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Shunpei Sato, Masa-aki Fukuwaka, and Shigehiko Urawa

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

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Shunpei Sato, Masa-aki Fukuwaka, and Shigehiko Urawa

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

ABSTRACT: This bibliography listed original papers and documents published in 2016 by Japanese scientists and/or their collaborators to review Japanese national researches for the 2016-2020 NPAFC Science Plan. The bibliography includes 32 articles with abstracts, corresponding to five research themes of the NPAFC Science Plan.

Key Words: 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 2016 by Japanese scientist and/or their collaborators. The current issue supplemented 32 articles published in 2016. 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 www.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 www.npafc.org).

BIBLIOGRAPHY

Theme 1. Status of Pacific Salmon and Steelhead Trout

Ando, D., K. Shimoda, H. Hayano and Y. Miyakoshi. 2016. The effect of age of males on the early growth of chum salmon fry. Nippon Suisan Gakkaishi 82: 298-305. (In Japanese with English abstract).

To evaluate the effect of male age and size on the early growth of chum salmon fry, a diallel cross was performed using 5 females (4 years old) and 9 males (3 males, 3 years old; 3 males, 4 years old; and 3 males, 5 years old). Further, heritabilities for body weight were estimated at each developmental stage. Although no significant relationships were detected between male body weight and fry size, the body weight of fry from crosses using 5-year-old males tended to be lower than that of fry from crosses using 3- to 4-year-old males. In addition, heritability increased as the fry developed. These results suggest that the age of males is one of the factors that influence the early growth of chum salmon fry.

Hara, M., G. Kawada, M. Enomoto, A. Tomiya, D. Morishita, S. Izumi, and M. Nakajima. 2016. Changes in radioactive Cesium (^{137}Cs) concentration in masu salmon, *Oncorhynchus masou*, and muddy sediment in rivers in Fukushima after nuclear accident. Fish Gent. Breed. Sci. 45: 33-39. (In Japanese with English abstract).

Fukushima Daiichi Nuclear Power Station accident occurred at March 11, 2011 led the deposition of the radioactive cesium (137Cs) at freshwater fishery grounds. Although more than three years have passed, high level of 137Cs has been detected from the muddy sediment and fishes in rivers of Fukushima. Since the situation of pollution by radioactive materials and its change is still unknown, the pollution will have physiological and genetic effects on freshwater fishes. For the understanding of the effects of 137Cs on fishes, the amount of remaining 137Cs and its changes in masu salmon, which is important fish as food resources and game fishing, was examined from 21 to 43 months after the accident. Multi-regression analysis was used for the identification of significant regression between the amount of 137Cs and variables. Significant regressions were observed between 137Cs concentration in fish and rivers, body weight and seasons. The positive regressions were observed in Ukedo R. and body weight, on the other hand negative regression was observed in summer. In the case of each river, negative regression was observed in the Abukuma and Mano rivers. On the other hand, significant decrease was not observed in the muddy sediment in each river. The decline tendency observed in the Abukuma and Mano rivers probably caused by the decline of the inflow amount from the surrounding environments.

Kasugai, K., and Y. Sasaki. 2016. Relationship between release sites and return of adult chum salmon to the rivers in the Nemuro Region, eastern Hokkaido. Sci. Rep. Hokkaido Fish. Res. Inst. 89: 17-21. (In Japanese with English abstract).

The relationships between the release sites of chum salmon fry and the return of adult salmon to the river was examined by comparing the number of released chum salmon fry from 1984 to 2012（brood years）and that of returned adult salmon four years after their release in the 11 rivers of the Nemuro Region, eastern Hokkaido, northern Japan, where fry were stocked and adults were captured. A significant positive correlation was observed between mean river return rates and downstream distances in each river-shorter the downstream distance, the lower the river return rate. Moreover, a significant negative correlation between the coefficient of variation for river return rate and downstream distance indicated that these rates might fluctuate considerably in rivers with short downstream distances.

Kasugai, K., M. Nagata, K. Takeuchi, M. Torao, Y. Murakami, Y. Sasaki, Y. Miyakoshi, and J. R. Irvine. 2016. Migratory timing of masu salmon and Dolly Varden smolts exiting the Uebetsu River near the Shiretoko World Heritage Site, Hokkaido, Japan, and potential angling effects. Ichthyol. Res. 63: 181-186.

Numbers of masu salmon and Dolly Varden in streams in the Shiretoko Peninsula, location of the Shiretoko World Heritage Site in north eastern Hokkaido, appear to be declining. One concern is whether masu salmon smolts continue to migrate during July, after the existing May to June angling closure established to protect migrating smolts in eastern Hokkaido. Smolt timing and relative abundances were monitored in the Uebetsu River near the World Heritage Site from May to July during 2005–2007. Each year some masu salmon smolts emigrated during July, especially in 2005 when 82% of smolts captured were caught that month. In contrast, most anadromous Dolly Varden smolts emigrated prior to early June when stream temperatures <8°C. Mean fork lengths of smolts in both species decreased during the runs. The current fishing closure period (May to June) may be insufficient to protect masu salmon smolts in this unique area from angling.

