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Japanese Bibliography in 2019 for NPAFC Science Plan

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ABSTRACT: This bibliography listed original papers and documents published in 2019 by Japanese scientists and/or their collaborators to review Japanese national researches for the 2016-2020 NPAFC Science Plan. The bibliography includes 62 articles with abstracts, corresponding to five research themes of the NPAFC Science Plan.

BACKGROUND

In 2016, the Science Sub-Committee (SSC) of the North Pacific Anadromous Fish Commission (NPAFC) developed a new five-year Science Plan 2016–2020 (SSC 2016). The SSC identified its primary goal “Understand Variations in Pacific Salmon Productivity in a Changing Climate” with five research themes: 1) Status of Pacific salmon and steelhead trout; 2) Pacific salmon and steelhead trout in a changing North Pacific Ocean; 3) New technologies; 4) Management systems; and 5) Integrated information systems. The new NPAFC Science plan is approximately consistent with the International Year of Salmon initiative (IYS-WG 2016).

The national research plan by Japan was established in July 2016 to correspond to the new NPAFC Science Plan (Fisheries Agency of Japan 2016). It is a high priority for Japanese salmon research to explain and forecast the annual variation of salmon production, corresponding to the new Science Plan themes. To review Japanese national researches for the NPAFC Science Plan, this bibliography listed original papers and documents published in 2019 by Japanese scientist and/or their collaborators. The current issue supplemented 62 articles published in 2019. The bibliography includes abstracts for most articles.

REFERENCES

- Fisheries Agency of Japan. 2016. Japanese salmon research under the NPAFC Science Plan 2016-2020. NPAFC Doc. 1673. 2 pp. (Available at <https://npafc.org>).
- International Year of the Salmon Working Group (IYS-WG). 2016. Outline proposal for an International Year of Salmon (IYS) ‘Salmon and People in a Changing World’. NPAFC Doc. 1663. 9 pp. (Available at www.npafc.org).
- The Science Sub-Committee (SSC). 2016. North Pacific Anadromous Fish Commission Science Plan 2016-2020. NPAFC Doc. 1665. 8 pp. (Available at <https://npafc.org>).

BIBLIOGRAPHY

Theme 1. Status of Pacific Salmon and Steelhead Trout

Ando, D., K. Shimoda, K. Takeuchi, A. Iijima, H. Urabe, Y. Shinriki, and M. Nakajima. 2019. Comparison of vertebral number between wild and hatchery-reared population, and effect of stock enhancement programs on vertebral number in masu salmon *Oncorhynchus masou*. *Nippon Suisan Gakkaishi* 85: 487–493 (In Japanese with English abstract). DOI: <https://doi.org/10.2331/suisan.19-00007>

Vertebral numbers in hatchery-reared and wild populations of masu salmon *Oncorhynchus masou* were compared. In addition, vertebral numbers were analyzed in wild masu salmon juveniles from rivers in which hatchery-reared fry, juveniles, and smolts had been stocked. Hatchery-reared masu salmon had fewer vertebrae than fish from wild populations. This difference may have been caused by environmental factors (incubation water temperatures) during the early developmental stages. Wild masu salmon from a river in which stock enhancement programs have been continued for a long time had fewer vertebrae than wild fish from neighboring rivers. Stock enhancement programs may genetically affect the vertebral number in wild masu salmon populations.

Asami, H., H. Hayano, S. Mano and M. Nagata. 2019. Prevalence of the hemiurid trematode *Brachyphallus crenatus* in the stomach of juvenile masu salmon *Oncorhynchus masou* in the coastal waters near Cape Erimo, Hokkaido, Japan. *Sci. Rep. Hokkaido Fish. Res. Inst.* 95: 19–24 (In Japanese with English abstract).

Prevalence of the hemiurid trematode *Brachyphallus crenatus* in the stomach of the juvenile masu salmon *Oncorhynchus masou* collected in the coastal waters near Cape Erimo off the Pacific coast of Hokkaido was investigated. Juvenile salmon were sampled at two different times of the day (early morning, 5:00, and day-time, 13:00) on June 10, 1994, using set nets extending from the shore to offshore areas at three stations. A total of 127 juveniles were collected (41 individuals in the early morning and 86 individuals during the day). Most of the juveniles were captured at the shore stations. Five tagged juveniles were also found at the shore stations during the day. The fork lengths of the juveniles collected at shore were smaller than those of the juveniles caught offshore. The ratio of small juveniles (<20 cm) caught was about 50 % during the day, and about 29% in the early morning. *B. crenatus* was present in over 95% of the total juvenile salmon collected during the early morning and day. Mean intensity of occurrence was higher in the early morning than during the day for both the males and females. A positive correlation was found between the fork length and intensity of *B. crenatus*. Differences in the prevalence incidence during the two periods of the day might relate to the differences in sea entry sites or in the time spent at sea. The effectiveness of *B. crenatus* as biological tags of juvenile salmon is discussed.

Bugaev, A. V., A. I. Chistyakova, and S. Urawa. 2019. Long-term trends of distribution and regional composition of hatchery-released juvenile pink and chum salmon in the Sea of Okhotsk during the fall of 2011–2017. *N. Pac. Anadr. Fish Comm. Tech. Rep.* 15: 46–48 (Available at <https://npafc.org>).

Iida, M., Y. Yagi, and T. Iseki. 2019. Timing of spawning of wild chum salmon in a non-enhanced river and their seaward migration in northern Honshu, Japan. *N. Pac. Anadr. Fish Comm. Tech. Rep.* 15: 49–50 (Available at <https://npafc.org>).

Iino, Y., T. Kitagawa, T. K. Abe, T. Nagasaka, Y. Shimizu, K. Ota, T. Kawashima, and T. Kawamura. 2019. Effect of temperature and amount of food on the growth rate/aerobic scope of juvenile chum salmon. *N. Pac. Anadr. Fish Comm. Tech. Rep.* 15: 82–84 (Available at <https://npafc.org>).

Kaeriyama, M. 2019. Ecological research toward the sustainable conservation and use of Pacific salmon. *Nippon Suisan Gakkaishi* 85: 266–275 (In Japanese). DOI: <https://doi.org/10.2331/suisan.WA2623>

Kaneko, N., M. Torao, Y. Koshino, M. Fujiwara, Y. Miyakoshi, and M. Shimizu. 2019. Evaluation of growth status using endocrine growth indices, insulin-like growth factor (IGF)-I and IGF-binding protein-1b, in out-migrating juvenile chum salmon. *Gen. Comp. Endocrinol.* 274: 50–59. DOI: <https://doi.org/10.1016/j.ygcen.2019.01.001>

This study aimed to utilize circulating insulin-like growth factor binding protein (IGFBP)-1b as a negative index of growth to evaluate the growth status of juvenile chum salmon (*Oncorhynchus keta*) in the ocean. First, rearing experiments using PIT-tagged juveniles were conducted to examine the relationship of circulating IGFBP-1b with growth rate of the fish in May and in June. The serum IGFBP-1b level negatively correlated with fish growth rate in both months, suggesting its utility as a negative index of growth. Next, the growth status of out-migrating juveniles in northeastern Hokkaido, Japan, was monitored for 3 years using the growth indices. Serum levels of IGF-I, a positive index of growth, in fish collected from the nearshore zone were low in May and high in June of all years. Levels of serum IGFBP-1b showed a trend opposite to that of serum IGF-I. However, the IGF-I/IGFBP-1b molar ratios well reflected the seasonal and regional trends. These findings suggest that the juveniles in June left the nearshore area under better growth conditions. The present study also suggests that the use of multiple growth indices would improve the sensitivity and accuracy to evaluate the current growth status of out-migrating juvenile chum salmon.

Kasugai, K. 2019. Seasonal changes in age and maturity of chum salmon *Oncorhynchus keta* landed on fishermen's cooperative associations in Hokkaido. *Sci. Rep. Hokkaido Fish. Res. Inst.* 96: 9–15 (In Japanese with English abstract).

Body size and period of early squamation in chum salmon juveniles *Oncorhynchus keta* were examined. The difference in squamation process between early- and late-run stocks (fertilized from late September to early October and from middle November to early December, respectively) were compared with juvenile fish from six rivers (Abashiri R., Shibetsu R., Tokachi R., Chitose R., Shizunai R. and Torisaki R.) in Hokkaido, Japan. The delay of early squamation was observed in the rivers where emerging juveniles were shown to have short fork length. The early squamation of late-run stocks was faster than that of early-run stocks in three rivers based on results comparing the period of fertilization. The fork length of juveniles at the first squamation day were observed to be significantly by the analysis of two-way ANOVA depending on the period of fertilization and populations in the rivers. These results suggest that the period of early squamation in chum salmon juveniles could be determined based on the body size at

emergence and at the first squamation day. Body sizes can explain the differences in early squamation period between juveniles from the six rivers and during the fertilization period.

