NPAFC
Doc. 1826
Rev.

Japanese Bibliography in 2018 for NPAFC Science Plan

by

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Submitted to the

NORTH PACIFIC ANADROMOUS FISH COMMISSION

by

Japan

March 2019

THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:
Sato, S., M. Fukuwaka, and S. Urawa. 2019. Japanese bibliography in 2018 for NPAFC Science Plan. NPAFC Doc. 1826. 19 pp. Hokkaido National Fisheries Research Institute, Japan Fisheries Research and Education Agency (Available at https://npafc.org).

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ABSTRACT: This bibliography listed original papers and documents published in 2018 by Japanese scientists and/or their collaborators to review Japanese national researches for the 2016–2020 NPAFC Science Plan. The bibliography includes 54 articles with abstracts, corresponding to five research themes of the NPAFC Science Plan.

Keywords: bibliography, Japanese science plan, NPAFC science plan, Japanese scientists

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 2018 by Japanese scientist and/or their collaborators. The current issue supplemented 54 articles published in 2018. 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 https://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

Abe, T., Y. Minowa, and H. Kudo. 2018. Molecular characterization and gene expression of synaptosome-associated protein-25 (SNAP-25) in the brain during both seaward and homeward migrations of chum salmon *Oncorhynchus keta*. Comp. Biochem. Phys. A 217: 17–25.

It is generally accepted that information about some of the odorants in the natal streams of anadromous Pacific salmon (Genus *Oncorhynchus*) is imprinted during their seaward migration, and that anadromous Pacific salmon use olfaction to identify their natal streams during the homeward migration. However, little is known about the molecular mechanisms of the various pre-synaptic functions that are important for olfactory imprinting and memory retrieval in the salmon brain. Synaptosome-associated protein-25 (SNAP-25) mediates pre-synaptic vesicle exocytosis and regulates synaptic transmission and neuronal plasticity. Despite the importance of synaptic plasticity for memorization, the expression of SNAP-25 in the salmon brain is not well understood. In this study, snap25 expression was detected in chum salmon (O. keta) brains using molecular biological techniques. Two cDNAs encoding salmon SNAP-25 were isolated and sequenced (SNAP-25a and SNAP-25b). These cDNAs encoded proteins with 204 amino acid residues, which showed marked homology with each other (97%). The protein and nucleotide sequences demonstrated a high level of homology between salmon SNAP-25s and those of other teleost species. By quantitative PCR, the expression of snap25a and snap25b was detected in all regions of the salmon brain, especially in the telencephalon. The expression levels of snap25a in the olfactory blub were higher during seaward migration than in upriver and post-upriver migrations, reflecting synaptogenesis in the olfactory nervous system, and snap25b in the telencephalon was increased during upriver period. Our results indicated that snap25s gene is involved in synaptic plasticity for olfactory imprinting and/or olfactory memory retrieval in Pacific salmon.

Ando, D. and S. Sato. 2018. Variation in the vertebral number of naturally spawning chum salmon among migrating seasons (Short paper). Sci. Rep. Hokkaido Fish. Res. Inst., 94: 53–57 (In Japanese with English abstract).

Naturally spawning chum salmon *Oncorhynchus keta* adults were collected from three rivers in Hokkaido during three different migrating seasons to represent early, middle, and late migrating populations. Vertebral numbers were then measured; the highest mean vertebral number was observed in the early migrating population. Remarkably, the difference in the mean vertebral number was larger between the (naturally spawning) early and late migrating populations than the differences reported in previous studies of hatchery-reared chum salmon populations. These results suggest that the vertebral number is useful to estimate the spawning environments of chum salmon.

Ando, D., K. Shimoda, K. Takeuchi, A. Iijima, H. Urabe, Y. Shinriki and M. Nakajima. 2018. Effect of incubation water temperature on vertebral number of masu salmon. Fish Gen. Breed. Sci., 48: 59–66 (In Japanese with English abstract).

The effect of incubation water temperature on the vertebral number of masu salmon *Oncorhynchus masou* was investigated. Vertebral numbers of juveniles incubated at temperatures

of 13–16°C were 65.2–66.6, whereas the number following incubation in spring water at temperatures of 8-9°C, which is frequently used in stock enhancement programs of masu salmon, were 64.6-65.8. Juveniles incubated in high water temperatures had 0.6–1.1 more vertebrae than those incubated in spring water. These results suggest that vertebral numbers of masu salmon are influenced by the incubation water temperature; populations incubated in spring water at temperatures of 8–9°C have fewer vertebrae than naturally spawning populations incubated at higher water temperatures greater than 13°C.

Hasegawa, K. 2018. Population densities of masu salmon and white-spotted charr in the tributaries of Shiribetsu River, southwestern Hokkaido, Japan. Nippon Suisan Gakkaishi, 84: 728–730 (In Japanese, no abstract).

Hasegawa, K., T. Ohta, and S. Takahashi. 2018. Are hatchery chum salmon fry a native invader? Direct and indirect effects of stocking salmon fry on stream organisms. Hydrobiologia 806: 111–121.

Native species may show invasiveness toward a recipient ecosystem through increases in abundance as a result of artificial stocking events. Salmonid species are typical examples of native invaders whose abundance is increased after stocking with hatchery fish. This study evaluated the effects of hatchery chum salmon fry on sympatric wild masu salmon fry, benthic invertebrate prey, and algae, after a single stocking event in Mamachi stream, Hokkaido, northern Japan. The results suggested that the stocked hatchery chum salmon fry decreased the foraging efficiency and growth of the wild masu salmon fry through interspecific competition and depressed the abundance of Ephemerellidae and total grazer invertebrates (Glossosomatidae, Heptageniidae, and Baetidae) through predation. Also, the hatchery chum salmon fry may increase algal biomass through depression of grazer abundance by predation (top-down effect). These results suggested that a single release of hatchery chum salmon fry into a stream may influence the recipient stream ecosystem.

Hasegawa, K. and A. Nakashima. 2018. Wild masu salmon is outcompeted by hatchery masu salmon, a native invader, rather than brown trout, a nonnative invader. Biol. Invasions 20: 3161–3166.

Artificially grown native species are released into natural environments to increase biological resources or to recover threatened populations. Such stocks typically have enhanced survivability and may outcompete wild conspecifics as so-called native invaders. In addition, it is likely that the competitive effects of native invaders on native species are more intense than those of nonnative invaders. To test these hypotheses, an enclosure experiment was conducted using young-of-the-year wild and hatchery (normally grown to a relatively large size to increase survival after stocking) native masu salmon, *Oncorhynchus masou*, and nonnative brown trout, Salmo trutta (which attain a smaller size than masu salmon). Competitive effects between these fishes were evaluated in terms of stomach fullness and specific growth rate of the wild masu salmon. The magnitude of the relationship between stomach fullness and growth between the experimental treatments revealed a similar pattern, suggesting that competition for foraging habitat most affected their growth. Wild masu salmon were negatively affected by hatchery conspecifics, and the effects were greater than those caused by brown trout. We propose that these outcomes were caused by competitive dominance as a consequence of body size differences. In conclusion, the results support the hypothesis that size-enhanced hatchery masu salmon have

the potential to function as native invaders, and the negative effects of artificial stocks on wild masu salmon could be greater than those caused by a nonnative invader.