Kasugai, K., H. Saneyoshi, T. Aoyama, Y. Shinriki, A. Iijima, and Y. Miyakoshi. 2016. Early marine migration of juvenile chum salmon along the Pacific coast of eastern Hokkaido. N. Pac. Anadr. Fish Comm. Bull. 6: 61–72. doi:10.23849/npafcb6/61.72.

The number of chum salmon returning to the eastern Pacific coast of Hokkaido has been rapidly decreasing over the last five years. The Kushiro River is the main production center for chum salmon enhancement in this area. In order to understand the recent decrease in the number of chum salmon returning to this area, we surveyed the distribution and migration of juvenile chum salmon in the coastal area of Kushiro from 2012 to 2014. Many juvenile chum salmon appeared in the nearshore area after late May–early June, corresponding to sea surface temperatures higher than 8°C. In the coastal area of Kushiro, a cold current with low salinity (called the Coastal Oyashio Current) flows westward near shore from spring to summer and may affect the distribution of juvenile chum salmon by altering the environmental conditions. We speculated that most juvenile chum salmon caught in the Kushiro nearshore area after late May might have grown outside this area because body lengths differed significantly between marked fish recaptured in ports and harbors and those in the nearshore area. In late June, the examination of the otolith marks applied to large juveniles that appeared in the Kushiro nearshore area suggests that most of the large juveniles were released in other regions of the Pacific coast, west of Kushiro. Most of the juvenile chum salmon were captured within 1 km of the Kushiro shoreline. Our results suggest that coastal environments in the nearshore area (< 1 km from shore) affect the distribution and survival of chum salmon. We further suggest that the Kushiro coastal area is an out-migration route for juvenile chum salmon from distant stocks along the Pacific coast of Japan.

Miyakoshi, Y., M. Fujiwara, D. Ando, and M. Nagata. 2016. Return of chum salmon released from a river and a net-pen in eastern Hokkaido. Sci. Rep. Hokkaido Fish. Res. Inst. 89: 9-15. (In Japanese with English abstract).

Marked juvenile chum salmon were released from the Abashiri River and a net−pen installed in the fishing port near the river mouth from 2003 to 2005 to compare the numbers of marked fish recovered in coastal commercial fishery and in river catch for broodstock. The number of marked fish recovered in the coastal fishery was higher for net−pen release than for river release for fish stocked in 2003, but lower for fish stocked in 2004 and 2005. The numbers of recovered fish in the river was observed to be lower for net−pen releases than for river releases in all cases

when compared to the number of recoveries in the coastal fishery. Although release from a net−pen can be an effective stocking method for chum salmon, it should not be considered for broodstock collection. In addition, return timing and maturity level also differed between fish released from the river and the net−pen.

Miyamoto, K. 2016a. Effect of visual and chemical stimuli on predator avoidance behavior in juvenile masu salmon *Oncorhynchus masou*. Aquacult. Sci. 64: 43-51.

Observation were undertaken to determine whether exposure to a visual (a model bird) or a chemical stimulus (skin extracts from a conspecific) were capable of inducing predator avoidance behaviors in masu salmon. The results showed that both visual and chemical stimuli induced predator avoidance behavior: hiding under a shelter, partially concealing themselves in gravel, freezing and ceasing to feed. To test whether the fish reacted differently to the two stimuli, the locations in the aquarium selected by the fish when exposed to the stimuli were compared. The number of fish that selected the gravel on the bottom as a hiding place was significantly greater during the visual (bird attack) than the chemical alarm cue stimulus. On the other hand, the number of fish that selected the shelter as a hiding place was significantly greater during the chemical alarm cue than bird attach trail. These results suggest that both visual and chemical stimuli are capable of inducing predator avoidance behavior in masu salmon and that each stimulus has a different effect on their selection of hiding place.

Miyamoto, K. 2016b. Effects of body color luminance and behavioral characteristics on predation risk in salmonid fishes. Hydrobiologia 783: 249-256.

We investigated the effects of body color luminance and behavioral characteristics of stocked juvenile white-spotted charr, masu salmon, rainbow trout, albino rainbow trout, and non-spotted rainbow trout on their predation risk by predatory land animals. Body color luminance and behavioral characteristics were scored before starting the predation test. The dorsal color luminance of the albino rainbow trout was brighter than that of the other fish. The white-spotted charr and non-spotted rainbow trout were less active than the masu salmon and rainbow trout, and the non-spotted rainbow trout stayed in the open more than the white-spotted charr during behavioral observations in an aquarium. A piscivorous bird, the grey heron was the most frequently observed land animal during the predation test conducted at a semi-natural stream study site. The survival rate of total fish groups was 21.4 %, only 3 % albino rainbow trout and 11 % non-spotted rainbow trout survived, which were significantly lower than the survival rate of the other fish. These results suggest that the body color luminance of albino rainbow trout and the behavioral characteristics of non-spotted rainbow trout were important vulnerability factors.

