

***NORTH
PACIFIC
ANADROMOUS
FISH
COMMISSION***



TECHNICAL REPORT 15

Second NPAFC-IYS Workshop on *Salmon Ocean Ecology in a Changing Climate*

Technical Editors: Jeongseok Park and Laura Tessier

Vancouver, Canada, 2019

Sustainable Conservation and Use of Chum Salmon under Warming Climate and Changing Ocean Conditions

Masahide Kaeriyama

Arctic Research Center, Hokkaido University, N21 W11, Kita-ku, Sapporo, 001-0021, Japan

Keywords: chum salmon, global warming, carrying capacity, dSST, intra- and inter-specific interaction, North Pacific Ocean, Arctic Ocean, sustainable conservation management

Since the 2000s, there has been a decreasing trend in southern populations (e.g., Japan, Korea, and British Columbia in Canada) of chum salmon (*Oncorhynchus keta*) but northern populations (e.g., Russia and Alaska in the USA) are stable or increasing. In the 2000's, it was predicted that: 1) the population of Japanese chum salmon would be half of its maximum carrying capacity by the 2010's due to internal natural growth rate. (Kaeriyama 2004), and 2) global warming affected the distribution of chum salmon in the North Pacific in this century (Kaeriyama 2008). Objectives of this paper are to 1) evaluate the influences of a warming climate and changing ocean conditions on distribution, growth, survival, and carrying capacity for Pacific salmon, and to 2) address potential progression of global warming for establishing the sustainable conservation and management of Pacific salmon.

Sea surface temperature (SST) in the North Pacific Ocean and the Arctic Ocean in 1930–2018 was obtained using the COBE-SST database in the Japan Meteorological Agency (Ishii et al. 2005). The carrying capacity of sockeye (*O. nerka*), chum (*O. keta*), and pink salmon (*O. gorbuscha*) were calculated from the NPAFC Salmonid Catch Statistics 1925–2017 (<https://npafc.org/statistics/>) based on a replacement point on the Ricker's reproduction curve. A year-class population was set as 20 brood-year populations in each species. To evaluate distribution area of chum salmon, I defined their optimum temperature range (OT: 8–12°C) and adaptable temperature range (AT: 5–8°C) of chum salmon based on growth rate, feeding behavior and catch per unit effort (CPUE) as population density, and the resident duration of juvenile chum salmon in coastal seas around Japan as a period from 5°C to 12°C in the SST (Kaeriyama 2004, 2018). This paper analyzed scales of female adult chum salmon at age 4 returning to the Ishikari and the Tsugaruishi Rivers in order to evaluate the yearling growth.

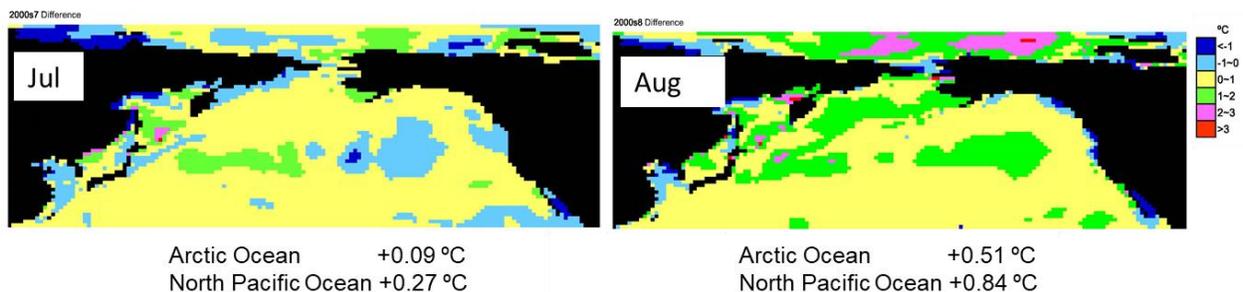


Fig. 1. Difference between predicted and actual SSTs in July and August of the 2000s in the North Pacific and Arctic Oceans. North Pacific Ocean: northward of 40°N. The predicted SST is based on the IPCC-A1B scenario (Kaeriyama 2008).