Honda, K., T. Kawakami, K. Shirai, T. Kitagawa, and T. Saito. 2018. Growth rate characteristics during early marine life and sea-entry conditions of juvenile chum salmon originating from two rivers along the Pacific coast of Hokkaido, Japan. N. Pac Anadr. Fish Comm. Tech. Rep. 11: 27–28 (Available at https://npafc.org).

Horita, J., Y. Iwasa, and Y. Tachiki. 2018. Evolutionary bistability of life history decision in male masu salmon. J. Theor. Biol. 448: 104–111.

Within the salmonid species, some male juveniles after spawning in fresh water stream migrate to the ocean and return to their natal streams after maturation, while others stay and mature in the fresh water stream only. Migration is relative to the size of the individuals. This is an evolutionary outcome according to the status-dependent strategy model, which assumes that the juveniles exhibit the optimal tactic based on their status. In this paper, we consider the case in which the density of adult residents suppresses juvenile growth and explore the dynamics of alternative tactics and the evolution of threshold size. We show that a fraction of the migratory tactic that might converge into a stable state or continue to fluctuate wildly, and that the evolutionary outcome might be evolutionarily bistable, resulting in a clearly different threshold size. In the case of evolutionary bistability, two threshold sizes differ in ecological dynamics either by stable fraction of migratory tactic or showing two-year periodic fluctuation.

Iida, M., K. Yoshino and S. Katayama. 2018. Current status of natural spawning of chum salmon *Oncorhynchus keta* in rivers with or without hatchery stocking on the Japan Sea side of northern Honshu, Japan. Fish. Sci., 84: 453–459.

Information on the status of natural spawning is needed on the Japan Sea side of northern Honshu, Japan for ecosystem-based sustainable management of chum salmon resources. We conducted on-site visual surveys in October-December of 2015 and 2016 that targeted spawning chum salmon redds in all rivers > 5 km long (total 94 rivers) in Akita, Yamagata, Niigata (including Sado Island), and Toyama prefectures. The ratio of rivers found to host natural reproduction to the total number of surveyed rivers was 93.6% (44/47) in stocked rivers and 74.5% (35/47) in non-stocked rivers. These results show that there is a wide occurrence of natural reproduction of chum salmon in these rivers, regardless of the history of hatchery stocking. The density of spawning redds (number of redds/1000 m^2) as an indicator of chum salmon escapements did not differ (P = 0.54) between stocked rivers (mean 3.5, N = 49) and non-stocked rivers (mean 2.4, N = 36), when rivers where no redds were observed were excluded from the analysis. These results suggest that chum salmon escapements into non-stocked rivers may not be negligible. Conservation measures for wild fish are needed in stocked and non-stocked rivers to promote enhancement programs based on natural reproduction.

Iida, M., M. Ban, D. Noguchi, Y. Miyauchi and S. Katayama. 2018. Comparison of return rates of chum salmon *Oncorhynchus keta* released at various times into the Gakko River, Yamagata Prefecture, Japan. Aquacult. Sci., 66: 137–140 (In Japanese with English abstract).

To determine the optimal time for releasing chum salmon into the Gakko River, otolith-marked juveniles reared to more than 1 g body mass were released in late February, mid-March, and late March of 2009 to 2011. Although factors that determine return rates are yet

unknown, the return rates were highest for the mid-March (0.62%-1.02%) groups of all three brood years. Return rates for the late February and late March groups were approximately half that of the mid-March groups. These results suggest that releasing chum salmon in mid-March is optimal for increasing return rates.

Inatani, Y., T. Ineno, S. Sone, N. Matsumoto, K. Uchida, and M. Shimizu. 2018. Assessment of the timing and degree of smolt development in southern populations of masu salmon *Oncorhynchus masou*. J. Fish Biol. 93: 490–500.

The present study assessed whether non-anadromous masu salmon *Oncorhynchus masou* in Miyazaki, southern Japan, smoltify, and if so, at what time of the year. Yearling *O. masou* of Miyazaki and an anadromous population from Hokkaido, northern Japan, were reared in hatcheries in their respective regions and sampled monthly from February to June to examine the spring smoltification period. The Hokkaido population showed a peak of gill Na+-K+-ATPase (NKA) activity in May, which was accompanied with an increase in mRNA levels of the seawater (SW)-type NKA alpha subunit, nka1b. Increases in gill NKA activity and nkaa1b levels were not seen in Miyazaki populations. Transferring yearling Miyazaki population to 70% SW (salinity of 23) in mid-April resulted in an increased serum osmolality over 4 days. These results suggest that they do not smoltify in their second spring. Next, profiles of gill NKA activity and its subunit mRNA levels in under-yearling Miyazaki population in the autumn were examined. Two phenotypes differing in body color during this period were categorized as parr and smolt-like fish. Smolt-like fish had higher gill NKA activity than parr in December while there was no significant difference in gill nka1b levels. Smolt-like fish acclimated to 70% SW better than parr as judged by lower serum osmolality. However, serum osmolality in smolt-like fish did not return to the basal level 7 days after transfer to 70% SW, suggesting that their hypo-osmoregulatory ability was not fully developed to a level comparable to anadromous populations of this species. The present study suggests that, if *O. masou* in Miyazaki go through a smoltification process, it occurs in its first autumn instead of the second spring and is less pronounced compared with anadromous populations.

Kasugai, K. 2018. Effects of environmental variability on the migration and survival of juvenile chum salmon in the coastal waters of Hokkaido. Aquabiol., 40: 335–341 In Japanese with English abstract).

Effects of coastal environment on the migration and survival of juvenile chum salmon have been studied in the eastern coastal waters of Hokkaido, northern Japan. Low sea surface temperatures (SSTs) in the coastal areas has affected the distribution and migration of juvenile chum salmon. Low coastal SST may be a factor causing mortality of juvenile chum salmon, because it caused a low return rate of adult fish. Low SST might affect the survival of juvenile chum salmon through (1) shortage of preys caused by restricting the migration of juveniles from the littoral zone to the nearshore area, (2) retardation of fish growth and swimming capacity, and (3) physiological disorders. To understand the survival mechanism of juvenile chum salmon in association with low SSTs in coastal water, laboratory experiments under controlled temperature, salinity feeding regimes, and so on are required in addition to field studies.

Kasugai, K., H. Sakamoto, Y. Miyakoshi, and M. Nagata. 2018. Returns of chum salmon released from net-pens and rivers in eastern Hokkaido, Japan. N. Am. J. Fish. Manage. 38: 24–30.