Myers, K.W., J.R. Irvine, E.A. Logerwell, S. Urawa, S.V. Naydenko, A.V. Zavolokin, and N.D. Davis. 2016. Pacific salmon and steelhead: life in a changing winter ocean. N. Pac. Anadr. Fish Comm. Bull. 6: 113–138. doi:10.23849/npafcb6/113.138.

How Pacific salmon and steelhead (*Oncorhynchus spp.*) respond to climate-driven changes in their oceanic environment is highly uncertain, in part due to limited information on winter distribution in international waters (high seas) of the North Pacific Ocean and Bering Sea. We review what is known and summarize what should be known to properly address the question: Where do Pacific salmon go in the high seas during winter and why, and how might this be affected by climate change? Historical high-seas research (1950s–1970s, all seasons) discovered that there are species and stock-specific distributions in the high seas; winter survey results provided some clues as to important winter locations and dominant oceanographic features of winter habitat. In succeeding decades (1980–2015), new fisheries-oceanographic survey methods, stock-identification techniques, remote-sensing technologies, and analytical approaches have enabled us to expand our knowledge of the winter distribution and ecology of salmon, although

empirical data are still very limited. In general, we learned that the “why” of ocean distribution of salmon is complex and variable, depending on spatio-temporal scale and synergies among heredity, environment, population dynamics, and phenotypic plasticity. The development of quantitative multispecies, multistage models of salmon ocean distribution linked to oceanographic features would help to identify key factors influencing winter distribution and improve understanding of potential climate change effects.

Ohkuma, K., K. Fukuda, T. Tojima, and I. Ono. 2016. Effect of cross breeding with domesticated males on smolting in masu salmon *Oncorhynchus masou*. Nippon Suisan Gakkaishi 82: 18-27. (In Japanese with English abstract).

The rehabilitation of masu salmon resources, which have been declining for a long time, is strongly desired by coastal fishermen, especially in the Japan Sea region of northern Japan. Meanwhile, inland fisheries cooperatives release large numbers of riverine masu salmon, so-called "yamame", which have been domesticated through many generations and show high growth and low smolting rates. Genetic contamination and the resulting reduction of smolting rate by the supposed cross-breeding of native anadromous female masu with the released male yamame are a serious issue. In this study, we experimentally bred anadromous female masu and male yamame, to investigate the effects on the smolting ratio. Regarding the maturation rate for young of the year (YOY) males, a higher rate was found in the Okutama-bred (OKT) group in five out of six compatible pairs, of which three were statistically significant ($p < 0.05$, chi-square test). As for the smolting ratio of male fish, the Chitose-bred(CTS) group showed a higher rate than the OKT group in all six pairs, and five pairs were significantly different ($p < 0.01$, chi-square test). Among the CTS group, almost all female fish were smoltified in every group, and the smolting rate of each group reflected the difference in smolting rate of male fish.

Qin, Y., and M. Kaeriyama. 2016. Feeding habits and trophic levels of Pacific salmon (*Oncorhynchus* spp.) in the North Pacific Ocean. N. Pac. Anadr. Fish Comm. Bull. 6: 469–481. doi:10.23849/npafcb6/469.481.

Feeding of Pacific salmon (*Oncorhynchus* spp.) was evaluated by diet composition and stable isotope analysis of carbon and nitrogen. Pacific salmon can be classified into 3 groups; Chinook salmon and steelhead trout as nekton feeders, chum and pink salmon as zooplankton feeders, and sockeye and coho salmon as alternative (zooplankton/nekton) feeders, depending on the conditions in their foraging habitats and intra- and inter-specific interactions. In some ecosystems of the North Pacific Ocean, food chains from phytoplankton to Pacific salmon have the same slope on the linear relationship between carbon and nitrogen stable isotopes based on the kinetic isotope effect. Based on the results of carbon and nitrogen stable isotope analysis, Chinook salmon occupied the highest trophic level (4.3 ± 0.3), followed by steelhead trout (4.1), sockeye (3.9 ± 0.1), coho (3.9 ± 0.4), chum (3.6 ± 0.3) and pink (3.5 ± 0.2) salmon. The framework and function of feeding patterns in Pacific salmon appears to be influenced by both the ecosystem structure in a given foraging habitat and their intra- and inter-specific interactions.

Sahashi, G., and K. Morita. 2016. Potential threat of introduced rainbow trout *Oncorhynchus mykiss* to native salmonids in the western part of Hokkaido, Japan. Ichthyol. Res. 63: 540-544.

The following five results were obtained in 10 rivers while elucidating the potential threat of introduced rainbow trout to native salmonids. First, native salmonid density decreased with increasing trout density. Second, four environmental variables, namely altitude, distance from the sea, river width, and river depth, did not significantly affect trout density. Third, the distribution of trout expanded, and trout were the dominant species in an unconfined river. Fourth, the trout

invasion has changed salmonid faunas over the last 20 years. Lastly, smolt trout were collected from a river. Therefore, the potential threat to native salmonids due to trout introduction is continuously increasing.

