Declines in the average body size and reproductive potential of Chinook salmon in the AYK region

We estimate changes in average reproductive potential of female Chinook salmon from the Yukon and Kuskokwim rivers since the 1970s using historical observations on fish length and sex in combination with a relationship between female length and total egg mass in the ovaries.

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Chinook salmon are widely distributed across the North Pacific Ocean and connected freshwater habitats. The watersheds of the Arctic-Yukon-Kuskokwim (AYK) region serve as spawning and nursery habitats for Chinook salmon, which have provided a key food and cultural resource to indigenous communities for millennia, and more recently have supported commercial, recreational, and subsistence fisheries. The Chinook salmon populations in the Yukon and Kuskokwim rivers are among the largest wild populations in the world. However, these populations have experienced precipitous but poorly understood declines in productivity and population abundance over the past 10-15 years.

Concurrent with the declines in population abundance of AYK Chinook salmon have been widespread declines in the average size and age of fish that reach the spawning grounds. These declines mirror broadly observed trends in the demographic structure of North American Chinook salmon populations. While it is typically assumed that the number of spawning females limits recruitment in Pacific salmon, declines in the average age and size of females can cause a reduction in the per-capita reproductive potential of spawners, and may thus affect population productivity.

We investigated the consequences of body size declines for the reproductive potential of Chinook salmon in the AYK region. Using estimates of drainage-wide trends in mean female length in combination with estimated relationships of fecundity or egg mass versus female length (**Figure 1**), we reconstructed historical changes in reproductive potential of female spawners. We also estimated variation in the proportion of females over time, and how trends in sex ratio and inferred egg mass per female have affected total population reproductive potential.

The demographic structure of Chinook salmon in the AYK region has changed significantly over the past 40-50 years. The length-at-age and proportion of older fish have decreased over time such that the mean length of fish returning to AYK rivers has declined markedly. Between the early 1970s and 2017, mean length of female spawners in the Yukon and Kuskokwim rivers has declined by roughly 6% and 9%, respectively (**Figure 2**). The trends in mean length are relatively consistent across sub-populations within watersheds, though differences by location exist, and are similar to trends reported for this species further south along much of the west coast.

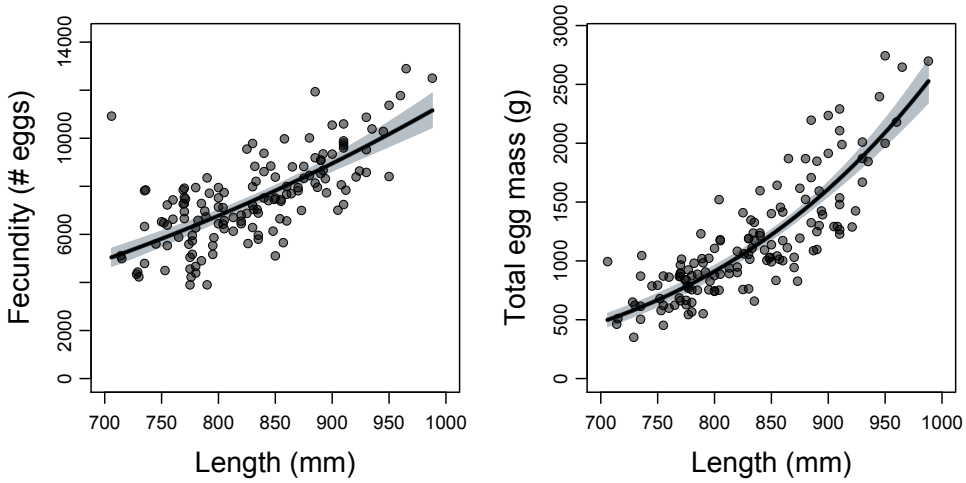

Figure 1: Relationships between female size and reproductive potential for Chinook salmon. Shown are data and non-linear fits for fecundity (left) and total egg mass (right) as a function of female length (mid-eye to fork of tail) for Canadian-origin fish sampled at Eagle in the Yukon River from 2008 to 2010 (data provided by Lara Horstmann, UAF).

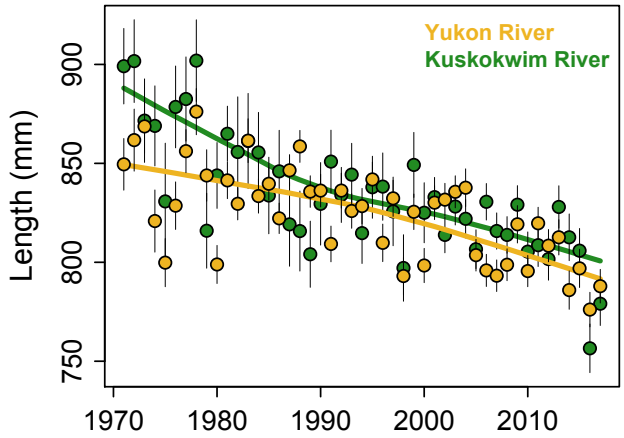

Figure 2: Estimated changes in mean length of female Chinook salmon in the Yukon (yellow) and Kuskokwim (green) rivers for the period 1970 to 2017.