The effectiveness of net-pen release of Chum Salmon *Oncorhynchus keta* in improving commercial coastal and river catches was examined by releasing marked fish from seawater net-pens in Nemuro Bay or into the Nishibetsu River, eastern Hokkaido, northern Japan. Between 100,000 and 130,000 Chum Salmon fry were reared in the hatchery and marked by clipping either the left or right pelvic fin in 2006 and 2007; the fin clip was used to distinguish between net-pen and river releases. Returning marked fish were surveyed in 17 set nets along the coast of Nemuro Bay, a small set net at the Betsukai Fishing Port, and a salmon weir in the Nishibetsu River 2-5years after release. No differences were observed in the coastal catch period between the net-pen-released and river-released fishes. Estimated coastal return rates of the net-pen-released fish (0.929% and 0.845%) were twice those of the river-released fish (0.488% and 0.406%). However, six to seven times more river-released fish (river catch rate=9.591% and 7.513%) migrated upstream than net-pen-released fish (1.292% and 1.192%). Our results suggest that the use of marine net-pens for Chum Salmon will not sustainably improve adult salmon catches in rivers, although it might increase coastal catches.

Kawashima, T., Y. Shimizu, K. Ohta and K. Yamane. 2018. Abundance and habitats of juvenile chum salmon and their adult returns in the Sanriku coast. Aquabiol., 40: 342–345 (In Japanese with English abstract).

The abundance of chum salmon returns in Iwate had increased with increasing the number of fry released from hatcheries. Considering the number of adult returns and their age structure and body size, we divided the annual variation of chum salmon abundance into three periods: (1) increasing period until the 1979 year class, (2) high stock level period from 1980 to 1994 year class, and (3) decreasing period from 1995 year class. Recently, the number of chum salmon fry releases has been almost stable, while the number of adult returns has been decreasing. The sea surface temperature along the coast of Iwate has showed a trend of increase, which may affect the survival of juvenile chum salmon, resulting in low adult returns.

Kudo, H., T. kimura, Y. Hasegawa, T. Abe, M. Ichimura, and S. Ijiri. 2018. Involvement of 11-ketotestosterone in hooknose formation in male pink salmon (*Oncorhynchus gorbuscha*) jaws. Gen. Comp. Endocr. 260: 41–50.

Mature male Pacific salmon (*Oncorhynchus* spp.) develop a hooknose, as a secondary male sexual characteristic, during the spawning period. It is likely that androgens regulate hooknose formation. However, endocrinological and histochemical details about the relationship between androgens and hooknose formation are poorly understood. In this study, we performed assays of serum androgens, detection of androgen receptor (AR) in hooknose tissues, external morphological measurement of hooknose-related lengths, and microscopic observation of hooknose tissues of pink salmon (*O. gorbuscha*) at different stages of sexual maturation. Expression of the ar beta gene was detected in hooknose tissues of males but not females. The elongation of these tissues was mediated directly via androgens. Serum 11-ketotestosterone (11-KT) concentrations indicated a significant positive correlation with both jaw lengths during sexual maturation of males. In the upper jaw, cartilage tissue developed during hooknose formation, and AR-immunoreactive chondrocytes were located in the rostal-vetral regions of hooknose cartilage in maturing male. The chondrocytes in maturing males before entering into rivers exhibited rich cytoplasm with high cell activity than at other sexual development stages.

On the other hand, in the lower jaw, the development of the spongiosa-like bone meshworks. AR-immunoreactivity was detected in a proportion of the osteocytes and osteoblast-like cells in the spongiosa-like bone meshworks. These results indicate that hooknose formation in pink salmon, which is associated with the buildup of a structure with sufficient strength that it can be used to attack other males on the spawning ground, is regulated by 11-KT.

Miyakoshi, Y. 2018. Current status of chum salmon stocks in Hokkaido. Aquabiol., 40: 330–334 (In Japanese with English abstract).

Chum salmon (*Oncorhynchus keta*) is one of the important commercial fish species in northern Japan. Commercial fishery of chum salmon in Hokkaido has been supported by intensive hatchery programs that would be one of the most successful example of marine stock enhancement programs. Number of adult chum salmon returning to Hokkaido increased since the 1970s due to the improvement of hatchery techniques and favorable ocean conditions. The number of chum salmon returns was historically high level during the 1990s and early 2000s, while it decreased in the last decade. The recent decrease of chum salmon returns might be caused by unfavorable ocean conditions around Hokkaido and the North Pacific; e.g., low sea water temperature in spring when juveniles enter the coastal ocean, and high temperature in fall when adults return for spawning. For the sustainable management of chum salmon stocks in Hokkaido, the procedures of the hatchery programs should be considered to adapt to the recent environmental conditions.

Miyakoshi, Y., H. Saneyoshi, and Y. Koshino. 2018. Environmental factors affecting the survival of juveniles and recent returns of chum salmon in the Okhotsk coast of Hokkaido. N. Pac Anadr. Fish Comm. Tech. Rep. 11: 44–45 (Available at http://www.npafc.org).

Miyamoto, K., T. E. Squires, and H. Araki. 2018. Experimental evaluation of predation of stocked salmon by riparian wildlife: effects of prey size and predator behaviours. Mar. Freshwater Res. 69: 446–454.

Predation after release is one of the major concerns of hatchery fish conservation and propagation. However, the relationships between the size of hatchery fish, the predator species and their behaviours in natural environments are largely unknown. To understand these relationships, we conducted predation experiments in outdoor tanks and a seminatural stream with exposure to local predators. Masu salmon (*Oncorhynchus masou*) of two different size classes were used as experimental prey fish in the present study. Camera trap data showed that grey herons (*Ardea cinerea*) were the primary predator in the experimental system, and that most herons used shallow areas in the morning or evening while feeding. Increasing the density of stocked salmon led to increases in the number of occurrences of grey heron. More importantly, predation by grey herons resulted in a significantly lower survival rate of larger salmon compared with smaller salmon. The results indicate that it is important to understand local predators, adjust the optimum body size of hatchery fish at release and choose the appropriate stocking site and time of day for maximising the effectiveness of fish stocking.

Morita, K. and G. Sahashi. 2018. On the ocean age of masu salmon *Oncorhynchus masou* in a natural population, Shiretoko Peninsula, Japan. J. Ichthyol. 58: 594–599.

In the Orumappu River, northeastern Hokkaido, 667 wild masu salmon smolts were tagged and released. During annual monitoring within the river, 10 individuals were recaptured, and an

additional individual was reported from a coastal fishery. All adult masu salmon were recaptured the year after their release, and all had spent one winter at sea. When examining scales of marked fish, four individuals lacked winter annuli and one individual had 2 or 3 resting zones (closely spaced circuli) in the oceanic zone. Accordingly, we believe it is uncertain to assess age of adult masu salmon based solely on scale annuli.