Sato, M., K.-I. Kikuchi, and J.-I. Tsuboi. 2016. Relationships between male type, spawning habitat, and survival rate at the eyed stage of the masu salmon *Oncorhynchus masou*. Nippon Suisan Gakkaishi 82: 581-586. (In Japanese with English abstract).

Relationships between male type (resident or anadromous), spawning habitat, and survival rate at the eyed stage of masu salmon were investigated in the Yoneshiro River, near the southern distribution limit of the species. A total of 24 pairs of resident-type male x anadromous-type female (RM x AF) and 11 pairs of anadromous-type male x anadromous-type female (AM x AF) were observed in nine tributaries. The total length of anadromous males was 2.1 times that of resident males. Sneaker males were also observed near the pairing sites. The number of sneaker males did not differ significantly between the RM x AF and AM x AF pairs. Also, water depth, water velocity, substrate (major axis), and cover rate of the spawning redd did not differ significantly between male types. Furthermore, the survival rate at the eyed stage did not vary by male type (small resident or large anadromous), perhaps because sperm from sneaker males fertilized the spawned eggs. In conclusion, it is important to conserve the resident male type to sustainably manage masu salmon populations.

Shimizu, T., M. Ban, Y. Miyauchi, K. Umeda, K. Nakao, M. Fujii and H. Mayama. 2016. Nutritional condition of hatchery and wild chum salmon *Oncorhynchus keta* fry migrating down the Chitose River. J. Fish. Technol., 8: 89-94.

The aim of this study was to compare the nutritional condition of hatchery-reared and wild chum salmon fry migrating down the Chitose River in Hokkaido, Japan. A total of 30,300,000 otolith-marked fry were released into the Chitose River from the Chitose Field Station during March and April 2013. A total of 186 chum salmon fry were subsequently captured downstream using net traps between April and June. The captured specimens included 56 hatchery-reared and 122 wild fry. Most of the hatchery-reared fry were captured shortly after being released in mid-April, while wild fish were captured throughout the sampling period with a peak in late May. The captured hatchery-reared fry were larger than the wild fish, but the condition factor, liver weight index and triglyceride content for the captured fry did not differ significantly between the hatchery-reared and wild fry. While the glycogen content of hatchery-reared fry was very high before they were released, these levels had decreased markedly compared to wild fry by the time of capture. The findings suggest that the hatchery-reared fish were under considerable nutritional stress in the river, but their nutritional condition did not threaten their survival.

Shimoda, K., T. Takami, T. Aoyama, H. Sakamoto, S.-I. Ohkubo and K. Takeuchi. 2016. Decadal changes in population densities of brown trout and native salmonid fishes in four rivers in Hokkaido, Japan (note). Sci. Rep. Hokkaido Fish. Res. Inst. 90: 33-45 (In Japanese, No abstract).

Takahashi, S., K. Hasegawa, H. Ito, M. Ban, and Y. Miyauchi. 2016. Comparisons of growth of chum salmon fry released into rivers of which temperature and prey abundance conditions were different. Nippon Suisan Gakkaishi 82: 559-568 (In Japanese with English abstract).

Riverine environments are important factors that must be considered when deciding on which rivers to carry out hatchery programs of chum salmon fry. In this study, the surveys were conducted in the Chitose River and its tributary, the Mamachi Stream, in order to compare the growth of released fry. These rivers were different in thermal condition and prey abundance, i.e.

the Chitose River was characterized as a high prey abundance, low temperature environment, and vice versa for the Mamachi Stream. In the two rivers, we monitored temporal changes of body size from 2008 to 2012, and in addition to body size, stomach fullness in 2012. The results showed that growth was greater in the Mamachi Stream than in the Chitose River. In addition, stomach fullness was greater in the Mamachi Stream than in the Chitose River, and the difference became greater with time. These results suggest that high temperatures caused high growth through high foraging efficiency. The relationships between prey abundance and growth were still unclear because of failure to evaluate the density of interacting fishes with released fry.

Urawa, S., T.D. Beacham, S. Sato, T. Kaga, B.A. Agler, R. Josephson, and M. Fukuwaka. 2016. Stock-specific abundance of chum salmon in the central Gulf of Alaska during winter. N. Pac. Anadr. Fish Comm. Bull. 6: 153–160.

