Thermal Habitats of Pacific Salmon: Does Climate Change Benefit Pink and Chum Salmon?

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

Because most physiological processes of ectotherms are controlled by temperature, climate warming could affect a variety of population processes in Pacific salmon. In the ocean, Pacific salmon actively move to preferred thermal habitats by migration. Generally, Pacific salmon migrate northward during summer and southward during winter (e.g., Yatsu and Kaeriyama 2005). For example, Japanese chum salmon move to the Bering Sea during the summer (sea surface temperature, ~6–11°C), and then move to the eastern North Pacific during winter (sea surface temperature, ~5–7°C; Fukuwaka et al. 2007). In addition, chum salmon control their body temperature using vertical migrations across the thermocline during summer in the Bering Sea (Azumaya and Ishida 2005; Morita 2011). Active migrations throughout their ocean lifespan allow salmon to narrow their habitat choices to their preferred temperatures. By contrast, Pacific salmon spend their juvenile and spawning stages in freshwater, where they are passively affected by ambient temperature. For example, river water temperatures in Hokkaido, Japan, vary from ~0–2°C during winter to over 20°C during summer; thus juvenile masu salmon, which spend more than one year in freshwater before seaward migration, have to adapt to this broad temperature range (Morita and Nagasawa 2010; Morita et al. 2011). Therefore, active control of thermal habitat mitigates the impact of seasonal and annual change in temperature during the ocean life stage, whereas passive control of thermal habitat operates during the freshwater life stage. These observed behavioral patterns lead to the hypothesis that climate warming would have a severe negative effect on species with long freshwater stages (e.g., masu, coho, Chinook, and sockeye salmon) and populations originating from southern populations, in particular. Moreover, preferred temperature ranges differ by species and age (body size) because older, larger fishes generally inhabit deeper and colder waters than younger, smaller fishes (Bergmann's rule). Similarly, pink salmon and small chum salmon tend to inhabit warmer waters than sockeye and large chum salmon (Morita et al. 2010a). Therefore, fish with a smaller body size (e.g., pink salmon) or shorter freshwater life (e.g., pink and chum salmon) may experience reduced or even beneficial effects from climate warming. In addition, rising temperatures involve reductions in the body size of many organisms (Gardner et al. 2011). The negative effect of rising temperature on growth is hypothesized to be more severe for large chum than for small chum salmon (Fig. 1; Morita et al. 2010b).

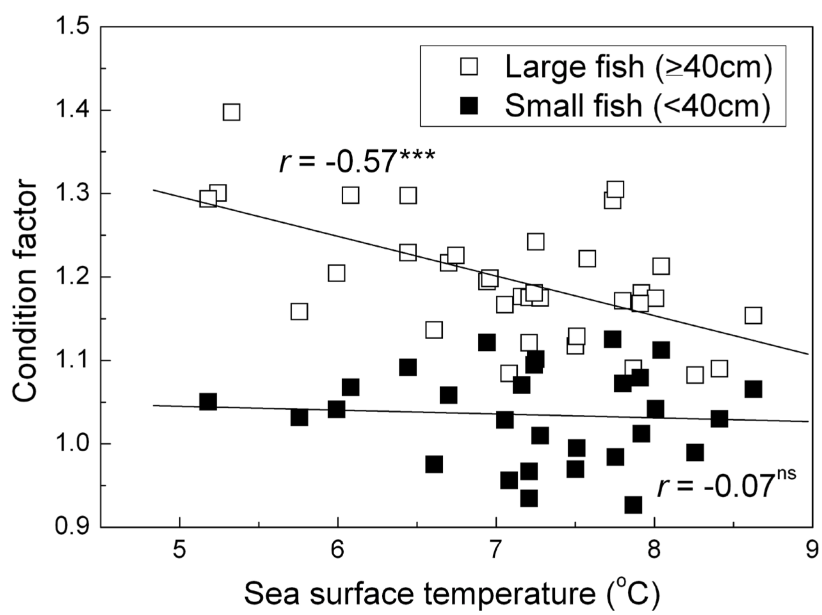

Fig. 1. Condition factor of large chum salmon is significantly and negatively related to sea surface temperature in the Bering Sea (1973-2008), even after accounting for annual trends and chum salmon CPUE (from Morita et al. 2010b).

All correspondence should be addressed to K. Morita.
e-mail: moritak@affrc.go.jp

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