Morita, K., J. Tsuboi, G. Sahashi, T. Kikko, D. Ishizaki, D. kishi, S. Endo, and Y. Koseki. 2018. Iteroparity of stream resident masu salmon *Oncorhynchus masou*. J. Fish Biol. 93: 750–754.

The degree of iteroparity in stream-resident forms of masu salmon *Oncorhynchus masou* was examined using mark-recapture studies in natural streams. In a partially migratory population, at least 10% of resident males survived after maturation and repeatedly matured for up to 5 years. In the landlocked amago salmon subspecies, the post-maturation survival rate was at least 7% and repeat maturation was observed for up to 3 years for both males and females.

Nakayama, K., A. Tohkairin, A. Yoshikawa and T. Nakabo. 2018. Detection and morphological characteristics of "Kunimasu" (*Oncorhynchus kawamurae*)/"Himemasu" (*O. nerka*) hybrids in Lake Motosu, Yamanashi Prefecture, Japan. Ichthyol. Res., 65: 270–275.

A recently discovered transplanted population of "Kunimasu" *(Oncorhynchus kawamurae*) in Lake Saiko, Yamanashi Prefecture, Japan, extinct in its original habitat, has been reported as almost never hybridizing with sympatric "Himemasu" (*O. nerka*). However, analyses of microsatellite and mitochondrial DNA markers disclosed extensive hybridization between these two species in Lake Motosu, Yamanashi Prefecture, a second lake to which Kunimasu had been transplanted. The rates of purebred Kunimasu, Kunimasu/Himemasu hybrids and purebred Himemasu were 0 %, 64.3 % and 35.7 %, respectively, and hybrid specimens had intermediate numbers of pyloric caeca and gill rakers compared with the parental species.

Sahashi, G. and K. Morita. 2018. Adoption of alternative migratory tactics: a view from the ultimate mechanism and threshold trait changes in a salmonid fish. Oikos 127: 239–251.

Partial migration, in which a portion of the population migrates while the rest of the population remains as residents, is a common form of migration. Alternative migratory tactics (AMTs) of partial migration are often determined by polygenic threshold traits. However, the ultimate mechanisms that drive inter-population variations in threshold traits are not well understood. We present a simple schematic model to explain how the threshold trait changes with fitness consequences under opposing natural and artificial selection forces. We conducted a field test to evaluate the effects of migration difficulty (as a natural selective force) and selective captive breeding (as an artificial selective force) on threshold traits of a partially migratory fish. Male masu salmon Oncorhynchus masou in the Shari River system have AMTs divided into three population categories of hatchery, wild/above the waterfall, and wild/below the waterfall (control). The wild/above the waterfall salmon live in a high-migration-cost situation, and the threshold trait changed in a direction that promoted residency. In hatchery salmon, which are produced by migrant-selective captive breeding, the threshold trait changed in a direction that promoted migration. In contrast, Dolly Varden charr Salvelinus malma displayed only resident tactics, and the threshold trait did not differ between the populations above and below the waterfall, indicating that environment did not explain the variation in the threshold trait. Our results support the model and suggest that opposing natural and artificial selection forces drive variations in the threshold traits and migratory patterns in the studied species. Our conceptual

framework for the ultimate mechanism may help to better understand adoption of AMTs and production of diverse intraspecific traits in migratory animals

Sahashi, G., K. Morita and D. Kishi. 2018. Spatial expansion and increased population density of masu salmon parr independent of river restoration. Ichthyol. Res., 65: 496–501.

Spatial expansion and increased population abundance of masu salmon *Oncorhynchus masou* have been recently reported following habitat restoration in some rivers, but no studies have examined these types of changes under natural conditions. We found spatial expansion and increased population density of masu salmon parr in rivers of eastern Hokkaido where no habitat restoration had occurred during the period examined. Changes in the distribution and population densities of parr are often regarded as effects of river habitat destruction and restoration, yet such changes should be evaluated while taking into account the effects of other ocean environmental conditions as well.

Saito, T. and M. Fukuwaka. 2018. Status of Pacific salmon production in the North Pacific Ocean. Aquabiol., 40: 319–329 (In Japanese with English abstract).

Total commercial catches of Pacific salmon (*Oncorhynchus* spp.) in the North Pacific have been almost high levels since the 1990s, but regional breakdown of the recent catches shows a north-south gradient along latitudes on both Asian and North American sides. In Asia, although Japan had caught a greater proportion of chum salmon from the 1970s to the mid-2000s, Russia currently catches the largest proportion of chum salmon. Chum catches have been in decline since 2010 along the Pacific coasts of Hokkaido and Honshu in Japan. Contrary to the Pacific coasts of Japan, Amur River chum catches have drastically increased since the mid-2000s. In this study, we focused on the early marine life of chum salmon and investigated relationships between chum brood-year strengths and sea surface temperatures during their coastal residency for chum stocks originating from the Pacific coasts of Japan and from the Amur River in Russia. Based on the results, we discussed possible factors explaining recent decline/increase of chum catches between Japan and Russia.

Saito, T. and Y. Miyakoshi. 2018. Current status of chum and pink salmon: what is reducing adult returns in Japan? N. Pac Anadr. Fish Comm. Tech. Rep. 11: 8–9 (Available at https://npafc.org).

Sato, S., A. Nakahsima, K. Yamaya, and S. Urawa. 2018. Geographical origins of juvenile chum salmon migrating along the Pacific coast of Hokkaido, Japan, during early summer. N. Pac Anadr. Fish Comm. Tech. Rep. 11: 24–26 (Available at https://npafc.org).

Shimoda, K., T. Watanabe and D. Ando. 2018. Variation in body silvering of chum salmon juveniles in seasonally spawning stocks. Sci. Rep. Hokkaido Fish. Res. Inst., 94: 41–46 (In Japanese with English summary).

In this study, body silvering in chum salmon juveniles (*Oncorhynchus keta*) was analyzed using a chromameter. For this, we observed O. keta juveniles in early- and late-run stocks (fertilized from late Sep to early Oct and from mid Nov to early Dec, respectively) in six rivers (Abashiri R., Shibetsu R., Tokachi R., Chitose R., Shizunai R. and Torisaki R.) in Hokkaido, Japan. L-value was used as body silvering index for comparison on a weekly basis between two seasonal stocks following spawn emergence. Higher L-values were noted for the late-run stocks

than for the early-run stocks. Thus, our results suggest that the developmental level of physiological traits of late-run stocks was faster than that of early-run stocks in chum salmon.

Tago, Y., N. Iida, S. Azuma and A. Nitta. 2018. Changes in vertical distribution of masu salmon during high flow in a large pool just below the Jin-san Dam in the Jinzu River. Ecol. Civil. Eng., 21: 45–52 (In Japanese with English abstract).