Since the 1930s, the decadal mean of SST (dSST) basically increased 0.18°C in the Arctic Ocean, and 0.10°C in the North Pacific Ocean (northward of 40°N). This represents that the SST increased 1.0°C in the North Pacific Ocean and 1.8°C in the Arctic Ocean in a century. The dSST showed higher in northern (0.13°C in the Okhotsk Sea, 0.14–0.15°C in the Bering Sea) than in southern (0.07°C in the Gulf of Alaska) ocean ecosystems (Table 1). Actual SSTs were higher than predicted SSTs by the IPCC-A1B scenario (Kaeriyama 2008) in July and August of the 2000s in the North Pacific and the Arctic Oceans (Fig. 1). This result suggests that global warming is progressing faster than predicted (the A1B Scenario).

Table 1. Simple regression analysis relating to the temporal changes in the decadal mean of SST (dSST) in the North Pacific Ocean (NPO), Arctic Ocean (AO), Okhotsk Sea (OS), Western- and Eastern-Bering Sea (W-BS, E-BS), and Gulf of Alaska (GA) from the 1930s to the 2010s.

Ecosystem	Slope	Intercept	R^2	F	P	n
NPO	0.100	6.013	0.865	44.687	< 0.001	9
AO	0.177	-1.774	0.928	89.770	< 0.001	9
OS	0.130	3.328	0.893	58.393	< 0.001	9
W-BS	0.150	3.583	0.865	45.000	< 0.001	9
E-BS	0.138	3.319	0.891	57.114	< 0.001	9
GA	0.072	8.197	0.452	5.767	0.047	9

The total carrying capacity of chum, pink, and sockeye salmon linked with the SST in the Okhotsk ($R^2 = 0.897$, $p < 0.001$) and Bering Seas ($R^2 > 0.810$, $p < 0.001$), despite no-correlation with climate-change indices such as the PDO and the ALPI (Fig. 2).

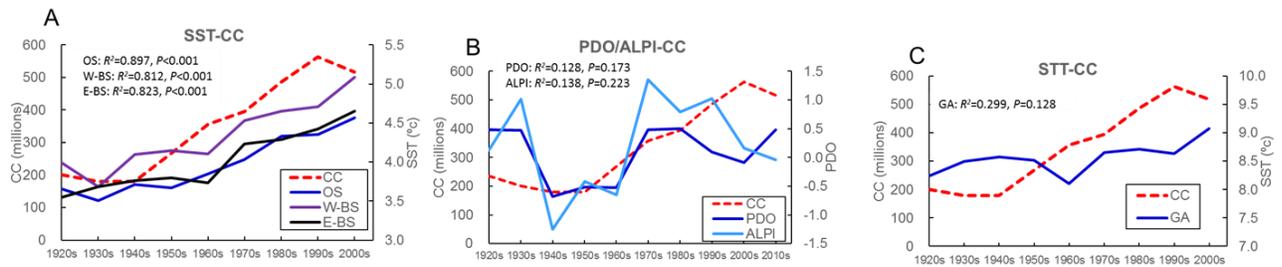


Fig. 2. Temporal changes in the decadal mean of SST (dSST), climate change indices and total carrying capacity of sockeye, chum, and pink salmon. OS: Okhotsk Sea, W- and E- BS: Western and Eastern Bering Sea, GA: Gulf of Alaska, CC: carrying capacity, PDO: Pacific Decadal Oscillation, ALPI: Aleutian Low-Pressure Index.

