ST} estimates with the microsatellite data. The historical genetic characteristics or the remnants of past population structure in Japanese chum salmon remain intact, despite the hatchery program operating more than 120 years.

Sato, S., W. D. Templin, L. W. Seeb, J. E. Seeb, and S. Urawa. 2014. Genetic structure and diversity of Japanese chum salmon populations inferred from single-nucleotide polymorphism markers. Transactions of the American Fisheries Society 143 (5): 1231-1246.

They estimated the genetic structure and diversity of Japanese chum Salmon *Oncorhynchus keta* populations using single-nucleotide polymorphism (SNP) markers to support the management and assessment of the Japanese salmon hatchery program. A total of 5,571 individuals from 57 Japanese chum Salmon populations were genotyped with 52 markers. A neighbor-joining tree, principal coordinate analysis, analysis of molecular variance, and average pairwise F-ST values indicated the existence of eight regional groups, six in Hokkaido and two in Honshu. Weak but significant isolation by distance was found within the populations of Hokkaido and the Pacific Ocean coast of Honshu. These results suggest that the genetic differentiation among the eight regional groups is small but distinct and occurred through low or restricted gene flow. Furthermore, our results also suggest the persistence of the historical genetic structure (or remnants of it) in extant populations in Japan despite the operation of a hatchery program for about 120 years. The genetic framework of the Japanese chum Salmon populations that we observed using SNP markers is basically similar to that found by previous studies using other molecular markers but the populations along the western Pacific Ocean coast of Hokkaido are separated into two regional groups.

Tsukagoshi, H., S. Terui, and S. Abe, S. 2015. Characterization of sixteen polymorphic microsatellite DNA loci in the chum salmon (*Oncorhynchus keta*) isolated by next-generation sequencing. Conservation Genetics Resources 7 (1): 173-175.

Chum salmon (*Oncorhynchus keta*) is an important fisheries resource around the North Pacific region. However, the genetic characteristics of this species mostly remain to be elucidated with competent molecular genetic markers for their effective resource management and sustainable use. A total of sixteen novel microsatellite markers in chum salmon were isolated using a next-generation sequencing approach. All loci were polymorphic with 6-21 alleles, with the observed and expected heterozygosities of 0.41667-0.97917 and 0.66184-0.92434, respectively. These new loci will provide a tool for examining the genetic diversity and population structure of chum salmon, which are an important information for the adaptive management of this species.

Yoon, S., E. Watanabe, H. Ueno, and M. J. Kishi. 2015. Potential habitat for chum salmon (*Oncorhynchus keta*) in the western Arctic based on a bioenergetics model coupled with a three-dimensional lower trophic ecosystem model. Progress in Oceanography 131: 146-158.

Chum salmon (*Oncorhynchus keta*) are predominantly located in the Bering Sea during summer and fall. However, several studies have recently reported a different tendency as follows. Observed densities of chum salmon were higher in the vicinity of the Bering Strait and the Chukchi Sea than the eastern Bering Sea in September 2007, and Japanese chum salmon migrated to northern areas in the Bering Sea during summer 2009. The sea surface temperature (SST) in the Arctic marginal seas has increased since the mid1960s, and especially since 2000. We speculated that the SST increase directly promoted salmon northing from the Bering Sea to the Western Arctic. In this study, we estimated the potential habitat for chum salmon in the Western Arctic using a bioenergetics model coupled with a three-dimensional lower trophic ecosystem model (3-D NEMURO). "Potential habitat" was defined as "an area where chum salmon could grow (i.e., the growth rate was positive)". In the bioenergetics model, the growth rate of an individual chum salmon was calculated as a function of water temperature, salinity, and prey density, which were obtained from the 3-D NEMURO model results. To evaluate the habitat responses under a global warming scenario, we used the modeled monthly change of water temperature between 2005 (averaged from 2001 to 2010) and 2095 (averaged from 2091 to 2100) under the IPCC SRES-A1 B scenario. Our calculations, following the global warming scenario, suggested that the potential habitat for chum salmon would expand to the north due to the increase in water temperature and prey density. In contrast, south of 71 degrees N during summer, the potential habitat would shrink regionally because the water temperature exceeded the optimal condition.