Vertical distribution of masu salmon, *Oncorhynchus masou masou*, during high flow was investigated by using the archival tags in a large pool (ca. 70 m long, ca. 150 m wide and Max. 13.7 m depth) just below the Jin-san Dam in the Jinzu River in 2009. The masu salmon, resided in the surface layer （ca. 1.0 m below the surface） under low flow conditions, moved to a deeper layer while repeating up-and-down movement with the increase in flow. It is supposed that the masu salmon took refuge in the middle layer （2-4 m）of weak current near the river bank aside to avoid surface and bottom of center layers (5-14 m) of rapid current when the flow has increased to the maximum level. And the masu salmon moved to a shallower layer again while repeating up-and-down movement with the decrease in flow. After the flow came to an ordinary level, masu salmon returned back to the surface layer. These results suggest that deep pools, having a variety of spaces ideal for creating weak currents, play an important role as refuge in case of high flow.

Ueda, H. 2018. Researches on mechanisms of natal stream imprinting and homing in Pacific salmon. Nippon Suisan Gakkaishi, 84: 590–602 (In Japanese, no abstract).

Ueda, S., T. Abe, Y. Koshino and H. Kudo. 2018. Origin of natural spawning chum salmon estimated from thermal otolith marks of adult salmon carcasses in the Yurappu River, southwestern Hokkaido, Japan. Nippon Suisan Gakkaishi, 84: 133–135 (In Japanese, no abstract).

Urabe, H. 2018. Influence of environmental variability on reproduction of chum salmon in rivers. Aquabiol., 40: 423–427 (In Japanese with English abstract).

Recent studies have revealed that wild chum salmon populations are broadly distribution across Hokkaido, northern Japan. The wild chum salmon, which still lives in its natural habitat, is essential for sustainable salmon fishery, which means that it should be conserved and managed appropriately. This article reviews and discusses the influence of environmental variability on chum salmon reproduction by focusing on their stream life stage. Increase in air temperature due to climate change may enhance chum salmon fry survival in cool temperate regions. However, an increase in the frequency of winter rainfall and changes in snowmelt-runoff timing due to higher temperatures during winter could decrease salmon survival during their early life stage. Artificial alterations to the river environment, channelization, and the construction of dams could also reduce the viability of wild chum salmon populations. A better understanding of river environment variability under climate change and the responses of chum salmon to this change is essential if the salmon is to be conserved. Furthermore, plans to rehabilitate and restore the river environment based on Eco-DRR should be implemented.

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

Azumaya, T., E. Sato, and S. Urawa. 2018. Decreasing area of chum salmon (*Oncorhynchus keta*) distribution in the North Pacific in summer 1982–2016. NPAFC Doc. 1767. 7 pp. Hokkaido National Fisheries Research Institute, Japan Fisheries Research and Education Agency (Available at https://npafc.org).

The area of chum salmon (*Oncorhynchus keta*) distribution in the North Pacific in summer from 1982 to 2016 was annually estimated using sea surface temperature (SST). Long term trends of SST in the North Pacific in summer were positive except for the United States west coast area. The maximum positive trend was about 0.07°C/year. In summer, SST in the whole North Pacific, except for the United States west coast, was warming so that the southern limit of chum salmon distribution has shifted northward. The interannual change in area of chum salmon distribution in summer had a statistically significant negative trend ($P<0.01$) which was about -30000 km2/year to -40000 km2/year. It is found that the area of chum salmon distribution in the North Pacific in summer has decreased approximately 10% during the last 35 years.

Azumaya, T., H. Kuroda, D. Takahashi, T. Unuma, T. Yokota and S. Urawa. 2018. Migration routes of juvenile chum salmon simulated with a hydrodynamic model. Aquabiol., 40: 453–458 (In Japanese with English abstract).

Factors affecting the migration of juvenile chum salmon (*Oncorhynchus keta*) in the Pacific coast of Hokkaido were investigated using a juvenile salmon migration model. The juvenile salmon migration model was driven by the active swimming and the passive transport by the currents which were hydrodynamic model's outputs. The juvenile salmon migration model reproduced the actual distribution of juvenile chum salmon in the Pacific coast of Hokkaido. Both the passive transport by the currents and the active swimming affected the migration of juvenile chum salmon to the coast of Hokkaido. As the velocity of the active swimming became larger, the number of juvenile chum salmon which reached the coast of Hokkaido increased. This result suggests that large juvenile chum salmon is advantageous for their successful migration.

Beacham, T. D., C. Wallace, and S. Sato. 2018. Microsatellite identification of sockeye salmon rearing in the south central Bering Sea during summer 2017. NPAFC Doc. 1752. 12pp. 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 2017 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 82.0% of all sockeye salmon caught, with the catch dominated by sockeye salmon of Bristol Bay origin (69.0%). Canadian-origin salmon accounted for an average of 14.6% of the catch, while Russian-origin sockeye salmon accounted for 2.5% of the catch, with 535 individuals of the catch genotyped. The research surveys have potentially provided an early indication that the return of Fraser River sockeye salmon in 2018 may rival or exceed that

observed in 2010.

Honda, K., T. Kawakami and T. Saito. 2018. Survival conditions of juvenile chum salmon on the basis of their growth characteristics. Aquabiol., 40: 346–350 (In Japanese with English abstract).

Juvenile chum salmon originating from rivers along the Pacific coast of Japan migrate northwards to the Sea of Okhotsk, typically passing off Konbumori, near the easternmost part of Hokkaido Island. We used daily-increment analysis of otolith to back-calculate the growth rate [mean daily growth in fork length (FL)] of 369 juveniles (56–146 mm FL) originating from various rivers southwest of Konbumori, and sampled at Konbumori during 2005–2014. Results show juvenile chum salmon originating from distant sources tended to grow faster than those originating from more proximal sources, likely contributing to larger FLs of the former. Additionally, growth rate of 16 Japanese and Russian juvenile chum salmon (180–286 mm FL) captured in the Sea of Okhotsk offshore during the autumn of 2002 was also estimated. Their growth rates were much higher than those sampled at Konbumori. These results suggest that Japanese juvenile chum salmon of which growth rate exceeded a certain level were better able to survive and reach the Sea of Okhotsk offshore.

Honda, K., S. Sato, T. Sato, A. Yoshida, T. Yamanaka, and K. Suzuki. 2018. The summer 2017 Japanese salmon research cruise of the R/V *Hokko maru*. NPAFC Doc. 1765. 16 pp. Hokkaido National Fisheries Research Institute, Japan Fisheries Research and Education Agency, and Hokkaido University (Available at https://npafc.org).

