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Temporal Patterns in Productivity of North American Sockeye and Chinook Salmon

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Abstract

Although recent catches of salmon in the North Pacific are at record levels, relative catches of some species have declined. We used a Kalman filter estimation procedure to estimate time series of productivity values for North American Sockeye and Chinook salmon. Generally, Sockeye stocks in Alaska are experiencing above average productivity while stocks in British Columbia have experienced below average productivity since the early 1990s. Coast wide Chinook salmon stocks experienced poor productivity in the early 1990s but Alaskan and Upper Columbia River stocks have shown improved productivity for the last decade. Common temporal patterns in productivity across distant stocks and species may be useful in identifying shared environmental factors to explain observed variations in productivity.

Introduction

Recent salmon abundance in the North Pacific, as indexed by aggregate commercial catches has been among the highest on record, with no indication of decline (Irvine et al. 2009). In contrast, aggregate North American salmon catches have experienced a declining trend, with an increasing gradient from north (Alaska) to south (Canada and southern US). Although the total abundance of Pacific salmon remains high, trends in abundance patterns vary among species. Pink and chum salmon have consistently been the most abundant species and increasingly account for a greater proportion of the total catch. Catches of Chinook and Coho salmon have declined over the last two decades. High catches of pink and chum salmon have been attributed to the generally favourable climate-related marine conditions in the western North Pacific Ocean, expanding hatchery operations, and improving hatchery technologies.

It is generally accepted that oceanographic regimes play a large role in the productivity of Pacific salmon species. Peterman et al. (1998) reported a positive correlation between time series of productivity indices for salmon stocks in close proximity, attributed to common local environmental experiences. We examined temporal trends in productivity of North American Sockeye and Chinook salmon to identify patterns that may contribute to our understanding of the factors that effect productivity of Pacific salmon.

Methods

We used a Kalman filter estimation procedure (Peterman et al. 2000; computer code from Dorner et al. 2008) to fit a Ricker model to spawner and recruit data for select North American sockeye and Chinook salmon stocks. The Ricker *a* parameter represents the average $\log_e$ (recruits/spawner) at extremely low abundance of spawners. The Kalman filter estimation procedure assumes that the Ricker *a* parameter was not necessarily constant, and could change over time as a result of observation error as well as natural variation in year to year survival. The Kalman filter analysis removes some of the observation error and other variation not associated with systematic changes in productivity and provides time series of smoothed a_t values that reflect time-varying total-life-cycle productivity of salmon. Values are presented in standard deviation units (a_t value in a given year minus the mean stock-specific a_t , divided by the standard deviation of the a_t time series) which allows comparison of time trends across stocks.

Results

Figures 1 and 2 show the smoothed Kalman filter estimates of time-varying Ricker a_t values (indicators of productivity) for North American Sockeye and Chinook salmon respectively. Orange circles indicate below average productivity and green circles above average productivity. Note that the size of the circles is in standard deviation units, and the standard deviations vary by stock. These figures are helpful in examining the relative change in productivity within stocks and the coincidence of temporal changes in productivity across stocks, but should not be used to judge whether the productivity of one stock has changed more than another in absolute terms.