Kishi, D. and T. Tokuhara. 2019. Distribution of anadromous red-spotted masu salmon *Oncorhynchus masou ishikawae* from 1927 to 1931 evaluated from data published in “River Fishery” by the Fisheries Agency, Ministry of Agriculture and Forestry, Japan. *Japan. J. Ichthyol.* 66: 187–194 (In Japanese with English abstract). DOI: <https://doi.org/10.11369/jji.19-011>

Distribution of the anadromous red-spotted masu salmon, *Oncorhynchus masou ishikawae* in Japan was evaluated from data published in “River Fishery, vol. 1–6” between 1930 and 1934 and in 1937 by the Fisheries Agency, Ministry of Agriculture and Forestry, Japan. Catches of salmon were recorded in 26 rivers from Shizuoka to Yamaguchi Prefecture on Honshu Island and 5 rivers in Tokushima and Kochi Prefectures on Shikoku Island, but no distribution was indicated in rivers in Fukuoka and Oita Prefectures on Kyushu Island between 1927 and 1931. The best-fitted model of Generalized Linear Model indicated that both of latitude and river length had significant positive effects on the presence of salmon. Salmon is possibly distributed only in large rivers, particularly in the southern region. Probability of distribution of salmon as correct classification in 64 rivers and misclassification in 15 rivers including the Shimanto River in southwestern Shikoku Island were calculated from the best-fitted model. Catch of salmon was not recorded in data published by the Fisheries Agency, but that published in 1912 by the local government in Hata, Kochi Prefecture, and our analysis indicated salmon presence in the Shimanto River. Although the Nahari River (the river mouth, 33° 25' 21" N, 134° 0' 42" E) in southeastern Shikoku Island had been shown to be the southern limit in data published by the Fisheries Agency, we suggested the Shimanto River (32° 55' 58" N, 132° 59' 39" E) the southernmost limit. In this study, we reveal previous distribution of the anadromous red-spotted masu salmon in 26 rivers in Honshu Island and 6 rivers including the Shimanto River, in Shikoku Island in Japan.

Kusakabe, M., S. Nobata, K. Saito, K. Ikeba, S. Ogasawara, K. Tanaka, Y. Takei, and S. Hyodo. 2019. Body condition and reproductive status of chum salmon during homing migration in Otsuchi Bay, Japan, after the 2011 Great East Japan Earthquake and Tsunami. *Fish. Sci.* 85: 43–51. DOI: <https://doi.org/10.1007/s12562-018-1255-9>

To understand how the earthquake and tsunami on March 11 2011 affected homing chum salmon *Oncorhynchus keta* in Otsuchi Bay, Japan, we monitored the body condition and reproductive status at the mouth of the bay in October, November, December, and January from 2012 to 2016. The average fork length in 2014 was larger than that in 2012 and 2015, due to the high proportion of 5- and 6-year-old salmon and the low proportion of 3- and 4-year-old salmon, possibly because of the decrease in the salmon fry released by the hatchery program after the disaster. Plasma estradiol-17 (E2) concentrations in females were high in October and November and declined in December and January, whereas plasma 11-ketotestosterone concentrations in males were consistently high throughout the sampling period. Plasma 17,20-dihydroxy-pregnen-3-one (17,20-P) increased in both sexes in December and/or January. These changes were consistently observed from 2012 to 2016; however, the rise in 17,20-P and decline in E2 levels in female salmon in December were conspicuous in 2013 and 2014, reflecting changes in age composition. These results suggest that the earthquake and tsunami temporarily affected the age composition and the physiological condition of chum salmon returning to Otsuchi Bay.

Kuwahara, M. 2019. Possibility of coexistence of Biwa salmon and amago in Lake Biwa water system. *Fish Genet. Breed. Sci.* 49: 1-5 (In Japanese).

Kuwahara, M., H. Takahashi, T. Kikko, S. Kurumi, and K. Iguchi. 2019. Trace of outbreeding between Biwa salmon (*Oncorhynchus masou* subsp.) and amago (*O. m. ishikawae*) detected from the upper reaches of inlet streams within Lake Biwa water system, Japan. *Ichthyol. Res.* 66: 67–78. DOI: <https://doi.org/10.1007/s10228-018-0650-7>

The establishment of fluvial fish populations from anadromous populations by natural or artificial barriers obstructing migration is a good research subject to study life history plasticity. Biwa salmon, *Oncorhynchus masou* subsp., a salmonid fish endemic to the Lake Biwa water system, exhibit life history variation (e.g., mature stream-resident males) in addition to a typical lacustrine life history type, indicating potential adaptations of life histories in response to emergence of barriers. Currently, fluvial populations that are morphologically similar to both stream-resident Biwa salmon and amago, the fluvial red-spotted masu salmon, *Oncorhynchus masou ishikawae*, are found upstream of dams which were constructed in the inflowing rivers of Lake Biwa. However, it is unknown whether they are Biwa salmon or amago. To explore that, the genetic characteristics of nine fluvial populations were investigated through AFLP and mtDNA analyses. Bayesian admixture analysis based on the AFLP data revealed that three fluvial populations were admixed populations between Biwa salmon and amago. In addition, a Biwa salmon mtDNA haplotype was detected in some individuals from three populations. However, no genetically pure fluvial populations of Biwa salmon were found, indicating no life history plasticity in this subspecies, and thus hybridization with amago boosted the ability of this subspecies to establish fluvial populations. Nevertheless, other scenarios, such as hybridization after establishment of fluvial populations of Biwa salmon, are also possible. The latter hypothesis could be supported by the fact that amago did not inhabit the river before emergence of barriers. However, a significant genetic population structure was found only in amago, suggesting that this subspecies is native to the Lake Biwa water system. But the possibility that multiple sources of amago have been released into rivers cannot be excluded. Therefore, further studies on the relationships between amago populations in the upper reaches of the Lake Biwa water system and other populations in the surrounding areas of the Lake Biwa water system are needed to clarify the origins of the admixed populations.

Machida, Y., A. Yamamoto, Y. B. Akiyama, K. Nomoto, M. Kanaiwa, T. Jinbo, H. Iwase and K. Hashimoto. 2019. Did multiple handmade fishways contribute to salmonid fish habitat recovery? *Ecol. Civil Eng.* 21: 181–189 (In Japanese with English abstract). DOI: <https://doi.org/10.3825/ece.21.181>

Effects of multiple fishways made by citizens on the fish community and the redds were examined in the Komaioi River of the Abashiri River system in eastern Hokkaido. Before installing fishways, in the river section above artificial drop structures any salmonid fish nor any redd were found but *Cottus nozawae* and *Lethenteron* sp. were present. After having installed seven handmade fishways in 2012, fish of *Salvelinus leucomaenis* and *Oncorhynchus masou masou* and their redds were observed at the river section. On a quantitative investigation at the river section in 2013 *O. m. masou* was the only collected salmonid species. In 2017 *O. m. masou* and *S. leucomaenis* were collected. Meanwhile, the number of *C. nozawae* seems to be decreased after fishway installations. These results clearly show that multiple handmade fishways installed to the Komaioi River enable the upstream migration of salmonid fish to above artificial drop

structures. However, due to river bank protection at the middlestream region, it might cause the delay in the population recovery of a sedentary fish.

Minegishi, Y. and J. Aoyama. 2019. Reconstruction of the bioresource values of chum salmon in the Sanriku region. *Japan. J. Ecol.* 69: 201–207 (In Japanese). DOI: https://doi.org/10.18960/seitai.69.3_201

Minegishi, Y., T. Kawakami, and J. Aoyama. 2019. Current status of chum salmon populations in the rivers with and without hatchery stock enhancement on the Sanriku coast, Japan. *N. Pac. Anadr. Fish Comm. Tech. Rep.* 15: 23–24 (Available at <https://npafc.org>).