A summer high-seas research cruise to investigate the biology of Pacific salmon was conducted from July 24 to August 2 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 4,065 salmonids were caught by surface trawls (excluding a test trawl) and angling at 17 monitoring stations. Chum salmon was the most abundant species (n = 3,112, 76.6%), followed by sockeye salmon (n = 846, 20.8%), pink salmon (n = 58, 1.43%), Chinook salmon (n = 38, 0.93%), coho salmon (n = 9, 0.22%), and Dolly Varden (n = 2, 0.05%). 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 future study. A total of six sockeye salmon and 48 chum salmon were tagged with disk tags and were released in the Bering Sea. Among them, seven large chum salmon were released with an archival tag. Age-specific catch per unit effort by surface trawl and annual mean body weight of each ocean age of chum salmon during 2007–2017 are documented here.

Kaeriyama, M. and Y. Urabe. 2018. Global warming effect for migration route of Japanese chum salmon. N. Pac Anadr. Fish Comm. Tech. Rep. 11: 91–95 (Available at https://npafc.org).

Koyama, T., A. Shinada, H. Kuroda and Y. Miyakoshi. 2018. Consideration on northward transport of juvenile chum salmon in the Sea of Japan off Hokkaido based on particle-tracking experiments (Short paper). Sci. Rep. Hokkaido Fish. Res. Inst., 93: 93–98 (In Japanese with English summary).

Using particle-tracking experiments, based on a high-resolution ocean model, we examined

the northward transport of juvenile chum salmon (*Oncorhynchus keta*), released into the Sea of Japan, by assuming that the particles represented juvenile chum salmon, which were transported passively by ocean currents. The experiments were undertaken for the two brood year classes of juvenile chum salmon; the 2009 brood year class released in the spring of 2010, which showed the lowest return rate among the 2007 to 2010 brood year classes, and the 2007 brood year class released in the spring of 2008, which showed the highest return rate. A remarkable difference in the distribution of the particles was observed between the two brood year classes; i.e., for the 2009 class, particles were transported across a wider range in offshore waters, and the timing at which particles were transported into the Okhotsk Sea through the Soya Strait was delayed. Moreover, the ambient sea water temperature experienced by the particles was lower for the 2009 year class. These results indicated that the post-release transport of juvenile chum salmon by ocean currents was remarkably different between the two years and it may contribute to the low return rate of the 2009 class on the Sea of Japan side of Hokkaido.

Saneyoshi, H., Y. Koshino, H. Shirakawa, N. Koshida, Y. Miyakoshi, and K. Miyashita. 2018. Migration and homing behavior of chum salmon tagged in the Okhotsk sea, eastern Hokkaido. N. Pac Anadr. Fish Comm. Tech. Rep. 11: 96–97 (Available at https://npafc.org).

Sato, S., T. Sato, K. Honda, K. Suzuki and S. Urawa. 2018. Status of Japanese chum salmon and their habitat environments in the high-seas ocean. Aquabiol., 40: 351–357 (In Japanese with English abstract).

High-seas researches on status of Japanese chum salmon and their habitat environments were reviewed in this paper. A considerable number of otolith-marked Japanese chum salmon juveniles were found in the Okhotsk Sea by Russian cruise surveys during the fall of 2011–2015. The estimated abundance of Japanese hatchery chum salmon juveniles in the Okhotsk Sea was extremely low (50–75 million fish) in 2013–2015. There was a high positive correlation between the estimated abundance of Japanese chum salmon juveniles in the Okhotsk Sea and adult returns by brood-year stocks. In the overwintering period, ocean age 1 chum salmon originating from Japan and Russia are mainly distributed in the western North Pacific Ocean, while older chum salmon (ocean age 2 ≤) mainly occur in the Gulf of Alaska. Winter survival status of chum salmon is still unclear, although winter is believed to be a critical period for salmon. Japanese monitoring surveys in the summer Bering Sea since 2007 have indicated that ocean conditions and chum salmon abundance have fluctuated by year. Mean SSTs in the Bering Sea were basically stable just below 10ºC during 2007–2013 seasons but fluctuated after 2014 seasons. Mean CPUE of immature chum salmon decreased in 2014 and 2015 but increased in 2016 and 2017. A high correlation between CPUE of Japanese chum salmon juveniles in the Okhotsk Sea and that of ocean age 1 fish in the Bering Sea was found among 2010–2014 brood-year stocks. These results suggest that the year class strength of Japanese chum salmon may be determined during their early ocean life.

Sato, T., K. Sakaoka, Y. Kajiwara, K. Imai, N. Hoshi, M. Ohwada, Y. Inagaki, and S. Takagi. 2018. Results of 2017 salmon research by the *Oshoro maru*. NPAFC Doc. 1760. 12 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, the T/V *Oshoro maru* conducted oceanographic

observations and fishing surveys in the western North Pacific (along the 155°E longitude line) and Bering Sea. The survey was conducted during the Cruise #039 in May, and the Cruise #040-Leg2, 4 from June to July 2017. Oceanographic observations and drift gillnet surveys were conducted along the 155°E during the Cruise #039. No significant shift from the last year was confirmed for the Polar Front observed in the vicinity of 44°N. A total of 1945 salmonids was caught by gillnet surveys, including 1896 Pink, 49 Chum salmons. Other species such as Steelhead and Sockeye salmon were not caught this year by the gillnet surveys. The fork lengths (F.L.) of chum salmon collected by C-gear gillnet ranged between 272-551 mm F.L., and those of pink salmon ranged between 322-495 mm F.L., 100% of Pink salmons caught along 155°E were adult fish. To collect salmon samples extensively and to collect fresh salmon blood, otoliths and various tissues, three hook-and-line gear samplings and a surface long-line sampling were conducted during the Cruise #040-Leg2, 4 as well as the Cruise #039. The dominant species caught by these gears during the Cruise #040 were Pink salmon (61 Pink, 18 Sockeye, 6 Chum, 3 Coho and 1 Chinook salmons).

Ueno, H., S. Yoon, E. Watanabe and M. J. Kishi. 2018. 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. Aquabiol., 40: 428–434 (In Japanese with English abstract).

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 Sea 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 have increased since the mid-1960s, 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 tropic ecosystem model (3-D NEMRO). “Potential habitat” was defined as “an area where chum salmon could grow (i.e. the growth rate was positive)”. In the bioenergetic 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 NEMRO 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 IPCC SRES-A1B 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°N during summer, the potential habitat would shrink regionally because the water temperature exceeded the optimal condition.

Theme 3: New Technologies

Amano, Y., M. Kuwahara, T. Takahashi, K. Shirai, K. Yamane, T. Kawakami, K. Yokouchi, H. Amakawa and T. Otake. 2018. Low-fidelity homing behavior of Biwa salmon *Oncorhynchus* sp. landlocked in Lake Biwa as inferred from otolith elemental and Sr isotopic compositions. Fish. Sci., 84: 799–813.