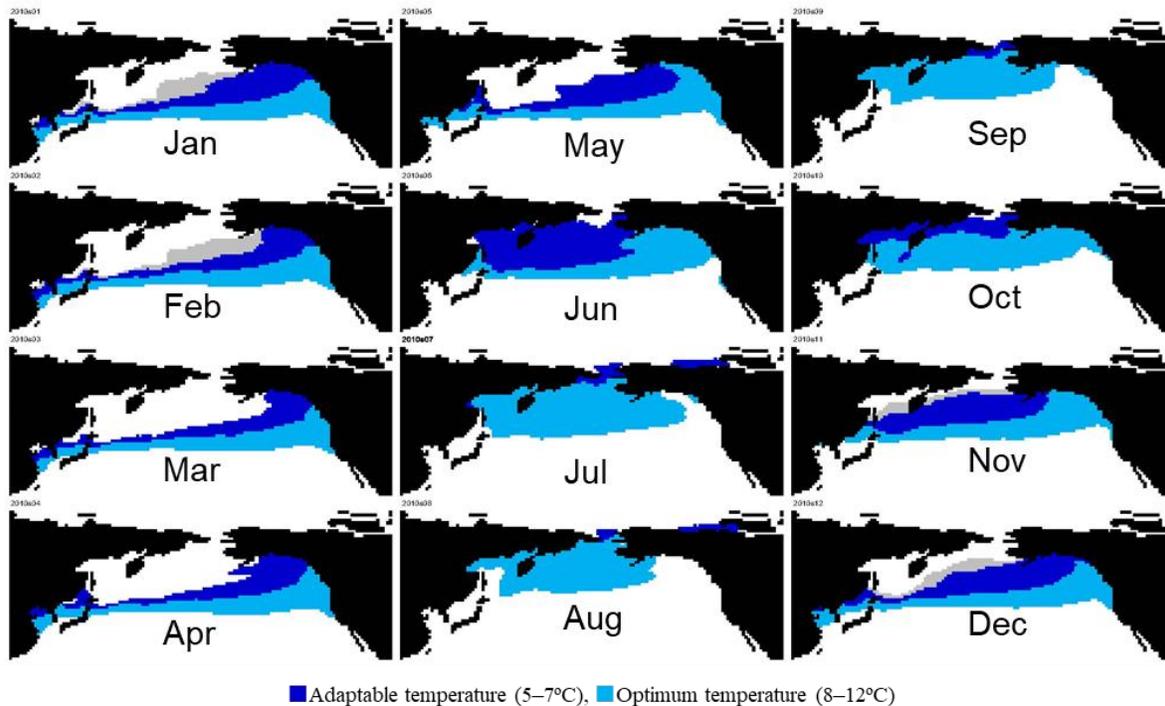


Fig. 3. Monthly change in areas of adaptable and optimum temperatures for chum salmon in the 2010s.

The monthly changes in areas AT and OT indicated that chum salmon appears like to distribute wider area in the eastern than in the western North Pacific Ocean (Fig. 3). Temporal changes in areas of AT and OT for chum salmon from the 1930s to the 2010s are as follows (Fig. 4):

- In the Okhotsk Sea, the area of AT showed an increasing trend for June, however, the area of OT showed has recently decreased in August.
- In the Bering Sea, areas of AT in June and OT in July were markedly increased.
- In the Arctic Ocean, the area of AT has gradually increased since the 1980s.
- In the Gulf of Alaska, the area of OT in the summer has decreased.

These results suggest that Okhotsk and Bering Seas are favorable ecosystems for survival and carrying capacity of Russian chum and pink salmon since the 2000s.

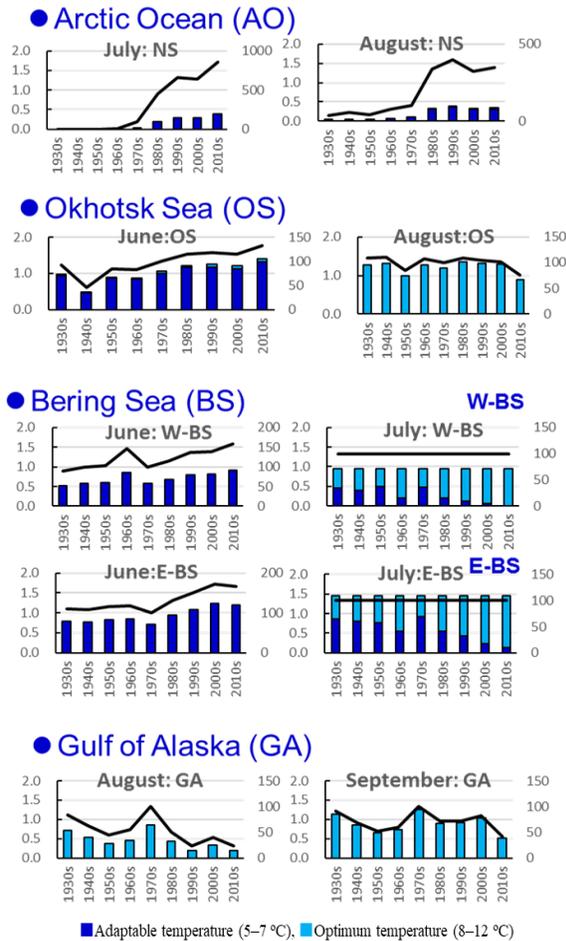


Fig. 4. Temporal changes in areas of adaptable and optimum temperatures for chum salmon from the 1930s to the 2010s.