Miyamoto, K., and H. Araki. 2019. Effects of water depth and structural complexity on survival and settlement of white-spotted charr (*Salvelinus leucomaenis*). *Hydrobiologia* 840: 103–112. DOI: <https://doi.org/10.1007/s10750-019-3887-x>

Both climate change and dam operations are affecting water levels in river systems worldwide and their influence can be especially drastic in upper streams, where juvenile salmonids hatch and grow. However, efficient means of mitigating such influence on salmonid populations have not been developed, at least not in a practical manner throughout the world. In this study, we investigated effects of declining water levels and structural complexity on populations of age-0 white-spotted charr (*Salvelinus leucomaenis*) in tank and pond experiments. Survival of the charr was lower in the shallow tanks (15 cm water depth) than in the deeper ones. Similarly, more fish survived in the tanks with artificial structures (cobble with Ringlong tape) compared to those without them. The grey heron (*Ardea cinerea*) was the most frequently observed predator during the tank experiment, and settlement of fish in the shallow ponds increased when artificial structures were provided. These results suggest that declining water levels and the loss of structural complexity may lead to a decrease in populations of white-spotted charr by increasing predation risk and interference competition.

Mizuno, S., S. Urawa, M. Miyamoto, M. Hatakeyama, N. Koide, and H. Ueda. 2019. Experimental evidence on prevention of infection by the ectoparasitic protozoans *Ichthyobodo salmonis* and *Trichodina truttae* in juvenile chum salmon using ultraviolet disinfection of rearing water. *J. Fish Dis.* 42: 129–140. DOI: <https://doi.org/10.1111/jfd.12920>

In northern Japan, juvenile chum salmon *Oncorhynchus keta* (Walbaum) are released from hatcheries to enhance the fishery resource. Infections with ectoparasitic protozoans, particularly the flagellate *Ichthyobodo salmonis* and the ciliate *Trichodina truttae*, occasionally cause severe mortality among hatchery-reared juveniles. This study examined the susceptibility of the two parasites to wide-ranging UV irradiation (experiment 1) and then investigated whether UV disinfection of the rearing water using a commercial device was useful for preventing infections among juveniles in a small-scale rearing system over a 28-day period (experiment 2). In experiment 1, parasite mortality reached 100% with UV irradiation doses of $\geq 9.60 \times 10^5 \mu\text{W s/cm}^2$ for *I. salmonis* and $\geq 8.40 \times 10^5 \mu\text{W s/cm}^2$ for *T. truttae*. In experiment 2, disinfection of the rearing water at a UV irradiation dose of $2.2 \times 10^6 \mu\text{W s/cm}^2$ succeeded in complete prevention of both parasites in the juvenile salmon. These results elucidate the minimum dose of UV irradiation for inactivation of *I. salmonis* and *T. truttae*, and demonstrate the usefulness of

water disinfection using a commercial UV irradiation device to prevent infections by these parasites in hatchery-reared juvenile chum salmon.

Morita, K. 2019. Earlier migration timing of salmonids: an adaptation to climate change or maladaptation to the fishery? *Can. J. Fish. Aquat. Sci.* 76: 475–479. DOI: <https://doi.org/10.1139/cjfas-2018-0078>

Recent studies reporting shifts in the timing of salmonid migrations have suggested global warming to be a cause. However, the specific mechanisms underlining the evolution of earlier migration timing in salmonid fishes are unknown. In this paper, I present a hypothesis by which fishery-induced selection works to advance the timing of salmonid migration, given that the timings of migration and breeding are genetically controlled heritable traits. Although late-spawning salmon brood lines enter rivers after early-spawning brood lines, there is evidence that all brood lines arrive in coastal fishing grounds at similar times. As such, late-spawning brood lines would be fished for longer periods of time, with their increased harvest rate imposing directional selection on earlier-spawning brood lines. Thus, fisheries-induced evolution could favor the earlier timing of river entry to escape coastal fisheries. Should earlier migration timing not be an adaptation to global warming—should it be a maladaptation to fisheries-induced selection instead—then it will have a negative impact on the sustainability of salmonid resources.

Morita, K. 2019. Trout and char of Japan. In *Trout and Char of the World* (Eds. Kershner, J. L., J. E. Williams, R. E. Gresswell, and J. Lobon-Cervia). 487–515p.

Morita, K., H. Fukuzawa and K. Suzuki. 2019. Comparison of fry-to-adult survival rates between wild and hatchery chum salmon in the Chitose River, Hokkaido, Japan. *J. Fish. Tech.* 11: 9–14 (In Japanese with English abstract).

Chum salmon stock enhancement that incorporates natural reproduction is required in Japan; for that purpose, it is necessary to accumulate information on the efficiency of natural reproduction. We estimated the fry-to-adult survival rates of wild and hatchery chum salmon in the Chitose River, Hokkaido, Japan, where the otoliths of all hatchery-released fry were thermally marked. The production of outmigrating wild fry was estimated by employing a rotary screw trap to determine the ratio of otolith thermally marked hatchery fish to non-marked wild fish, multiplied by the total number of hatchery-released fry. The numbers of returning wild and hatchery origin adults were estimated at the weir by identifying the ratio of the otolith thermally marked hatchery fish to the non-marked wild fish. The fry-to-adult survival rates (2006 and 2008–2011 brood years) of the wild fish were estimated as 0.22%–0.86%, whereas those of hatchery fish were estimated as 0.17%–1.29%. Even though the average body sizes of wild fry were significantly smaller than those of hatchery-released fry, and the wild fry outmigrated significantly later than the hatchery-released fry, the fry-to-adult survival rates did not differ significantly between fish of natural and hatchery origin.

Muhlfeld, C. C., D. C. Dauwalter, V. S. D'Angelo, A. Ferguson, J. J. Giersch, D. Impson, I. Koizumi, R. Kovach, P. McGinnity, and J. Schoffmann. 2019. Global status of trout and char: Conservation challenges in the twenty-first century. In *Trout and Char of the World* (Eds. Kershner, J. L., J. E. Williams, R. E. Gresswell, and J. Lobon-Cervia). 717–760p.

Nakamura, S., N. Kaneko, T. Nonaka, D. Kurita, Y. Miyakoshi, and M. Shimizu. 2019. Fasting in freshwater severely affects growth of juvenile chum salmon when entering cold seawater. *Fish. Sci.* 85: 655–665. DOI: <http://doi-org-443.webvpn.fjmu.edu.cn/10.1007/s12562-019-01313-3>

We conducted rearing experiments to examine the cumulative effects of fasting in freshwater and transfer to cold seawater on the growth of juvenile chum salmon. In the first experiment in May 2016, juvenile fish were either fed or fasted in freshwater for 5 days and acclimatized to seawater of either optimal (10 °C) or cold (5 °C) temperature for 10 days with feeding. Despite resumed feeding, fish that were fasted in freshwater and transferred to cold seawater showed the poorest growth. Serum levels of insulin-like growth factor (IGF)-I, a positive indicator of growth, were also the lowest in this group, suggesting a synergistic negative effect of fasting in freshwater and transfer to cold seawater on growth in chum salmon. A similar experiment in May 2017 suggested that the depressed growth and serum IGF-I in cold seawater might be due to the predominant allocation of energy to liver glycogen. On the one hand, serum levels of IGF-binding protein-1b, a negative indicator of growth, were not affected by seawater temperature but by fasting in seawater. The present study shows that relatively short-termed fasting in freshwater critically affects growth of juvenile chum salmon transferred to cold seawater.

Sato, S. and K. Morita. 2019. Genetic uniqueness of wild chum salmon populations in Hokkaido, Japan. *Japan. J. Ecol.* 69: 209–217 (In Japanese). DOI: https://doi.org/10.18960/seitai.69.3_209

Saneyoshi, H., Y. Koshino, R. Ishida, I. Tatsuoka, H. Shirakawa, Y. Miyakoshi, and K. Miyashita. 2019. Migration and homing behavior of chum salmon tagged in the Okhotsk Sea, eastern Hokkaido. *N. Pac. Anadr. Fish Comm. Tech. Rep.* 15: 63–64 (Available at <https://npafc.org>).

Shimoda, K., H. Urabe, and H. Kawamura. 2019. Recovery process of masu salmon stock after the construction of fish ways. *Nippon Suisan Gakkaishi* 85: 305–313 (In Japanese with English abstract). DOI: <https://doi.org/10.2331/suisan.18-00054>

To evaluate the population recovery of masu salmon *Oncorhynchus masou* by fish ways, we investigated the number and distribution of spawning redds, population density and body size of juveniles for a total of 10 years before and after the construction of fish ways in the Shirai River, Hokkaido, Japan. Before the fish ways were constructed, most juveniles were distributed in the lowermost reach of the river. The population density of juveniles was high and their growth rate was low. After the fish ways were constructed, the distribution of spawning redds expanded into the upper reaches of the river, while in the lower reaches the population density of juveniles reduced and their growth rate increased. After construction, the number or size of potential smolts increased. The total number of spawning redds of the third generation after construction was 2.8 times as many as that of the first generation. We supposed that expansion of the spawning area and habitat of juveniles by constructing fish ways might lead to an increase of the number or size of potential smolts and an increase of the number of ascending adults and spawning redds.