Winter is believed to be a critical period for marine salmon survival. In February 2006, a winter research cruise was conducted to examine the stock-specific distribution and biological status of salmon in the central Gulf of Alaska (GOA). By surface trawl, 519 chum salmon were caught at seven stations (48–54ºN, 145ºW) where the surface seawater temperature ranged from 5.2ºC (54ºN) to 7.0ºC (48ºN). Ocean age-2 and -3 fish were dominant at all sampling stations, and young fish (ocean age-1) were distributed in the southern stations. The stock composition of chum salmon abundance (CPUE) estimated by microsatellite DNA analysis was 11% western Alaska/Alaska Peninsula, 11% Prince William Sound (PWS), 16% Southeast Alaska (SEAK), 6% northern British Columbia (BC), 17% southern BC, 2% Washington, 17.5% Russian, and 20% Japanese stocks. There was a latitudinal shift in the stock-specific distribution: North American stocks were dominant in northern waters, and Asian stocks were dominant in southern waters. All young fish (ocean age-1) were North American origin (mostly PWS, SEAK and southern BC), while the proportion of Asian (Japan and Russia) stocks increased with ocean age. The samples included 48 otolith-marked fish released from hatcheries in PWS (n = 7), SEAK (n = 37), BC (n = 1), and Japan (n = 1). A comparison of CPUEs estimated by genetic stock identification and otolith mark recoveries suggested that the contribution of hatchery fish was variable among brood years (0–51%, PWS stock; 19–87%, SEAK stock). Microsatellite and otolith mark analyses confirmed that various stocks of North American and Asian chum salmon inhabit the central GOA during winter. Their winter distribution pattern is different among regional stocks or age groups, maybe reflecting stock- or age-specific preferences for habitat water temperatures to maximize survival.

Wagawa, T., T. Tamate, H. Kuroda, S.-I. Ito, S. Kakehi, T. Yamanome, and T. Kodama. 2016. Relationship between coastal water properties and adult return of chum salmon (*Oncorhynchus keta*) along the Sanriku coast, Japan. Fish. Oceanogr. 25: 598-609.

We investigated the relationship between adult (age-4) return rates for chum salmon originating from the Iwate Prefecture, Japan, and coastal environmental conditions during their early ocean life in coastal residency. We analyzed distributions of water properties via intensive hydrographic observations using a conductivity–temperature–depth profiler. Both the return rates and water properties vary strongly over interannual time scales. We found that the time when the return rate decreased drastically corresponded well to the time when the frequency of warm waters in the coastal residency increased.

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

Beacham, T.D., J.R. Candy, S. Sato, and S. Urawa. 2016. Microsatellite identification of sockeye salmon rearing in the Bering Sea during 2009, and 2011–2014. N. Pac. Anadr. Fish Comm. Bull. 6: 421–432. doi:10.23849/npafcb6/421.432.

Stock composition of sockeye salmon caught in the southern central Bering Sea during Japanese research cruises in the summers of 2009, 2011, 2012, 2013, and 2014 was estimated through an analysis of microsatellite DNA variation. Ocean age x.1 individuals were well separated from ocean age x.2 and x.3 individuals in fork length, with a bimodal distribution observed in fork length for all five sampling years. Body weight distributions were similarly well defined between age x.1 and x.2 individuals, with x.1 individuals typically less than 800 g in weight, reflective of the bimodal distribution of body weight. Based upon geography and relative abundance, sockeye salmon of Bristol Bay origin should be expected to dominate catches of immature sockeye rearing in the Bering Sea, with sockeye salmon originating from Russia the next most abundant stock. These were precisely the results observed from our analysis of immature sockeye salmon rearing in the central Bering Sea in July and August (2009–14). Alaskan-origin sockeye salmon were the most abundant in the catch, comprising approximately 85% of all sockeye caught, with the catch dominated by sockeye of Bristol Bay origin. Russian-origin salmon accounted for approximately 10% of the annual catch, while Canadian-origin sockeye accounted for 5% of the annual catch.

Beacham, T. D., C. Wallace, S. Sato, and S. Urawa. 2016. Microsatellite identification of sockeye salmon rearing in the Bering Sea during summer 2015. NPAFC Doc. 1627. 11 pp. (Available at http://www.npafc.org).

Stock composition of sockeye salmon caught in the southern central Bering Sea during a Japanese research cruise in the summer of 2015 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, comprising 91% of all sockeye salmon caught, with the catch dominated by sockeye salmon of Bristol Bay origin (74%). Canadian-origin salmon accounted for an average of 8% of the annual catch, while Russian-origin sockeye salmon accounted for 1% of the annual catch.

Iida, T., K. Sakaoka, Y. Kajiwara, N. Hoshi, M. Ohwada, K. Imai, and S. Takagi. 2016. Results of 2015 salmon research by the *Oshoro-maru*. NPAFC Doc. 1635. 10 pp. (Available at www.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). The survey was conducted during the Cruise #012 in May 2015. Nine oceanographic observations, three drift gillnet surveys, four line and hock surveys and one surface long-lime survey were conducted along the 155°E line. A total of 75 salmonids including 72 pink and 3 chum salmon was caught by gillnet and hock-line surveys. Pink salmon was the dominant species in this region. The fork length (FL) of pink salmon collected by C-gear gillnet ranged between 356-472 mm. To collect salmon samples extensively and to collect fresh salmon blood and various tissues, one surface long-line and four hook-and-line gear samplings were

conducted during the Cruise #012. Almost all of caught by these gears were pink salmon. A total of one chum and 12 pink salmon were collected during the Cruise #012.

Ishida, Y., A. Yamada, and K. Nagasawa. 2016. Future climate-related changes in fish species composition including chum salmon (*Oncorhynchus keta*) in northern Japanese waters, inferred from archaeological evidence. N. Pac. Anadr. Fish Comm. Bull. 6: 243–258.