Location-specific models for Chinook salmon sampled from fisheries catches or near spawning grounds showed that the mean length of fish caught in commercial and subsistence fisheries has changed more dramatically than that of spawners, particularly since the 2000s. This difference is explained largely by changes in the gillnet mesh sizes used to catch fish. For instance, in the Yukon River the mean length of fish recorded in upper river subsistence catches has declined by 10%, while the mean length of fish caught in lower river commercial fisheries has declined by 18% after controlling for changes in gear used.

The loss of older and larger fish and the decline in average size mean a reduction in the total energy content per fish as well as reproductive potential of spawners. Declines in caloric value are of particular concern to Alaska Native and First Nation communities that rely on Chinook salmon for their nutritional needs.

We estimated that the drainage-wide decline of 6% in mean length of Chinook salmon in the Yukon River would mean a decline in mean fecundity (number of eggs per female) of about 15% and a decline in total egg mass per female of about 28% (**Figure 3**). Female spawners in the Kuskokwim River were estimated to carry on average 21% fewer eggs, and 35% lower egg mass compared to four decades ago.

Changes in the population sex ratios differed between the two drainages. In the Yukon River, the proportion female has varied around a mean of 0.4 with a weak declining trend. Apparent trends towards increasing male dominance in fishery catches were mostly driven by changes in capture methods, i.e. smaller mesh sizes of gillnets used in recent years. By contrast, the proportion female in the Kuskokwim River has declined by about 7.5% since the early 1970s.

The potential consequences of reduced reproductive potential for the management of Chinook salmon was explored using an existing stock-recruitment model for Canadian-origin Chinook salmon in the Yukon River. These analyses suggest that female length has a strong effect on expected recruitment, but that the relationship between recruitment and total egg mass is uncertain compared to the effect of female length on escapement at MSY.

The reported decline in the average reproductive potential of females may have contributed to recent declines in population productivity. Further research is needed to shed light on the relative contribution of changes in spawner abundances, body size, and environmental effects to the reduced run sizes of AYK Chinook salmon populations..

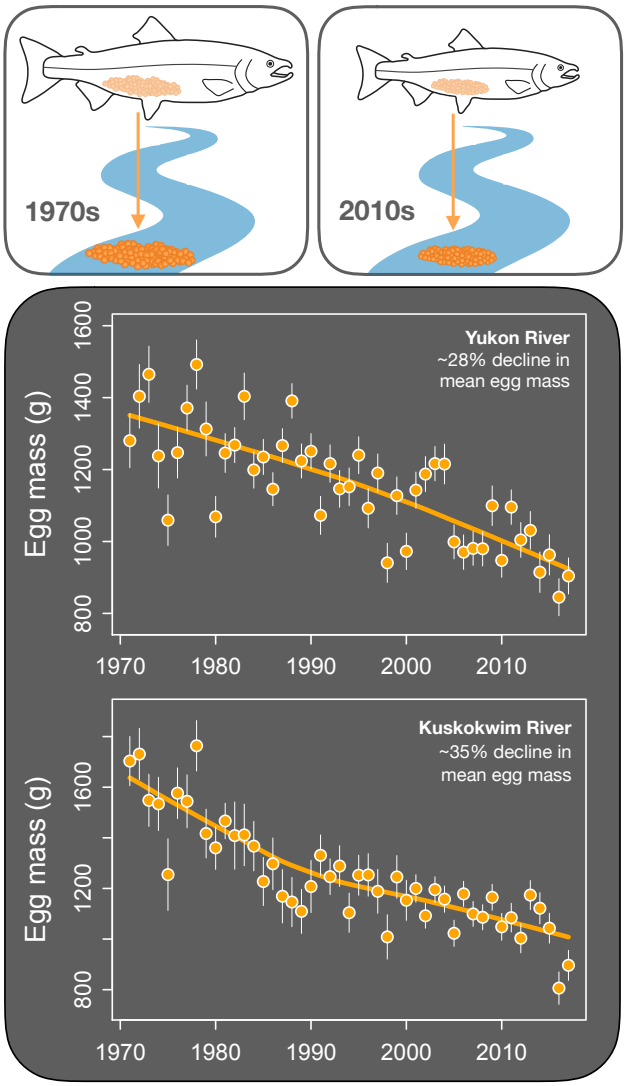

Figure 3: Estimated changes in average reproductive potential, measured as total egg mass per female, for Chinook salmon in the Yukon (top) and Kuskokwim (bottom) rivers for the period 1970 to 2017.

This research was made possible with support from AYK-SSI

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