Shimoda, K., T. Watanabe and D. Ando. 2019. Differences in early squamation of chum salmon *Oncorhynchus keta* juveniles among river populations in seasonally spawning stocks. *Sci. Rep. Hokkaido Fish. Res. Inst.* 96: 17–26 (In Japanese with English abstract).

Body size and period of early squamation in chum salmon juveniles *Oncorhynchus keta* were examined. The difference in squamation process between early- and late-run stocks (fertilized from late September to early October and from middle November to early December, respectively) were compared with juvenile fish from six rivers (Abashiri R., Shibetsu R., Tokachi R., Chitose R., Shizunai R. and Torisaki R.) in Hokkaido, Japan. The delay of early squamation was observed in the rivers where emerging juveniles were shown to have short fork length. The early squamation of late-run stocks was faster than that of early-run stocks in three rivers based on results comparing the period of fertilization. The fork length of juveniles at the first squamation day were observed to be significantly by the analysis of two-way ANOVA depending on the period of fertilization and populations in the rivers. These results suggest that the period of early squamation in chum salmon juveniles could be determined based on the body size at emergence and at the first squamation day. Body sizes can explain the differences in early squamation period between juveniles from the six rivers and during the fertilization period.

Susa, K., T. Ozeki, T. Sato and Y. Hoshino. 2019. Summering habitat of returning adult masu salmon *Oncorhynchus masou* in the Jinzu River: use of pools created by a habitat rehabilitation project. *Ecol. Civil Eng.* 22: 61–71 (In Japanese). DOI: <https://doi.org/10.3825/ece.22.61>

Tamate, T., K. Ohmoto, K. Sasaki and M. Yatsuya. 2019. Density and body size of wild chum salmon *Oncorhynchus keta* fry in the lower reaches of a small stream on the Sanriku coast, northern Honshu, Japan. *Japan. J. Ichthyol.* 66: 211–216 (In Japanese with English abstract). DOI: <https://doi.org/10.11369/jji.18-033>

The density and body size of wild chum salmon *Oncorhynchus keta* fry were surveyed in spring each year from 2012–2015 inclusive, immediately above the mouth of the Otobe River, a small stream on the Sanriku coast, northern Honshu Island. In each survey year, fry density peaked in late April or early May, typically exhibiting a sharp decrease afterwards. Mean fork length generally ranged between 42–47 mm, the observed minimum and maximum lengths during the survey being 34 mm and 83 mm, respectively.

Ueda, H. 2019. Sensory mechanisms of natal stream imprinting and homing in *Oncorhynchus* spp. *J. Fish Biol.* 95: 293–303. DOI: <https://doi.org/10.1111/jfb.13775>

Juvenile *Oncorhynchus* spp. can memorise their natal stream during downstream migration; juveniles migrate to feed during their growth phase and then they migrate long distances from their feeding habitat to their natal stream to reproduce as adults. Two different sensory mechanisms, olfaction and navigation, are involved in the imprinting and homing processes during short-distance migration within the natal stream and long-distance migration in open water, respectively. Here, olfactory functions are reviewed from both neurophysiological studies on the olfactory discrimination ability of natal stream odours and neuroendocrinological studies on the hormonal controlling mechanisms of olfactory memory formation and retrieval in the brain. These studies revealed that the long-term stability of dissolved free amino-acid composition in the natal stream is crucial for olfactory imprinting and homing. Additionally, the

brain-pituitary-thyroid and brain-pituitary-gonadal hormones play important roles in olfactory memory formation and retrieval, respectively. Navigation functions were reviewed from physiological biotelemetry techniques with sensory interference experiments during the homing migration of anadromous and lacustrine *Oncorhynchus* spp. The experiments demonstrated that *Oncorhynchus* spp. used compass navigation mechanisms in the open water. These findings are discussed in relation to the sensory mechanisms involved in natal stream imprinting and homing in *Oncorhynchus* spp.

Watz, J., Y. Otsuki, K. Nagatsuka, K. Hasegawa, and I. Koizumi. 2019. Temperature-dependent competition between juvenile salmonids in small streams. *Freshw. Biol.* 64: 1534–1541. DOI: <https://doi.org/10.1111/fwb.13325>

1. Biotic interactions affect species distributions, and environmental factors that influence these interactions can play a key role when range shifts in response to environmental change are modelled.
2. In a field experiment using enclosures, we studied the effects of the thermal habitat on intra- versus inter-specific competition of juvenile Dolly Varden *Salvelinus malma* and white-spotted charr *Salvelinus leucomaenis*, as measured by differences in specific growth rates during summer in allopatric and sympatric treatments. Previous laboratory experiments have shown mixed results regarding the importance of temperature-dependent competitive abilities as a main driver for spatial segregation in stream fishes, and no study so far has confirmed its existence in natural streams.
3. Under natural conditions in areas where the two species occur in sympatry, Dolly Varden dominate spring-fed tributaries (cold, stable thermal regime), whereas both species often coexist in non-spring-fed tributaries (warm, unstable thermal regime). Enclosures (charr density = 6 per m²) were placed in non-spring-fed (10-14 °C) and spring-fed (7-8 °C) tributaries.
4. In enclosures placed in non-spring-fed tributaries, Dolly Varden grew 0.81% per day in allopatry and had negative growth (-0.33% per day) in sympatry, whereas growth rates were similar in allopatry and sympatry in spring-fed tributaries (0.68 and 0.58% per day). White-spotted charr grew better in sympatry than in allopatry in both thermal habitats. In non-spring-fed tributaries, they grew 0.17 and 0.79% per day and in spring-fed tributaries 0.46 and 0.75% per day in allopatry and sympatry, respectively.
5. The negative effect of inter-specific competition from white-spotted charr on Dolly Varden thus depended on the thermal habitat. However, there was no strong evidence of a temperature-dependent effect of intra- and inter-specific competition on white-spotted charr growth.
6. Multiple factors may shape species distribution patterns, and we show that temperature may mediate competitive outcomes and thus coexistence in stream fish. These effects of temperature will be important to incorporate into mechanistic and dynamic species distribution models.

Wong, M. K. S., S. Nobata, and S. Hyodo. 2019. Enhanced osmoregulatory ability marks the smoltification period in developing chum salmon (*Oncorhynchus keta*). *Comp. Biochem. Physiol. A-Mol. Integr. Physiol.* 238: 110565. DOI: <https://doi.org/10.1016/j.cbpa.2019.110565>

The freshwater (FW) life of chum salmon is short, as they migrate to the ocean soon after emergence from the substrate gravel of natal waters. The alevins achieve seawater (SW)

acclimating ability at an early developmental stage and the details of smoltification are not clear. We examined the stage-dependent SW acclimating ability in chum salmon alevins and found a sharp increase in SW tolerance during development that resembles the physiological parr-smolt transformation seen in other salmonids. Perturbation of plasma Na^+ after SW exposure was prominent from the hatched embryo stage to emerged alevins, but the plasma Na^+ became highly stable and more resistant to perturbation soon after complete absorption of yolk. Marker gene expression for SW-ionocytes including Na/K-ATPase (NKA α 1b), Na-K-Cl cotransporter 1a (NKCC1a), Na/H exchanger 3a (NHE3a), cystic fibrosis transmembrane conductance regulators (CFTR I and CFTR II) were all upregulated profoundly at the same stage when the alevins were challenged by SW, suggesting that the stability of plasma Na^+ concentration was partly a result of elevated osmoregulatory capability. FW-ionocyte markers including NKA α 1a and NHE3b were consistently downregulated independent of stage by SW exposure, suggesting that embryos at all stages respond to salinity challenge, but the increase in SW osmoregulatory capability is restricted to the developmental stage after emergence. We propose that the "smoltification period" is condensed and integrated into the early development of chum salmon, and our results can be extrapolated to the future studies on hormonal controls and developmental triggers for smoltification in salmonids.