Biwa salmon *Oncorhynchus* sp. is endemic to Lake Biwa, Japan, where it is an important commercial and recreational fisheries species. However, no information is currently available on its population structure and migration ecology. Therefore, here we evaluated whether otolith Sr/Ca, Ba/Ca and Sr-87/Sr-86 ratios can be used as natural signatures in Biwa salmon and then used these to determine the natal origins of lake-migration-phase individuals and spawning adults, and the homing ability of spawning adults in the Lake Biwa water system. Quadratic discriminant function analysis demonstrated that the lake-migration school comprised individuals with multiple origins, including rivers to the east, west and north of Lake Biwa, and that the homing rate of spawning adults was low (18 out of 80 individuals), with ca. 78% of fish straying into non-natal rivers. However, this straying behaviour was not spatially random, with fish tending to migrate upstream in rivers neighbouring their natal rivers. The high rate of straying in spawning adults is considered important for establishing and maintaining this species, which is highly adapted to life in the Lake Biwa water system where environmental disturbances often occur.

Kitagawa, T. 2018. Analysis of swimming behavior of chum salmon in coastal waters using micro data-logger. Aquabiol., 40: 449–452 (In Japanese with English abstract).

Biologging is a powerful technique to measure biological information of free-ranging animals and the ambient environmental conditions they experience. Recent technological developments have made it possible to simultaneously monitor and record the swimming behavior of various fish species including chum salmon *Oncorhynchus keta*, along with the ambient physical environmental conditions they experience and internal physiological information. In this paper, a few studies on swimming behavior of chum salmon off the Sanriku coast, Japan that used biologging techniques are introduced. The directions for future biologging research on the species in the open ocean are also discussed.

Kitanishi, S., T. Yamamoto, H. Urabe, and K. Shimoda. 2018. Hierarchical genetic structure of native masu salmon populations in Hokkaido, Japan. Env. Biol. Fish. 101: 699–710.

Identification of the spatial extent of genetic structuring that may be influenced by evolutionary, ecological and historical factors is critical for effective conservation or management strategies. Masu salmon *Oncorhynchus masou* is commonly distributed in Far East, however, many local populations have been under threats of decline due to habitat destruction, overexploitation, and genetic introgression. To reveal the spatial genetic structure of native masu salmon populations in Hokkaido, masu salmon samples were collected from 16 rivers in which there was no official record of artificial releases of any masu salmon stock and were analyzed using 15 microsatellite loci. A Bayesian assignment test revealed that masu salmon populations were divided into two genetically distinct groups: the northeastern and southwestern groups. For within-group genetic structure, all populations, except for geographically proximate populations, were significantly different from each other. AMOVA revealed that genetic variation at among-group level based on groups identified assignment test was greater than that of groups based on geographic locations. There was no significant IBD for the 16 populations. However,

the Mantel test revealed significant IBD for the northeastern group, but did not for the southwestern group. This study suggested that native masu salmon populations in Hokkaido exhibit a hierarchical genetic structure that is largely a result of their precise homing behavior. The results of this study also highlight the importance of defining populations by using genetic data rather than by using predefined populations based on geographic locations for the correct determination of genetic structure.

Mizuno, S., S. Urawa, M. Miyamoto, M. Hatakeyama, Y. Sasaki, N. Koide, S. Toda, and H. Ueda. 2018. Effects of dietary supplementation with oregano essential oil on prevention of the ectoparasitic protozoans *Ichthyobodo salmonis* and *Trichodina truttae* in juvenile chum salmon *Oncorhynchus keta*. J. Fish Biol. 93: 528–539.

The present study performed three experiments to establish a practical prevention strategy for the ectoparasitic flagellate *Ichthyobodo salmonis* and ciliate *Trichodina truttae* in hatchery-reared juvenile chum salmon *Oncorhynchus keta* using dietary supplementation with oregano essential oil. Experiment 1 showed that a diet supplemented for 3 weeks with 0.02% oregano essential oil significantly prevented infection with *I. salmonis* and *T. truttae* in juveniles reared in small tanks. Experiment 2, in outdoor hatchery ponds, demonstrated that the oregano treatment completely prevented *I. salmonis* infection for 52 days and *T. truttae* infection for 38 days. Oregano-treated juvenile mortality attributable to infection with these protozoans also decreased to 7.6% of control juvenile mortality, confirming the utility of this treatment in cultured *O. keta*. Physiological analyses of the oregano-treated juveniles elucidated the treatment's safety in relation to their metabolism, osmoregulation, natural immunity and olfactory responses and also detected carvacrol (a major component of oregano essential oil which shows antimicrobial activity) on the skin. In experiment 3, exposure of the two protozoans to oregano essential oil revealed a weak antiparasitic action on the body surface of the juvenile *O. keta*. The overall results demonstrate that dietary oregano supplementation is a practical prevention strategy for *I. salmonis* and *T. truttae* in hatchery-reared juvenile *O. keta* and suggest the possibility that its anti-parasitic action is attributable to a component of the oil that emerges onto the skin of the body of the fish.

Tsukagoshi, H. and T. Goto. 2018. Genetic structure and population traits of chum salmon in Sanriku. Aquabiol., 40: 435–440 (In Japanese with English abstract).

Understanding of the populations characteristics in chum salmon is important for planning their effective resource management for sustainable fisheries. We estimated the population characteristics of Sanriku chum salmon, the Pacific coast of northern Honshu, Japan, using both fisheries ecological and population genetic approaches. Cluster analysis based on periods of spawning eggs showed three groups of coastal early-run, coastal middle-run and coastal late-run. In addition, population genetic analysis revealed three groups of coastal early-run, coastal-late run and Kitakami River groups. These results suggested that coastal early-run populations were obviously differentiated from coastal late-run populations.

Tsunagawa, T. and K. Shirai. 2018. Migration history of masu salmon *Oncorhynchus masou* in the Naka River, Tochigi, Japan, estimated from otolith Sr:Ca ratio analysis. Jap. J. Ichthyol., 65: 151–163 (In Japanese with English abstract).

The migratory histories of individual masu salmon *Oncorhynchus masou* collected from the Naka River, Tochigi, Japan were clarified from otolith strontium (Sr) and calcium (Ca) concentrations using X–ray electron microprobe analysis. Mapping and line analysis indicated

three migratory types of the species. In addition to the conventional types, such as freshwater resident and typical anadromous (spending one year in marine waters), a new migratory pattern of short marine term anadromous (remaining in marine waters for several months) was apparent. Detailed life histories of short marine term anadromous individuals were estimated from otolith Sr fluctuations and ageing, from both scale and otolith daily increments. Consequently, more than half of the Naka River population was estimated to migrate to a marine environment upon reaching a total length of 178–252 mm (one year old) in December–January, thereafter staying in marine waters for approximately five months, before returning to the river in May–July at 345–463 mm total length. These findings may help establish an enhancement method for this species as a recreational fishery stock. Future investigations, including tagging, verification of age evaluation methods, and gene analysis are necessary to confirm the existence of the short marine term anadromous form.