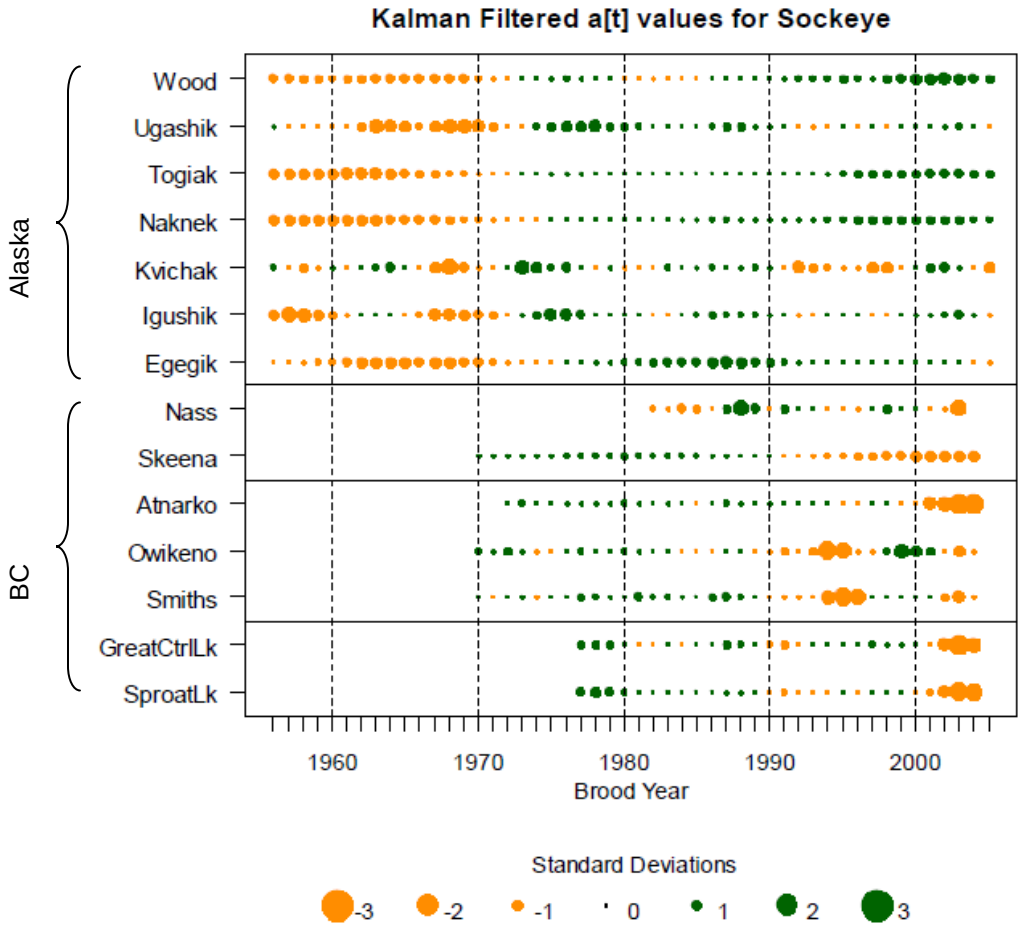

Figure 1. Time series trends in smoothed Kalman filter Ricker a_t values (total life-cycle productivity) for North American Sockeye salmon stocks listed in order from north to south. Values are presented in standard deviation units.