Yamamoto, S., K. Morita, and G. Sahashi. 2019. Spatial and temporal changes in genetic structure and diversity of isolated white-spotted charr (*Salvelinus leucomaenis*) populations. *Hydrobiologia* 840: 35–48. DOI: <https://doi.org/10.1007/s10750-019-3924-9>

In Japan, numerous artificial dams constructed for erosion control or hydroelectric power generation have affected almost all rivers and resulted in isolation and fragmentation of many freshwater fish populations. We examined genetic structure and diversity of two temporally isolated samples (spanning 15 years) from 23 white-spotted charr (*Salvelinus leucomaenis*) populations, including above- and below-dam populations, on Hokkaido Island. We used microsatellite DNA markers to elucidate how habitat fragmentation by damming can spatiotemporally alter population genetic structure. An isolation-by-distance genetic structure was found for anadromous populations on Hokkaido Island, which indicates substantial gene flow among populations. After habitat fragmentation by damming, isolated populations were indiscriminately subjected to genetic differentiation from anadromous (below-dam) populations within river systems, and to the subsequent loss of genetic diversity. Effective population sizes of isolated populations were less than 50. We found that substantial decreases in heterozygosity and allelic richness occurred in some isolated white-spotted charr populations over 15 years. This study shows that habitat fragmentation by damming induces significant spatial changes in population genetic structure and genetic diversity within river systems. Our findings also provide an important implication that most isolated white-spotted charr populations will continuously lose genetic diversity in the future.

Theme 2. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean

Azumaya, T., and S. Urawa. 2019. Long-term shifts of chum salmon (*Oncorhynchus keta*) distribution in the North Pacific and the Arctic Ocean in summer 1982–2017. *N. Pac. Anadr. Fish Comm. Tech. Rep.* 15: 132-133 (Available at <https://npafc.org>).

Beacham, T. D., C. Wallace, and S. Sato. 2019. Microsatellite identification of sockeye salmon rearing in the south central Bering Sea during summer 2018. *NPAFC Doc. 1827*. 12 pp. Fisheries and Oceans Canada, Pacific Biological Station, and Hokkaido National Fisheries Research Institute, Japan Fisheries Research and Education Agency (Available at <https://npafc.org>).

Stock composition of sockeye salmon (*Oncorhynchus nerka*) caught in the southern central Bering Sea during a Japanese research cruise in the summer of 2018 was estimated through an analysis of microsatellite variation. Variation at 14 microsatellites was analyzed for immature sockeye salmon, and a 415-population baseline spanning Japan, Russia, Alaska, Canada, and Washington State was used to determine the stock composition of the fish sampled. Alaskan-origin sockeye salmon were the most abundant in the catch of immature individuals, comprising 71.5% of all sockeye salmon caught, with the catch dominated by sockeye salmon of Bristol Bay origin (67.5%). Russian-origin sockeye salmon accounted for 26.3% of the catch, while Canadian-origin salmon accounted for an average of 2.1% of the catch, with 388 individuals of the catch genotyped.

Hirakawa, K., T. Kaga, T. Sato and H. Kasai. 2019. Regional characteristics of zooplankton as food for juvenile chum salmon *Oncorhynchus keta* in the coastal waters around Hokkaido, with special reference to copepod community structure. *Bull. Plankton Soc. Japan* 66: 72–85 (In Japanese with English abstract). DOI: https://doi.org/10.24763/bpsj.66.2_72

We investigated regional differences of zooplankton—especially the community structure of copepods—as an important food for juvenile chum salmon (*Oncorhynchus keta*) in the coastal waters around Hokkaido, using multivariate statistical techniques. Zooplankton samples were collected by vertical hauls from 20 m depth or, at shallower stations, from near-bottom to the surface using a Norpac net (mesh opening: 0.33 mm) at four sampling sites (regions); Atsuta (JS: Hokkaido Sea of Japan), Shari (OH: Okhotsk), Shiraoi (WP: West Hokkaido Pacific) and Konbumori (EP: East Hokkaido Pacific) in spring and summer 2007. Copepod community structure was classified into three clusters ($F_{2,121}=65.8$, $p<0.001$) that contained significantly different indicator species compositions: Cluster 1, “cold water–neritic/oceanic group,” was characterized by *Neocalanus plumchrus*, *Eucalanus bungii*, *Acartia tumida*, *Pseudocalanus minutus*, *Pseudocalanus newmani*, *Calanus glacialis* and *Neocalanus flemingeri*. Cluster 2, “cold/warm water–neritic/oceanic group,” was characterized by *Mesocalanus tenuicornis*, *Oithona atlantica*, *Tortanus discaudatus*, *Paracalanus* sp., *Clausocalanus pergens*, *Metridia pacifica* and *Corycaeus affinis*. Cluster 3, “cold water–neritic group,” was characterized by *Acartia longiremis*, *Centropages abdominalis* and *Eurytemora herdmani*. Food conditions of juvenile chum salmon were better in Cluster 1 (“cold water–neritic/oceanic group”) than in the other groups. Cluster 1 copepods had a greater mean copepod abundance ($F_{2,121}=12.11$, $p<0.001$)

and were represented by large, lipid-rich *N. plumchrus*. Furthermore, while copepods in Cluster 2 had small-medium bodies, their mean abundance was substantially lower than that of Cluster 1. Similarly, the relatively abundant Cluster 3 copepods were much smaller in size than those of Cluster 1, which resulted in less available biomass for juvenile chum salmon. Comparing relationships between the spatiotemporal distributions of three clusters and hydrographic conditions (surface temperature and water mass structure) at each site, feeding conditions of juvenile salmon may be regionally evaluated as follows: favorable in EP (mostly Cluster 1 in Konbumori), unfavorable in JS (exclusively Cluster 2 in Atsuta) and seasonally variable in OH/WP (a mixture of three clusters in Shari/Shiraoi). For Japanese juvenile chum salmon migrating eastwards into the Sea of Okhotsk along the Pacific coast of Hokkaido, summer coastal environmental conditions off Konbumori (EP) on their assumed migration route may play an important role in improving feeding conditions for their growth, which have deteriorated because of changes in the copepod community structure (that is, from “cold water–neritic/oceanic group” to “cold water–neritic group”), the early disappearance of *N. plumchrus* and higher surface temperatures (>13°C) in Shiraoi (WP).

Honda, K., T. Kawakami, T. Saito, and S. Urawa. 2019. First report of growth rate of juvenile chum salmon *Oncorhynchus keta* captured in the Sea of Okhotsk offshore. *Ichthyol. Res.* 66: 155–159. DOI: <https://doi.org/10.1007/s10228-018-0643-6>

The growth rate of 16 juvenile chum salmon *Oncorhynchus keta* (180–286mm fork length) captured in the Sea of Okhotsk offshore during autumn 2002 was estimated using daily-incremental analysis of otoliths. The specimens originated from Hokkaido, Japan, and Sakhalin and Kamchatka, Russia. The average (range) of estimated mean daily growth in fork length was 1.19 (1.02–1.54) mm/day through the entire early ocean life and 1.05 (0.84–1.21) mm/day during the first 30 days after sea entry. These growth rates were higher than those reported previously for coastal resident or migrant juvenile chum salmon along the coast of Japan.

Honda, K., T. Sato, S. Ueda, Y. Matsunami, T. Abe, I. Tatsuoka, S. Sato, and K. Suzuki. 2019. The summer 2018 Japanese salmon research cruise of the R/V *Hokko maru*. *NPAFC Doc. 1825*. 17 pp. Hokkaido National Fisheries Research Institute, Japan Fisheries Research and Education Agency, University of Tokyo, and Hokkaido University (Available at <https://npafc.org>).

A summer high-seas research cruise to investigate the biology of Pacific salmon was conducted from 23 July to 3 August 2018 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. A total of 2,448 salmonids were caught by surface trawls (excluding a failed station) and hook-and-line at 17 monitoring stations and adjacent waters. Among those caught by trawls, chum salmon was the most abundant species (n = 1,930, 80.6%), followed by sockeye salmon (n = 403, 16.8%), Chinook salmon (n = 36, 1.50%), pink salmon (n = 20, 0.84%), and coho salmon (n = 6, 0.25%). 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, and seawater samples were obtained for the future study. A total of 36 chum salmon were tagged with archival and disk tags and were released in the Bering Sea. Age-specific catch per unit effort by surface trawl and annual mean

body weight of each ocean age of chum salmon during 2007–2018 are documented here.