Fish remains found at archaeological sites in Kushiro (Hokkaido) and Satohama (Miyagi) in northern Japan are reviewed to infer future climate-related changes in fish species composition including chum salmon in northern Japanese waters. Published seawater temperature ranges of contemporary fish distribution are also examined. Marine fish assemblages, including chum salmon found in Kushiro and Satohama, contained 12–16 and 13–17 species, respectively. Sharks, Japanese sardine, Pacific herring, fat greenling, and Japanese sea bass were common at both sites. Pacific cod and rainbow smelt were detected only in Kushiro, and bartail flathead and threadsail filefish, only in Satohama. Based on contemporary temperature ranges of fishes from Kushiro, mean seawater temperature (MST) is estimated to have declined from 16.3ºC in the early Jomon period (7,000–4,500 yr BP) through 15.8ºC in the final Jomon period (3,000–2,400 yr BP) to 15.1ºC in the Satsumon and Ainu periods (700–200 yr BP). Similarly, the data from Satohama suggest that MST decreased from 16.9ºC in the early Jomon period (7,000–4,500 yr BP) through 16.6ºC in the middle Jomon period (4,500–3,500 yr BP) to 16.1ºC in the final Jomon period (3,000–2,400 yr BP). Chum salmon were found in a period when MST was lower than 16.3ºC in Kushiro and 16.1ºC in Satohama. According to the most current IPCC (Intergovernmental Panel for Climate Change) report, the mean and maximum global SSTs are projected to increase by 1.25–2.10ºC, respectively, by 2060. Based on such information, the mean and maximum MSTs in 2060 are projected to be 15.5–15.7ºC in Kushiro, and 15.8–16.0ºC in Satohama, suggesting that the present-day fish species composition in northern Japanese waters is likely to be similar to that of the final Jomon period. Therefore, our results suggest that chum salmon will remain in both Kushiro and Satohama under mean and maximum projected global SST increase scenarios.

Saito, T., Y. Hirabayashi, K. Suzuki, K. Watanabe, and H. Saito. 2016. Recent decline of pink salmon (*Oncorhynchus gorbuscha*) abundance in Japan. N. Pac. Anadr. Fish Comm. Bull. 6: 279–296. doi:10.23849/npafcb6/279.296.

We analyzed the 1976–2014 time series of in-river Japanese pink salmon catch from 22 stocks along the Sea of Okhotsk coast to identify regional variability in abundance and to examine the effects of sea surface temperature (SST) on regional variability. Residuals from regressions of catch between parental and off spring generations for the 22 stocks were integrated into five regional groups by principal components analysis. Each of the principal components was associated with coastal SSTs, particularly during early ocean residency of juveniles and/or adult spawning migrations. Negative SST anomalies in spring have increased abruptly during summer since the mid-2000s, which is probably related to the decrease in pink salmon survival in recent years. The catch period decreased in all regions during the study, accompanied by an earlier peak in some regions. Catch diversity in southern stocks was negatively correlated with mean coastal SSTs during April–September. Although the loss of diversity was possibly associated with the recently higher SSTs, we could not deny that artificial hatchery selection for early migrants, which has occurred for more than a decade, may have significantly altered migration timing.

Sato, S., K. Honda, T. Sato, M. Tomiyasu, A. Seitz, and K. Suzuki. 2016. The summer 2015 Japanese salmon research cruise of the R/V *Hokko maru*. NPAFC Doc. 1640. 16 pp. (Available at www.npafc.org).

A summer high-seas research cruise to investigate the biology of Pacific salmon was conducted from July 24 to August 13 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 2,427 salmonids were caught by trawls, Live-Box, and angling. Chum salmon was the most abundant species (75.0%), followed by sockeye salmon (18.7%), Chinook salmon (4.49%), pink salmon (1.57%), and coho salmon (0.21%). 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. There were 50 chum, 14 sockeye, 10 Chinook, and one pink salmon tagged with disk tags and released in the Bering Sea. Among tagged fish, five large chum salmon and six large Chinook salmon were released with DST magnetic tags and pop-up satellite archival tags, respectively. Age-specific catch per unit effort for each surface trawl (CPUE) and annual mean body weight in each ocean age of chum salmon from 17 monitoring stations from 2007 to 2015 are documented here.

Sato, T., S. Sato, S. Urawa, and T. Nagasawa. 2016. Variation in zooplankton and micro-nekton biomass in response to seawater temperature changes in the central Bering Sea during summer. N. Pac. Anadr. Fish Comm. Bull. 6: 207–217. doi:10.23849/npafcb6/207.217.

