

Freshwater Growth and Recruitment in Two Western Alaskan Populations of Chinook Salmon

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The importance of Chinook salmon *Oncorhynchus tshawytscha* to western Alaskan communities along the Yukon and Kuskokwim rivers is difficult to overstate. Recent years have seen a decline in total harvest of Chinook salmon in Alaskan fisheries (commercial, subsistence, test, and sport) from these two rivers (Fig. 1). Although both economic and biological factors have contributed to reduced landings (Linderman and Bergstrom 2009), a series of fisheries and economic disaster declarations (beginning in 1997 and including 2012) underscore a sense of fear and uncertainty about the future of Chinook salmon in the region.

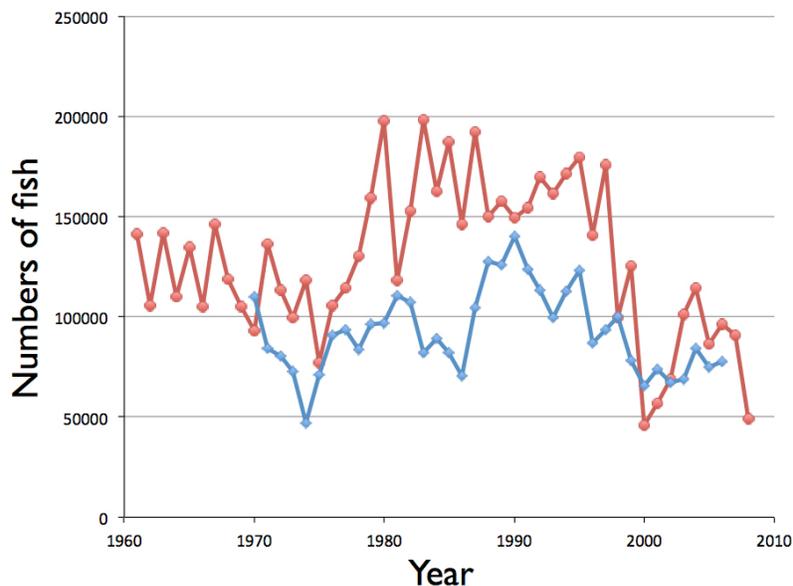


Fig. 1. Total Alaskan harvest (commercial, subsistence, test and sport fisheries) from Yukon (red circles) and Kuskokwim (blue diamonds) rivers by year. Data sources: Yukon River—Evenson et al. (2009); Kuskokwim River—Linderman and Bergstrom (2009).

The objective of this research was to examine the role that freshwater growth might play in declines in Chinook salmon populations in western Alaska. The critical-size/critical-period hypothesis (Beamish and Mahnken 2001) suggests that size-dependent mortality soon after salmon smolts reach the nearshore marine environment has a strong influence on recruitment. For stream-type Chinook salmon such as those in western Alaska (Taylor 1990), freshwater growth could influence early marine survival through its effect on smolt size.

Relatively long time series of escapement and age/sex composition data, as well as archived scale samples, were available from the Alaska Department of Fish and Game (ADFG) for two Chinook salmon escapement monitoring sites in western Alaska: the Andrefsky River weir (Yukon drainage) and the Kogrukluk River weir (Holitna River, Kuskokwim drainage; Fig. 2). We used these data and scale collections to (1) reconstruct time series of freshwater and marine growth

increments from the 1970s to 2000s, and (2) test correlations between stock productivity and freshwater and marine growth increments. We analyzed only growth of females, as the fitness effects of large body size are more straightforward than they are in males (reviewed in Quinn 2005), and females likely influence recruitment to a greater extent than do males via their direct effect on total amount of egg deposition.