Kaeriyama, M. 2019. Sustainable conservation and use of chum salmon under warming climate and changing ocean conditions. *N. Pac. Anadr. Fish Comm. Tech. Rep.* 15: 109–112 (Available at <https://npafc.org>).

Sato T., Y. Inagaki, K. Sakaoka, K. Imai, M. Ohwada, K. Oguma, K. Sawada, and S. Takagi. 2019. Results of 2018 salmon research by the *Oshoro maru*. *NPAFC Doc. 1820*. 11 pp. T/V *Oshoro maru*, Graduate School of Fisheries Sciences and Faculty of Fisheries, Hokkaido University (Available at <https://npafc.org>).

In order to accumulate oceanographic and biological data (including salmonids) and to clarify the oceanic structure and marine ecosystem, T/V *Oshoro maru* conducted oceanographic observations and fishing surveys in the western North Pacific (along with the 155°E longitude line) and the Bering Sea. The survey was conducted during the cruise #054 in May, and cruise #056-Leg1 in June 2018. Oceanographic observations and drift gillnet surveys were conducted along the 155°E during the cruise #054. Due to the unfavorable weather, only one drift gillnet survey was conducted, and no observation or survey was made from 41°45'N southward throughout the cruise this year. A total of 357 salmonids was caught by gillnet survey, including 355 pink, 2 chum salmon. Other species such as steelhead and sockeye salmon were not caught during the cruise#054. The fork lengths (F.L.) of pink salmon collected by C-gear gillnet were all adult fish ranging between 318–406 mm. To collect salmon samples including fresh salmon blood, otoliths, and various tissues extensively three hook-and-line gear samplings were conducted during the Cruise #056-Leg1 as well as the cruise #054. The predominant species caught by hook-and-line gear samplings during the cruise #056-Leg-1 were pink salmon (84 pink, 74 sockeye, 60 chum).

Yamada, Y., K. Sasaki, K. Yamane, M. Yatsuya, Y. Shimizu, Y. Nagakura, T. Kurokawa, and H. Nikaido, H. 2019. The utilization of cold-water zooplankton as prey for chum salmon fry (*Oncorhynchus keta*) in Yamada Bay, Iwate, Pacific coast of northern Japan. *Reg. Stud. Mar. Sci.* 29: 100633. DOI: <https://doi.org/10.1016/j.rsma.2019.100633>

The food availability of chum salmon fry is one of the principal factors affecting survival in their coastal residence period. The aim of this study was to better understand the quality and quantity of available food resources and the feeding habits of salmon fry in nearshore waters. We examined stomach contents of salmon fry and the zooplankton community structure of the water column during salmon fry's coastal residence period (April and May) over four years in Yamada Bay, a coastal embayment of the Pacific Ocean in northern Japan. The mean water temperatures during study period were low in 2014 and 2013 (6.7 and 8.3°C, respectively), and high in 2016 and 2015 (11.1 and 9.4°C, respectively). *Neocalanus plumchrus* and *Themisto japonica*, typical cold-water zooplankton dominated the stomach contents of chum fry (except for 2016), however, they were not necessarily the most dominant in the water column, suggesting that chum fry selectively preyed upon these cold-water zooplankters. On the other hand, chum fry preyed primarily on decapod larvae in 2016 the warmest water year. Condition factor of chum fry were higher in cold-water years than those of warm-water years. Because these two cold-water zooplankton species are typically abundant in the Oyashio Current, the magnitude of Oyashio inflow may affect prey availability for chum salmon fry and their nutritional status. The relationship between the food environment at the coastal residence period of chum fry and the adult return rate after three years was also discussed.

Theme 3: New Technologies

Abe, T., and H. Kudo. 2019. Molecular characterization and gene expression of syntaxin-1 and VAMP2 in the olfactory organ and brain during both seaward and homeward migrations of chum salmon, *Oncorhynchus keta*. *Comp. Biochem. Physiol. A-Mol. Integr. Physiol.* 227: 39–50. DOI: <https://doi.org/10.1016/j.cbpa.2018.09.008>

Anadromous Pacific salmon (Genus *Oncorhynchus*) imprint odorants from their natal streams during their seaward migration, and adult salmon use olfaction to identify their natal streams during their homeward migration. However, little is known about the molecular mechanisms of olfactory imprinting in the salmon nervous system. Our previous study suggested that the snap25s gene (encoding a soluble N-ethylmaleimide-sensitive factor attachment protein receptor [SNARE] protein) is involved in pre-synaptic functions for olfactory imprinting and/or olfactory memory retrieval in chum salmon (*O. keta*). In this study, the expression of other SNARE proteins was analyzed in chum salmon brains. Three cDNAs, encoding salmon SNARE proteins (STX-1a, STX-1b, and VAMP2), were isolated and sequenced, which are well-conserved among vertebrates. Quantitative PCR detected the expression of stx1s and vamp2 in all regions of the brain, and especially highly in the olfactory bulb (OB) and telencephalon. The expression levels of snares in the olfactory rosette (OR) were higher during seaward migration than in adult life stages, subsequently vamp2 in the OB and telencephalon increased during seaward migration, corresponding well with development of the olfactory nervous system. Both stx1s in the OB and stx1b in the telencephalon were elevated in the seaward period, whereas stria in the telencephalon increased continuously until the feeding period. Both stx1s in the telencephalon increased in the last phase of upriver migration, possibly related to the retrieval of imprinted memory. Our results indicated the involvement and distinct roles of upregulated snares in synaptic plasticity for olfactory imprinting and/or olfactory memory retrieval in Pacific salmon.

Abe, T. K., T. Kitagawa, Y. Makiguchi, and K. Sato. 2019. Chum salmon migrating upriver adjust to environmental temperatures through metabolic compensation. *J. Exp. Biol.* 222: jeb 186189. DOI:10.1242/jeb.186189

Ectotherms adjust their thermal performance to various thermal ranges by altering their metabolic rates. These metabolic adjustments involve plastic and/or genetic traits and pathways depend on species-specific ecological contexts. Chum salmon (*Oncorhynchus keta*) are ecologically unique among the Pacific salmonids as early-run and late-run populations are commonly observed in every part of their range. In the Sanriku coastal area, Japan, early-run adults experience high water temperatures (12–24°C) during their migration, compared with those of the late-run adults (4–15°C), suggesting that the two populations might have different thermal performance. Here, we found population-specific differences in the thermal sensitivities of metabolic rates [resting metabolic rate, RMR, and maximum (aerobic) metabolic rate, MMR] and critical temperature maxima. Using these parameters, we estimated thermal performance curves of absolute aerobic scope (AAS). The populations had different thermal performance curves of AAS, and in both populations high values of AAS were maintained throughout the range of ecologically relevant temperatures. However, the populations did not vary substantially in the peak (MS at optimal temperature, T_{optAAS}) or breadth (width of sub-optimal temperature range) of the performance curves. The MS curve of early-run fish was shifted approximately 3°C higher than that of late-run fish. Furthermore, when the data for RMR and MMR were aligned to the

thermal differences from T_{optAAS} , it became clear that the populations did not differ in the temperature dependence of their metabolic traits. Our results indicate that chum salmon thermally accommodate through compensatory alterations in metabolic rates. Our results imply that metabolic plasticity and/or the effect of genetic variance on plasticity might play a pivotal role in their thermal accommodation.

Araki, H., H. Mizumoto, T. Kanbe, and S. Sato. 2019. Evaluation of an environmental DNA method as a potential tool for monitoring salmonid fishes in the wild. *N. Pac. Anadr. Fish Comm. Tech. Rep.* 15: 164–167 (Available at <https://npafc.org>).

Imamura, A., K. Hayami, M. K. Sakata and T. Minamoto. 2019. Are *Salvelinus* species on Hokkaido Island, Japan, endangered by damming and invasive rainbow trout: Results from eDNA analysis. *Japan. J. Cons. Ecol.* 24: 71–81 (In Japanese with English abstract). DOI: https://doi.org/10.18960/hozen.24.1_71

We investigated the distributions of two native (Dolly Varden *Salvelinus malma malma* and whitespotted char *Salvelinus leucomaenis leucomaenis*) and one invasive (rainbow trout *Oncorhynchus mykiss*) salmonid species using environmental DNA (eDNA) analysis in the centre of Hokkaido Island, Japan. The native species' populations are fragmented by damming and threatened by invasive species. Therefore, DNA real-time PCR assays specific to these three salmonids were used to investigate the effects of damming and invasive species on the two native salmonids. *Salvelinus malma* populations exhibited separation due to damming. Additionally, they were not eliminated by invasive *O. mykiss* but rather lived together at some sites. *Salvelinus leucomaenis* populations occupied the lower reaches more than did *S. malma* populations. We detected *S. leucomaenis* and the invasive *O. mykiss* population less frequently than expected. We were unable to clarify the seasonal movements of species, even during their reproductive phase, despite conducting eDNA surveys throughout the year, including during the coldest parts of winter. We hypothesise that damming may function both as a protective barrier against invasive species and as an impassable barrier preventing migration; however, the significance of these potential functions was not revealed in this study. From a long-term perspective, fragmentation may negatively affect the viability of native *Salvelinus* populations. Conservation efforts for native *Salvelinus* species would be aided by additional studies using eDNA surveys, which can be effectively conducted even in mid-winter.