We investigated biomass of zooplankton and micro-nekton using Norpac and bongo nets in the central Bering Sea in summer, 2007 to 2014 (except for 2010). We determined the biomass of zooplankton (including euphausiids, copepods, amphipods, decapods, chaetognaths, appendicularians, gastropods, hydrozoans, ostracods, and polychaetes) and micro-nekton (cephalopods, myctophids, and other fishes) in the central Bering Sea. The mean biomass of total zooplankton collected with the Norpac net increased from 2007 to 2009, but fluctuated from 2011 to 2014. Biomass of each prey category collected with bongo nets showed different tendencies among years. There were negative correlations between integrated mean seawater temperature and biomass of zooplankton collected with both Norpac and bongo nets. The biomass of copepods, amphipods, and hydrozoans was significantly lower in warm years. Other zooplankton categories (euphausiids, decapod larvae, ostracods, chaetognaths, and appendicularians) showed slightly negative or positive (polychaetes and gastropods) correlations with seawater temperature. These variations could not be explained by temperature changes alone. On the other hand, there was almost a constant correlation between integrated mean temperature and biomass of micro-nekton collected with bongo nets. The results of this study suggested that variation in zooplankton and micro-nekton biomass in the central Bering Sea may be affected by the seawater temperature.

Ueno, H., M. Kaeriyama, M. Otani, M. Oe, Y. Qin, M.N. Aita, S. Yoon, and M.J. Kishi. 2016. Temporal and spatial variation in growth condition of Pacific salmon. N. Pac. Anadr. Fish Comm. Bull. 6: 181–187. doi:10.23849/npafcb6/181.187.

Temporal and spatial variation in the growth condition of Pacific salmon (*Oncorhynchus* spp.) were investigated using the prey-density function for consumption. Zooplankton prey density was estimated from an ecosystem model, NEMURO, embedded in a 3D physical model for the years 1948–2007. This study focused on three species of Pacific salmon (chum, pink, and sockeye salmon), all of which are zooplankton feeders. The prey dependence function for

consumption of Pacific salmon varies on a decadal time scale, and its empirical orthogonal function first mode was correlated with the Pacific Decadal Oscillation. The variation in the prey dependence function for consumption in the Bering Sea and the Western Subarctic Gyre was correlated with the variation in the carrying capacity of chum, pink, and sockeye salmon, indicating that these are key areas for connecting climate variability to the carrying capacity of Pacific salmon. In these areas, prey density increased after the 1976/77 regime shift, in synchrony with the increase in primary production due to enhanced nutrient supply through deepening of the mixed layer and/or stronger Ekman upwelling.

Urawa, S., and 25 co-authors. 2016. Forecasting Pacific salmon production in a changing climate: a review of the 2011–2015 NPAFC Science Plan. N. Pac. Anadr. Fish Comm. Bull. 6: 501–534. doi:10.23849/npafcb6/501.534.

In recent decades, the marine production of Asian and North American Pacific salmon and steelhead populations has undergone significant variability linked to climate change. Improved forecasts of the abundance and distribution of salmon are needed that will benefit stock management in all salmon producing countries around the North Pacific Rim. The North Pacific Anadromous Fish Commission (NPAFC) Science Plan is a long-term comprehensive strategy for international cooperative research. The primary goal of the 2011–2015 Science Plan was to explain and forecast annual variations in Pacific salmon production. The plan was developed with an overarching research theme "Forecast of Pacific Salmon Production in the Ocean Ecosystems under Changing Climate" and five research topics. This paper describes progress made on each research topic and the overarching theme, much of which was assessed at an international symposium in Kobe, Japan, on May 17–19, 2015. In summary, the reliability of stock identification methods including genetic and otolith mark analyses has improved, enabling better monitoring of stock-specific ocean distribution and abundance. Salmon marine survival depends on early marine coastal environments but also on conditions later in life, including winter. Models incorporating fish mortality and various environmental factors improve our ability to forecast returns of specific salmon stocks. However, limitations on our ability to accurately explain and forecast annual variations in Pacific salmon production remain, in part because of uncertainty in the factors responsible for salmon mortality and from the effects of climate warming on the marine distribution and abundance of salmon. It is more important than ever to promote cooperative and innovative international research to identify and better understand the ecological mechanisms regulating the distribution and abundance of salmon populations for sustainable salmon and steelhead management.

Theme 3: New Technologies

Azumaya, T., S. Sato, S. Urawa, and T. Nagasawa. 2016. Potential role of the magnetic field on homing in chum salmon (*Oncorhynchus keta)* tracked from the open sea to coastal Japan. N. Pac. Anadr. Fish Comm. Bull. 6: 235–241. doi:10.23849/npafcb6/235.241.

In order to examine the Earth's magnetic intensity and inclination during homing migration of chum salmon and to present tracking data consistent with the geomagnetic imprinting hypothesis that salmon migrate homeward using the Earth's magnetic intensity or inclination, archival tagging operations were carried out in the Bering Sea in 2012 and 2013. DST magnetic tags were attached to the bodies of chum salmon on board a research ship. The tags recorded temperature, depth, magnetic intensity and inclination, compass heading, and tilt of the fi sh. Two tagged chum salmon were subsequently recovered near the coast of Hokkaido, Japan, in 2012 and 2013, respectively. The estimated homing route of the 2012 fish was linear from the release

site to the coast of Hokkaido, Japan. The 2013 fish reached the coast of Hokkaido by way of the east coast of Kamchatka, Russia. These estimated homing routes were not consistent with the great circle route. The estimated homing migration routes were consistent with the isoline of magnetic intensity rather than magnetic inclination. For the tag recovered in 2012, the homing migration route was approximately along the isoline of magnetic intensity at the recovery site. Therefore, we conclude that this study supports the geomagnetic imprinting hypothesis that magnetic intensity plays an important role in the homing migration of chum salmon in the open sea.