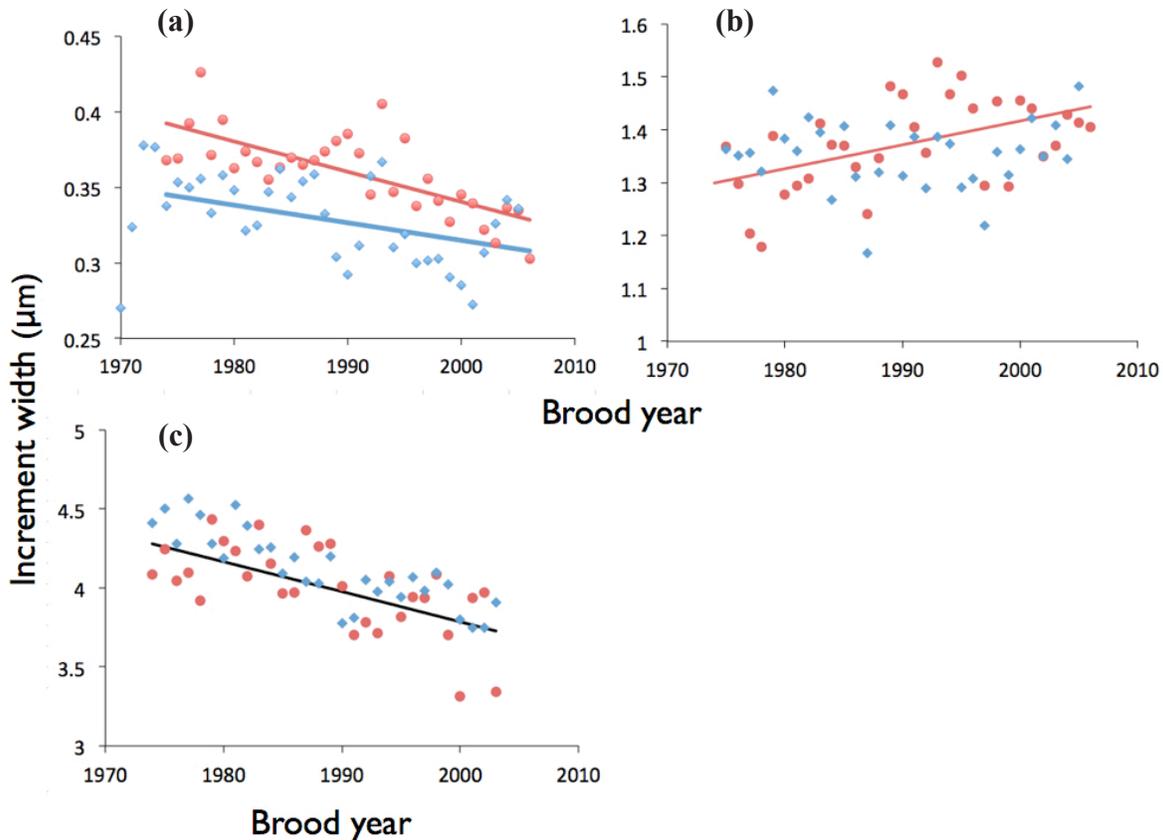


Fig. 2. Average growth increments of female Chinook salmon by brood year: (a) FW1, (b) SW1, and (c) total marine growth. Red circles: Andreafsky River; blue diamonds: Kogruklu River.

Scales were collected at each weir from the preferred body area for salmonids, placed on gum cards, and readings were conducted on acetate impressions following the methods described in Hagen et al. (2001). Up to 25 females per age class were analyzed per year and system, although sample sizes were lower in the less common age-classes. For each readable scale, the number of circuli and total increment width were measured for the following growth zones: first year in fresh water (FW1), additional freshwater growth after the first year (FW+), first year in saltwater (SW1), second year in saltwater (SW2), and so on, up to additional marine growth after last winter at sea (SW+). Analyses reported herein were restricted to increment width data for FW1, SW1, and total marine growth (SW1 through SW+).

Scale data were available for brood years 1974-2006 for the Andreafsky River and brood years 1970-2005 for the Kogruklu River. Simple linear regressions between increment widths and brood year were used to test for temporal trends in growth. Freshwater growth (FW1) declined significantly with brood year (Andreafsky: $p < 0.001$, $R^2 = 0.51$; Kogruklu: $p < 0.01$, $R^2 = 0.16$; Fig. 2a). The SW1 increased slightly with brood year in Andreafsky samples ($p < 0.005$, $R^2 = 0.22$), but did not change significantly with brood year in Kogruklu samples ($p = 0.094$; Fig. 2b). Total marine growth also declined over time ($p < 0.001$, $R^2 = 0.50$; Fig. 2c).

Estimates of escapement, age, sex composition, and harvest were used to estimate stock productivity as recruits per female spawner, or (escapement + harvest)/females, for both Andreafsky and Kogruklu stocks. Details of these calculations are given in Leon (2013). Spearman rank correlation coefficients were then calculated for each stock between productivity (transformed by natural logarithm) and three brood-year growth increments: FW1, SW1, and total marine growth. Exact tests indicated that none of these correlations were statistically significant (Table 1).

Table 1. Spearman rank correlation coefficients (and P-values for exact tests) between growth increments (brood year means) and stock productivity (recruits/female spawner, ln-transformed).

Growth increment	Andreafsky River	Kogruklu River
FW1	0.005 ($p = 0.99$)	0.044 ($p = 0.87$)
SW1	-0.35 ($p = 0.15$)	0.15 ($p = 0.56$)
SW-all	0.22 ($p = 0.37$)	0.11 ($p = 0.68$)

To summarize, we found declines in freshwater (FW1) and total marine growth over time in both Andreafsky and Kogruklu escapement samples of Chinook salmon. Declines in total marine growth were due largely to a lower proportion of older females represented in more recent scale samples (data not shown); this is consistent with reports from local fishermen of fewer older, larger females returning to these rivers (A. Bassich, abassich@gmail.com, personal communication). Although environmental change could be driving declines in FW1, we hypothesize that a decrease in FW1 might also be attributed to smaller average size of female spawners, as egg size is often correlated with body size in Chinook salmon (Beacham 2010).

Despite these declines in growth, we detected no significant correlations between growth increments (freshwater or marine) and stock productivity. We had limited power to detect such correlations, however. First, the long lifespan of Chinook salmon (up to 7 years in these stocks) restricted our analysis of productivity to brood years 2006 and earlier. Second, our estimates of stock productivity compounded uncertainty in spawner number, escapement, and harvest (which was a particularly coarse estimate). Therefore, we cannot confidently rule out declines in growth as contributing to population declines in western Alaska.

Finally, we urge caution in interpreting the results presented here. First, growth increments were estimated from escapement samples, which represented the individuals that survived periods of freshwater, marine, and fishing mortality, thus obscuring episodes of size-related mortality. Second, although scale sampling was designed to minimize bias (Leon 2013 and references therein), logistical constraints can result in field sampling that deviates slightly from sampling protocols; this potential bias was not fully evaluated here. Finally, autocorrelation between growth zones can also obscure results (e.g., Ruggerone et al. 2009a, b), making retrospective analyses of growth and abundance difficult to interpret. However, the temporal trends we observed in freshwater and total marine growth suggest that the demographic consequences of these changes in western Alaskan Chinook salmon deserve further attention.

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