Kaneko, N., M. L. Journey, C. M. Neville, M. Trudel, B. R. Beckman, and M. Shimizu. 2019. Utilization of an endocrine growth index, insulin-like growth factor binding protein (IGFBP)-1b, for postsmolt coho salmon in the Strait of Georgia, British Columbia, Canada. *Fish Physiol. Biochem.* 45: 1867–1878. DOI: [10.1007/s10695-019-00681-y](https://doi.org/10.1007/s10695-019-00681-y)

Monitoring the growth of salmon during their early marine phase provides insights into prey availability, and growth rates may be linked to risks of size-dependent mortality. However, the measurement of growth rate is challenging for free-living salmon in the ocean. Insulin-like growth factor (IGF)-I is a growth-promoting hormone that is emerging as a useful index of growth in salmon. In addition, laboratory-based studies using coho salmon have shown that one of circulating IGF-binding proteins (IGFBPs), IGFBP-1b, is induced by fasting and thus could be used as an inverse index of growth and/or catabolic state in salmon. However, few studies have measured plasma levels of IGFBP-1b in salmon in the wild. We measured plasma IGFBP-1b levels for postsmolt coho salmon collected in the Strait of Georgia and surrounding waters, British Columbia, Canada, and compared regional differences in IGFBP-1b to ecological

information such as seawater temperature and stomach fullness. Plasma IGFBP-1b levels were the highest in fish from Eastern Johnstone Strait and relatively high in Queen Charlotte Strait and Western Johnstone Strait, which was in good agreement with the poor ocean conditions for salmon hypothesized to occur in that region. The molar ratio of plasma IGF-I to IGFBP-1b, a theoretical parameter of IGF-I availability to the receptor, discriminated differences among regions better than IGF-I or IGFBP-1b alone. Our data suggest that plasma IGFBP-1b reflects catabolic status in postsmolt coho salmon, as highlighted in fish in Eastern Johnston Strait, and is a useful tool to monitor negative aspects of salmon growth in the ocean.

Kaneko, T., R. Suzuki, S. Watanabe, H. Miyanishi, S. Matsuzawa and M. Furihata. 2019. Past seawater experience enhances subsequent growth and seawater acclimability in a later life stage in rainbow trout *Oncorhynchus mykiss*. *Fish. Sci.* 85: 925–930. DOI: <https://doi.org/10.1007/s12562-019-01351-x>

In the present study, we attempted to investigate the effects of temporal seawater experience on subsequent growth and later seawater acclimability in rainbow trout. To elucidate seawater acclimability of small juveniles (3–4 g), fish were transferred to seawater diluted to 25 ppt (25-ppt seawater) and the change in blood osmolality was examined. All the juveniles survived transfer to 25-ppt seawater for 7 days with blood osmolality remaining within a physiological range, indicating successful acclimation to 25-ppt seawater. For the preparation of seawater-experienced fish, young adults of rainbow trout (about 40 g) were exposed to 25-ppt seawater for 7 days without feeding, transferred back to fresh water, and reared with feeding for another 76 days. The daily growth rate was higher in seawater-experienced fish (1.86%/day) than in control fish (1.66%/day). The seawater-experienced and control fishes were then transferred directly to full-strength seawater. The blood osmolality stayed within a normal range with a transient increase just after transfer in seawater-experienced fish, but kept increasing without a declining trend in control fish. Our findings showed that temporal seawater exposure in the past enhances subsequent growth and seawater acclimability in the later life stage in rainbow trout.

Kawakami, T., T. Saito, K. Nishida, T. Yamakawa, and T. Otake. 2019. Relationships between growth traits and scale stable isotopes ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$) of adult chum salmon *Oncorhynchus keta* in Hokkaido, Japan. *J. Appl. Ichthyol.* 35: 570–575. DOI: <https://doi.org/10.1111/jai.13860>

Stable isotope analysis (SIA) in combination with growth analysis using scales collected from adult chum salmon *Oncorhynchus keta* migrating back to Hokkaido, Japan, was performed to describe the variation of isotopic composition of carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) in scales and to examine relationships with growth traits [age, fork length (FL), and relative growth ratio in the last growth period [(RGR)^{last}]]. Scale stable isotope (SI) values in 3- to 6-year-old fish were highly variable, ranging from -17.6‰ to -14.3‰ for $\delta^{13}\text{C}$ and 9.5‰ to 13.4‰ for $\delta^{15}\text{N}$. The $\delta^{15}\text{N}$ was positively correlated with FL, and this tendency may indicate changes in trophic level with growth. Significant effect was not detected between $\delta^{15}\text{N}$ and RGR^{last}, it can be inferred that factors potentially yielding high $\delta^{15}\text{N}$ may not necessarily result in higher growth rates. No trend found between FL and $\delta^{13}\text{C}$ may imply that there is no clear segregation in feeding locations between the 3- to 6-year groups. This study provided basic information for scale SI values of chum salmon adults and indicated that SIA using scales could be a new approach to elucidating the trophic ecology of chum salmon.

Kitagawa, T., N. Sato, S. Nobata, H. Mitamura, Y. Miyamoto, N. Arai, K. Uchida, H. Shirakawa, and K. Miyashita. 2019. Developing an inter-individual communication biotelemetry system and application to chum salmon returned to off Japanese waters. *N. Pac. Anadr. Fish Comm. Tech. Rep.* 15: 164–167 (Available at <https://npafc.org>).

Minamoto, T., K. Hayami, M. K. Sakata and A. Imamura. 2019. Real-time polymerase chain reaction assays for environmental DNA detection of three salmonid fish in Hokkaido, Japan: Application to winter surveys. *Ecol. Res.* 34: 237–242. DOI: <https://doi.org/10.1111/1440-1703.1018>

Dolly Varden (*Salvelinus malma*) and Whitespotted Char (*Salvelinus leucomaenis*) are representative native fish of the family Salmonidae that inhabit the upper reaches of rivers on Hokkaido Island, Japan. They are threatened by the invasive Rainbow Trout (*Oncorhynchus mykiss*). In this study, environmental DNA (eDNA) real-time polymerase chain reaction (PCR) assays to detect these three salmonids were developed and used to clarify the distribution pattern of these fish. A specificity test for each assay was conducted using DNA extracted from both target and closely related fish, and the specificity of each assay was confirmed. Then, we carried out eDNA surveys in two mountainous rivers around Mt. Daisetsu in winter, when snow depth was maximized. In the winter surveys, eDNA of all three species were successfully detected from river water samples, including under - ice water samples. The results of eDNA detection corresponded with the results of an earlier distribution survey performed with Japanese-style fly-fishing and lure-fishing. These results suggested that the eDNA assays developed in this study are applicable for inter-seasonal surveys for these species.

Minegishi, Y., M. K. S. Wong, T. Kanbe, H. Araki, T. Kashiwabara, M. Ijichi, K. Kogure, and S. Hyodo. 2019. Spatiotemporal distribution of juvenile chum salmon in Otsuchi Bay, Iwate, Japan, inferred from environmental DNA. *PLoS One* 14: e0222052. DOI: <https://doi.org/10.1371/journal.pone.0222052>.