Tsukagoshi, H. 2016. Genetic characteristics of salmon in the Sanriku-region, Japan. Fish Gent. Breed. Sci. 45: 3-8. (In Japanese with English abstract).

Genetic characteristics of chum and masu salmon in the Sanriku-region, where is the southernmost region of their natural range, mostly remain to be elucidated for their effective resources management for sustainable fisheries with competent molecular genetic markers. Novel polymorphic microsatellite (ms)DNA markers in chum and masu salmon have been developed using next generation sequencing approach. Sanriku chum and masu salmon were genetically differentiated from those of Hokkaido and the Sea of Japan coast in Honshu. In addition, cluster analysis of chum populations using developed msDNA markers suggested three groups of coastal early-run, coastal late-run, and Kitakami samples in Sanriku.

Tsukagoshi, H., S. Terui, G. Ogawa, S. Sato, and S. Abe. 2016. Genetic variation in chum salmon in the Sanriku region, Japan, inferred from mitochondrial DNA analysis. N. Pac. Anadr. Fish Comm. Bull. 6: 451–454. doi:10.23849/npafcb6/451.454.

Genetic variation in about 500 chum salmon representing seven populations in the Sanriku region and one population in Fukushima, on the Pacific coast of northern Honshu, Japan, was estimated by mitochondrial DNA analysis. A total of nine haplotypes of 479–481 bp in the 5’ first half of the control region were found in the chum populations examined. The observed haplotype diversity ranged from 0.424 ± 0.084 to 0.805 ± 0.056, which was lower than previously reported diversity in Japan’s Hokkaido populations, but higher than Russian and North American populations. AMOVA suggested moderate genetic differentiation among local populations within Sanriku and Fukushima, but no large-scale regional differences were detected.

Shimizu, T., T. Morita, and Y. Yamamoto. 2016. A water-recycling system for hatchery rearing of chum salmon fry. N. Pac. Anadr. Fish Comm. Bull. 6: 107–111. doi:10.23849/npafcb6/107.111.

We developed a closed water-recycling system for rearing chum salmon alevins and fry at hatcheries with insufficient water supplies. The system included a bio-filter and an intermittent water-fl ow system. The experiment was carried out in two fish-rearing tanks (1,200 L each) with a common water recycling system. The water recycling system contained bio-filters made of crushed coral, a glass-ring filter, and a nylon string fi lter set in 100-L and 200-L plastic boxes. The maximum water flow was 126 L/min. A total of 22,600 alevins (initial mean body weight = 0.2 g) was held in each of the two rearing tanks. Ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen concentrations were controlled in the water-circulation system, and the average water temperature was maintained at 9°C. The alevins stayed healthy, and fry could be fed without water exchange in the rearing tanks. The mean body weight of fish reached 1 g after 98 days of rearing. No diseases occurred among the test fish, all of which tolerated a seawater challenge test. These results suggest that our closed water-recycling system is effective in producing heathy salmon fry at hatcheries where water shortages and diseases frequently occur.

Theme 4: Management Systems

Nagata, M., Y. Miyakoshi, M. Fujiwara, K. Kasugai, D. Ando, M. Torao, H. Saneyoshi, and J.R. Irvine. 2016. Adapting Hokkaido hatchery strategies to regional ocean conditions can improve chum salmon survivals and reduce variability. N. Pac. Anadr. Fish Comm. Bull. 6: 73–85. doi:10.23849/npafcb6/73.85.

Returns of chum salmon in Hokkaido, Japan, have increased remarkably since the 1970s, but there have been significant regional variations in survival. We surveyed chum salmon dynamics in several regions to test the hypothesis that variations in survival were related to the nearshore ocean environment, especially sea surface temperatures (SSTs). Time series analyses of return rate data for chum salmon from 14 regions around Hokkaido revealed 4 geographical groups (Japan Sea, Okhotsk Sea, Nemuro Strait, and Pacific Ocean) that had distinct survival patterns. In the Okhotsk Sea, Nemuro Strait, and Eastern Pacific Ocean, survival patterns were associated with SST patterns in the nearshore environment at the times and places occupied by young chum salmon. In the Okhotsk Sea, SSTs below 8°C appeared to restrict the off shore movement of juvenile chum salmon, while SSTs over 13°C accelerated their off shore movement, apparently resulting in salmon moving prematurely. We recommend that SSTs of 7–11°C are most appropriate for the release of chum salmon. As SSTs are expected to warm but also become increasingly variable as a result of climate change, we encourage an adaptive approach whereby the nearshore environment is monitored in order to align juvenile chum salmon releases with optimal conditions.

Theme 5: Integrated Information Systems

No publication.