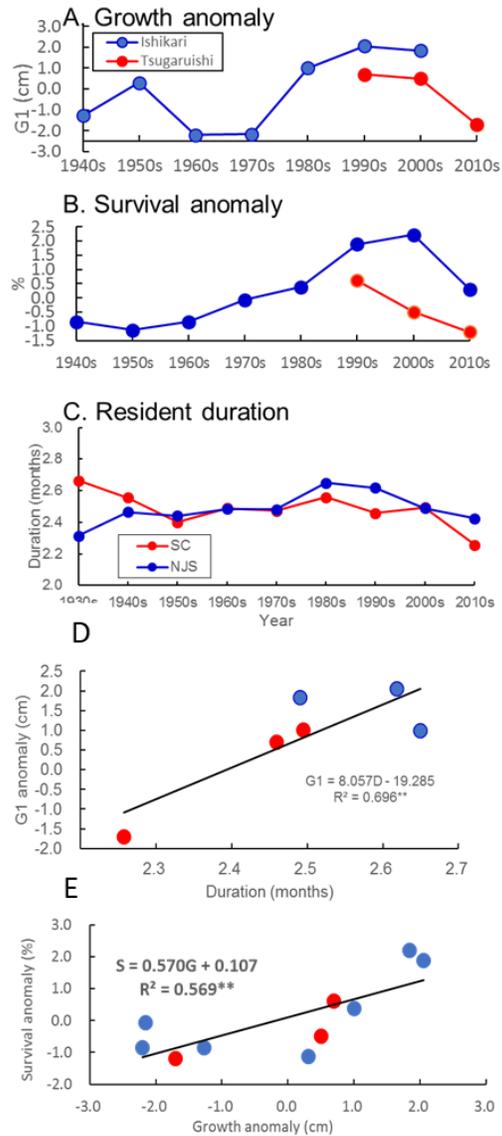


Fig. 5. Temporal changes in anomalies of growth at the age-1 (A) and survival (B), and resident duration of juvenile (C) for chum salmon returning to the coast in the Northern Japan Sea (NJS) and Sanriku (SC) from the 1930s to the 2010s. Relationships between the resident duration and the growth anomaly at age 1 (D), and between growth anomaly at age 1 and survival anomaly for chum salmon returning to the northern Japan Sea (blue circle) and the Sanriku coasts (red circle) from the 1940s to the 2010s (E).

In the 2010s, the area of OT has quietly departed from Hokkaido even though it touched Hokkaido until the 2000s. Therefore, Japanese juvenile chum salmon will have a difficult time migrating to the Okhotsk Sea (Kaeriyama and Urabe 2018). Temporal changes in the growth at age 1, the survival rate, and the resident duration of juvenile chum salmon in Hokkaido and Sanriku Coast from the 1940s to 2010s suggest that the decline in resident duration leads to decreased growth at age-1 and survival rates for Japanese chum salmon with the progression of global warming (Fig. 5).

In the near future, Japanese and Russian chum and pink salmon will have the following issues during the summer, depending on the progress of global warming and the decrease in the carrying capacity: 1) an intraspecific interaction between wild and hatchery salmon, and 2) a population density-dependent effect. Under the changing climate, therefore, Japan needs to establish sustainable conservation management for chum salmon, based on the back-casting approach. Final goals for the management are: 1) how to conserve and use the salmon, 2) how to establish the monitoring and management systems for interaction between aquatic ecosystems and Pacific salmon, and 3) how to provide restoration and resilience for wild salmon and river ecosystems.

REFERENCES

- Ishii, M., A. Shouji, S. Sugimoto, and T. Matsumoto. 2005. Objective analyses of sea-surface temperature and marine meteorological variables for the 20th century using ICOADS and the Kobe Collection. *Int. J. Climatol.* 25: 865–879.
- Kaeriyama, M. 2004. Population ecology of chum salmon. *In: the ecology and evolution of salmonids. Edited by K. Maekawa.* pp. 137–163. Bunichi-sogoshuppan, Tokyo. (In Japanese)
- Kaeriyama, M. 2008. Ecosystem-based sustainable conservation and management of Pacific salmon. *In: Fisheries for Global Welfare and Environment. Edited by K. Tsukamoto, T. Kawamura, T. Takeuchi, T.D. Beard, Jr. and M.J. Kaiser.* pp. 371–380. TERRAPUB, Tokyo.
- 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>)