Theme 4: Management Systems

Kaeriyama, M., H. Araki, K. Miyashita, M. Nagata, Y. Sasaki and S. Urawa. 2018. Sustainable conservation management and research issues for Japanese chum salmon under the changing climate. Aquabiol., 40: 459–466. In Japanese with English summary.

Since the late 1990s, population size and survival rate of Japanese chum salmon (*Oncorhynchus keta*) have indicated a decreasing trend. Juvenile chum salmon migrate from coastal seas around the northern Japan to the Okhotsk Sea at the developmental stage of post-fingerling (8-12 cm in fork length) from the end of June to July. We addressed potential progress of the warming climate effect of Japanese chum salmon using the COBE-SST Database and the NOAA NCEP-ESRL Database, and the growth back-calculation method based on the scale analysis. We also used the optimum temperature (OT; 8-12°C) and the adaptable temperature (AT; 5-7°C) for chum salmon based on their feeding and migrating behavior, distribution and growth rate. The survival of chum salmon should be evaluated by the growth through the first-year of ocean life, because the body size in the age 1 had higher correlation with adult returns than it at the offshore migration. The resident duration of juvenile in the coast decreased since the 1960s. The area of AT and OT has suddenly decreased in the 2010s in the North Pacific Ocean, and also quietly departed from Hokkaido Island since the 2010s in the Okhotsk Sea. The survival rate of Hokkaido chum salmon showed a significant increase trend within the OT, but turned to decrease when the SST was over the OT in the southern Okhotsk Sea in July. These results suggest that Hokkaido juvenile chum salmon may miss a migration route to the Okhotsk Sea, in a decline of their early survival rate under the warming climate in the Okhotsk Sea. To protect and use Japanese chum salmon under the changing climate, we should establish the ecosystem-approach sustainable salmon conservation management based on the back-cast method, including the adaptive management and the precautionary principles, while conserving wild populations and recovering the natural river ecosystem. The final conservation management goals are: (1) to establish concepts of conservation and use of chum salmon, (2) to clarify relationship between Pacific salmon aquatic ecosystems (freshwater and ocean), and (3) to restore wild salmon populations and the natural river ecosystem for the natural reproduction in Japan.

Kasai, H and M. Yoshimizu. 2018. Health management of hatched fry for sustainable propagation of chum salmon (*Oncorhynchus keta*). Aquabiol., 40: 441–448. In Japanese with English summary.

Chum salmon (*Oncorhynchus keta*) is important species for hatchery reared and related fish. Viral, bacterial and parasitical diseases are one of the limitations of successful propagation of this species. Methods currently used to control the diseases are 1) hygiene and sanitation in the facility, 2) using a pathogen free rearing water, 3) surveillance of pathogens for matured fish, 4) eggs management and disinfection, and 5) health monitoring of hatched fry before release. Under these circumstances, hatched fry are healthy and specific pathogen free. There is still possibility of infection by some pathogens in environment after they are released to river. For prospective studies, development of effective vaccines, vaccination methods and immunological tools for monitoring an immunological response are necessary.

Morita, K. and N. Aruga. 2018. Management procedure for determining the stocking effects of salmon fry in Toyohira River. Towards a balance between wild fish conservation and population persistence. Jap. J. Conserv. Ecol., 22: 275–287 (In Japanese with English abstract).

The Toyohira River, which flows through the Sapporo metropolitan area, is annually supplemented with ~200,000 fry of the chum salmon *Oncorhynchus keta*. The river additionally supports a naturally spawning chum salmon population composed of over half of all salmon returning to the river. Recent studies have suggested that hatchery releases may exert negative effects on wild salmon productions. However, it is unclear whether the salmon population of the Toyohira River would persist without hatchery supplementation. We proposed a management procedure for determining the stocking efforts of salmon fry with a feedback control loop to reduce the risk of population decline. The performance of the management procedure was evaluated by simulation using the operating model. The operating model was based on the age-structured Ricker-logistic population model with environmental and demographic stochasticity. Our results showed that implementation of the management procedure with a feedback control loop wherein the number of fry released was adjusted based on the number of returning adults resulted in relatively good performance with a small risk of population decline. Thus, this procedure, implemented in 2016, reduced the number of hatchery fry released in that year to 85,100 (43% of the normal level).

Urawa, S., H. Araki, K. Miyashita, M. Nagata, Y. Sasaki and M. Kaeriyama. 2018. Sustainable management of chum salmon in changing environments: a prologue for the International Year of the Salmon. Aquabiol., 40: 315-318. In Japanese with English summary.

Chum salmon migrate widely in the North Pacific Ocean and adjacent seas, and finally return to their natal river for spawning. In Japan, chum salmon enhancement was initiated in 1880s, and the adult reruns increased from the 1970s with a peak of 89 million fish in 1996 due to the improvement of hatchery technologies and favorable ocean condition. Chum salmon are an indispensable fisheries resource in northern Japan, but the recent adult returns have trended decreasing with considerable interannual and regional fluctuations. Pacific salmon are biologically and economically important for North Pacific rim countries, while they are facing unpredictable future: e.g., considerable reduction in salmon habitats and survivals may be caused by global warming. The North Pacific Anadromous Fish Commission (NPAFC) and North Atlantic Salmon Conservation Organization (NASCO) are leading to promote a major program

"the International Year of the Salmon (IYS)" with focal year in 2019. The IYS is an international framework for collaborative research and outreach to ensure that salmon and their habitats are conserved against increasing environmental variability. In association with the IYS, a JSFS Spring Meeting Symposium entitled "Sustainable Management of Chum Salmon in Changing Environments" was held at Tokyo University of Marine Science and Technology in Tokyo, Japan on March 26, 2018. The symposium aimed to: (1) comprehend the vision of IYS program; (2) understand the present status of chum salmon populations and their habitats; (3) assess effects of environmental variability on chum salmon distribution and survival; (4) evaluate new research technologies to advance salmon science; and (5) identify future research topics for their sustainable management. The program included a keynote presentation by Dr. R. Beamish and 14 oral presentations, followed by a panel discussion. The symposium proceedings are recorded in August and October issues of Aquabiology Volume 40.

Yatsuya, M., K. Sasaki, Y. Shimizu, K. Ohta, K. Yamane, Y. Yamada, S. Moriyama, Y. Nagakura, and H. Nikaido. 2018. Effects of duration of net-pen acclimation and timing of river stocking on early growth and adult return of chum salmon along the Pacific coast of Honshu, Japan. N. Pac Anadr. Fish Comm. Tech. Rep. 11: 127–128 (Available at https://npafc.org).

Iida, M. 2018. Homing ability of Japanese chum salmon and differences in their return timing by reproductive season. N. Pac Anadr. Fish Comm. Tech. Rep. 11: 135–136 (Available at https://npafc.org).

Theme 5: Integrated Information Systems

No publication.