To understand the ecology of juvenile chum salmon during early marine life after their downstream migration, we developed a quantitative PCR-based environmental DNA (eDNA) method specific for chum salmon and investigated the spatiotemporal distribution of eDNA in Otsuchi Bay, Iwate, Japan. Indoor aquarium experiments demonstrated the following characteristics of chum salmon eDNA: (1) the eDNA shedding and degradation were time- and water temperature-dependent and the bacterial abundance could contribute to the eDNA decay, (2) fecal discharge may not be the main source of eDNA, and (3) a strong positive Pearson correlation was found between the number of juveniles and the eDNA amounts. As we discovered strong PCR inhibition from the seawater samples of the bay, we optimized the eDNA assay protocol for natural seawater samples by adding a further purification step and modification of PCR mixture. The intensive eDNA analysis in the spring of 2017 and 2018 indicated that juvenile chum salmon initially inhabited in shallow waters in the shorefront area and then spread over the bay from January to June. The eDNA data also pointed out that outmigration of juvenile chum salmon to open ocean temporarily suspended in April, possibly being associated with the dynamics of the Oyashio Current as suggested by a previous observation. The eDNA method thus enables us large-scale and comprehensive surveys without affecting populations to understand the spatiotemporal dynamics of juvenile chum salmon.

Nobata, S., T. Kitagawa, K. Tanaka, K. Komatsu, Y. Aoki, K. Sato, Y. Takei, and S. Hyodo. 2019. Spreading of river water guides migratory behavior of homing chum salmon *Oncorhynchus keta* in Otsuchi Bay, a narrow inlet with multiple river flows. *Zool. Sci.* 36: 449–457. DOI: <https://doi.org/10.2108/zs190026>

The Sanriku-ria coast of Japan, a homing area for chum salmon, *Oncorhynchus keta*, is characterized by a large number of small closed bays into which one or multiple short rivers flow. The present behavioral investigation of chum salmon in this region was designed to gain deeper insight into the migration of chum salmon to their natal rivers. Eighty-three fish caught at the middle part of Otsuchi Bay were tracked using an acoustic transmitter in the narrow inlet into which flow three rivers: the Otsuchi, Koduchi, and Unosumai. The majority of 18 fish that entered the Unosumai River, which flows into the southwest side of the bay, directly approached the river along the southern coast. More than half of fish that entered the Otsuchi and Koduchi Rivers, which flow into the northwest side, also migrated into the inner bay via the southerly route, and then entered these rivers frequently after passing the mouth of the Unosumai River. In the inner bay, the salinity of sea surface water suggested that water from the three rivers circulates in a counterclockwise direction at a depth of less than 1.0 m, flowing eastwardly along the southern coast. The observed migratory paths of homing salmon in Otsuchi Bay thus correspond well with the counterflow of surface river water in the bay. The present results suggest that homing migration of salmon in the Sanriku narrow inlet is guided by natal river flows.

Tokuhara, T., M. Sato, K. Ohara, H. Tsuji and D. Kishi. 2019. Egg number and eyed egg rate in artificial spawning sites for masu salmon *Oncorhynchus masou masou* and *O. m. ishikawae* in streams. *J. Fish. Tech.* 11: 91–96 (In Japanese with English abstract).

We compared egg number and the eyed egg rate between artificial and natural spawning sites in streams for both masu salmon *Oncorhynchus masou masou* and red-spotted masu salmon *O. m. ishikawae*. No differences in egg number or eyed egg rate for both subspecies were found between the artificial and natural spawning sites. Artificial spawning sites may enhance reproduction of masu salmon and red-spotted masu salmon in degraded streams.

Theme 4: Management Systems

Aruga, N., K. Morita and M. Okamoto. 2019. Toward a coexistence between human and wild salmon in urban rivers. *Japan. J. Ecol.* 69: 229–237 (In Japanese). DOI: https://doi.org/10.18960/seitai.69.3_229

Kataoka, T., M. Nunokawa, Y. Tashiro, A. Tanise and M. Murayama. 2019. Collaboration project of salmon spawning habitat rehabilitation between industry, research institute, government and citizen. *Japan. J. Ecol.* 69: 219–227 (In Japanese). DOI: https://doi.org/10.18960/seitai.69.3_219

Kondo S. 2019. A history of salmon fishing and contemporary issues in the upper Kuskokwim region, Alaska, U.S.A. *Bull. Hokkaido Mus. North. Peop.* 28: 7–31 (In Japanese with English abstract).

In this paper, I describe a history of indigenous salmon fishing technologies and management issues in the Upper Kuskokwim region, Alaska, U.S.A. As a traditional food, salmon has been an important part of culture for the Upper Kuskokwim Athabascan people. Intensive contacts with non-Natives in the early 20th century brought some changes to Upper Kuskokwim people's subsistence technologies including fishwheels, which made it possible to obtain large amount of salmon efficiently in siltladen main streams of the Upper Kuskokwim tributaries. Conflicts with non-Native wildlife management regime began after Alaska's statehood when the State banned salmon fishing technology which involves blocking the entire width of a river or stream. As a result, Upper Kuskokwim people were forced to abandon their fishing weirs and fences at Salmon River since the late 1960s. After a decade or so, subsistence salmon fishing with rods and reels resumed at Salmon River. Nowadays, Salmon River Culture Camp has been organized by Nikolai Village Council to revitalize their fishing traditions. Since the 2010s, severe decline of king salmon populations in Alaska and Yukon has become a serious issue in indigenous societies of the areas. Local people think that commercial fishing (including bycatch) in high sea negatively affects the king salmon populations, while some others point out that increased activities by beavers and low-level of water in interior rivers might have been causing disruption of salmon's upstream migration. Through my observation of people's activities in salmon spawning areas, I argue that making a small opening to beaver dams (instead of totally destroying them) may actually benefit spawning salmon populations.

Morita, K. 2019. Thinking about the conservation activities using chum salmon as an environmental icon in northern Japan. *Japan. J. Ecol.* 69: 197–199 (In Japanese). DOI: https://doi.org/10.18960/seitai.69.3_197

Sano., M. 2019. Mechanism, characteristics and prospects of the development of salmon farming industry in Japan. *J. Reg. Fish.* 59: 117–128 (In Japanese).

Sasaki, A. 2019. Relationship between catchment land use and river water quality of salmon breeding river in Nemuro area, Hokkaido. *Papers Env. Inform. Sci.* 33: 253–258 (In Japanese with English abstract). DOI: https://doi.org/10.11492/ceispapers.ceis33.0_253.

Hokkaido Nemuro district has a northern area and a southern area. Salmon (*Oncorhynchus*

keta) catch is 20.3% in the southern region compared to the northern region. It is pointed out that this may be due to differences in the survival rate of salmon fry. This can be attributed to changes in river water quality due to basin land use. Compared to the northern district, the southern district had a smaller basin forest rate, more nitrogen input per hectare of the basin, and higher concentrations of NO₃-N, acid-soluble Fe, and acid-soluble Al in river water. These facts suggest that river water quality changes due to basin land use, and there is a concern that it has some effect on salmon fry.

Suzuki, T., T. Oishi, H. Kurokura, and N. Yagi. 2019. Which aspects of food value promote consumer purchase intent after a disaster? A case study of salmon products in disaster-affected areas of the Great East Japan Earthquake. *Foods* 8: 14. DOI: 10.3390/foods8010014

This research examined post-disaster consumer perception of food value and their effects on purchase intent by focusing on Japanese seafood industry after the Great East Japan earthquake. Online surveys on consumers living in Tokyo and Osaka Prefectures were conducted to investigate consumer value perceptions of Miyagi salmon in 2012 and 2015. Multiple-group structural equation modeling (SEM) on the 2012 survey results showed that desire to contribute to restoration (social value) had the greatest positive influence on purchase intent in both regions. Concern about radiation threats (safety value) had a negative influence on purchase intent, with a stronger impact in Osaka than Tokyo. In comparison, the 2015 results revealed a reduction in the effects of these two potent factors (i.e., safety value and social value) on purchase intent only in Osaka. The beneficial value of seafood had a general positive influence on purchase intent, but its magnitude of effect differed by regional and chronological context. Among these three values, sales promotion with emphasis on social value is more effective than with other values. In cases of future disasters in a similar context, marketers are recommended to adopt different value transfer strategies according to geographical and temporal diversity.

Yamao, M. and M. Amano. 2019. Conditions on supporting enhancement activities of salmon and trout in Hokkaido: A case study on Kitami salmon enhancement program association. *J. Reg. Fish.* 59: 71–80 (In Japanese).

Yamashita, H. 2019. A study on the changes of consumer preferences on salmon in Japan and overseas. *J. Reg. Fish.* 59: 89–96 (In Japanese).

Yoshimura, K. and J. Aoyama. 2019. Social function of the salmon in Sanriku area from the viewpoint of historical transitions in the distribution. *J. Reg. Fish.* 59: 138–145 (In Japanese).

Theme 5: Integrated Information Systems

No publication.