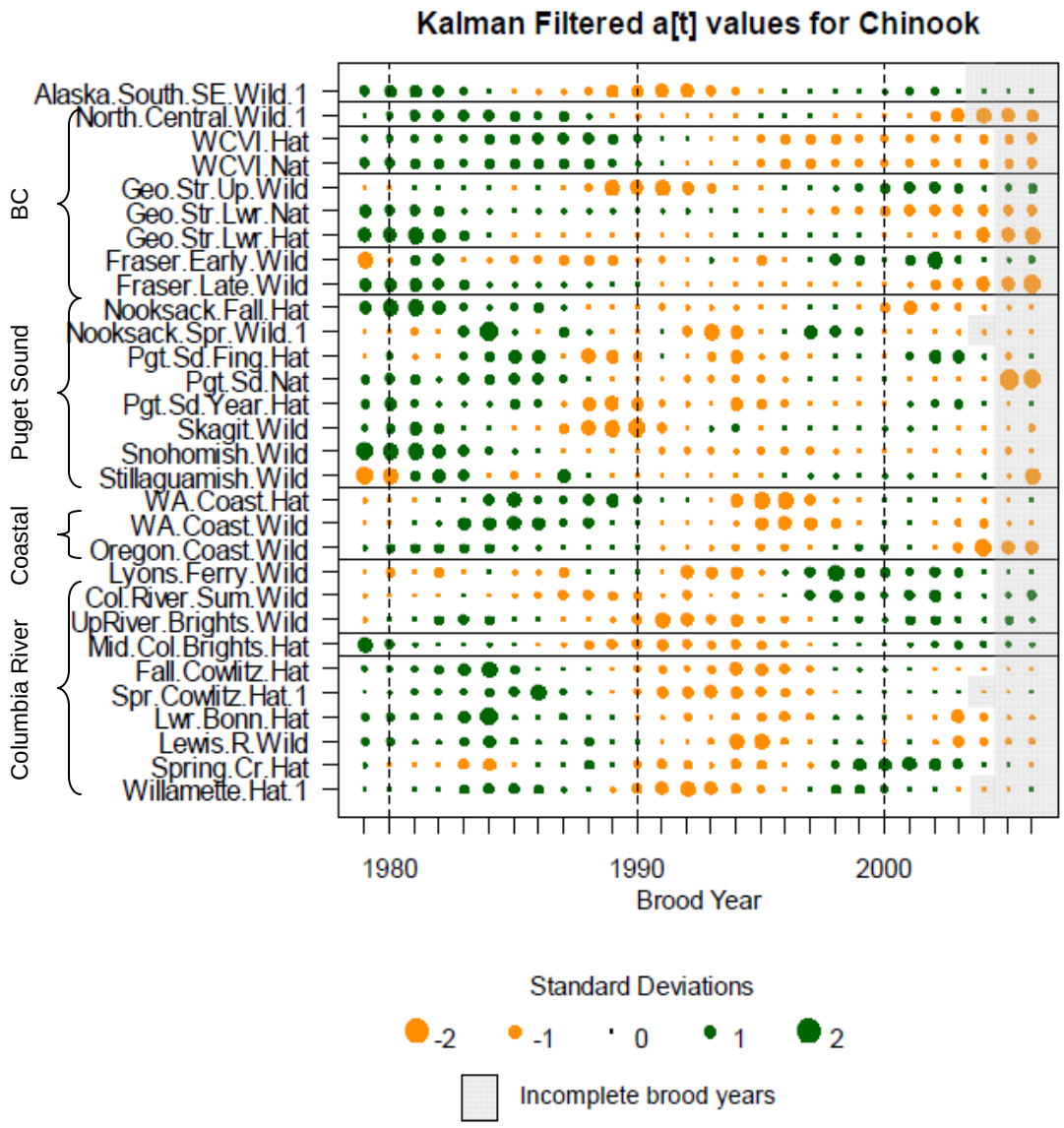

Figure 2. Time series trends in smoothed Kalman filter Ricker a_t values (total life-cycle productivity) for North American Chinook salmon aggregate stocks listed in order from north to south. Chinook stocks are presented in CTC model stock aggregates for convenience. Values are presented in standard deviation. Type: H- Hatchery aggregate, W – wild aggregate; Run : 0 – fall, 1- spring.

Comparison of coast wide trends in Sockeye productivity (Figure 1) shows Alaskan Sockeye stocks are generally doing better than stocks to the south where productivity started to decline in the early 1990s. Note some Alaskan stocks (2005 brood year, 2007 ocean entry year) show less than average productivity.

Trends in productivity for Chinook salmon stocks (Figure 2) are presented in CTC model stock aggregates for convenience. The 1990s was a period of below average productivity

consistent for Chinook stocks coast wide. Generally below average productivity continued for Canadian, Washington, and Oregon coastal Chinook stocks into the 2000s, while Alaskan and Columbia River (Oregon) stocks show improved productivity. Within the Fraser River, British Columbia, two aggregates with different life histories show opposite trends, the Fraser Late aggregate are currently below average productivity, while the Fraser Early aggregate is above average productivity.

Discussion

Coast wide Sockeye and Chinook salmon stocks experienced good productivity in the 1980's. This was followed by a decline in productivity in the 1990s for Sockeye stocks south of Alaska and coast wide for Chinook stocks. Some Chinook stocks, notably in Alaska and Columbia River have shown improved productivity in the last decade. A similar decline in productivity since the 1990s has been reported for Fraser River Sockeye populations but not for Fraser Pink and Chum salmon (Dorner et al. 2008; Peterman et al. 2010).

Pacific salmon are characterized by complex life histories, both within and between species, including freshwater and marine phases of variable time and distribution. The common temporal patterns in productivity observed across many distant stocks of Sockeye and Chinook salmon suggests that shared environmental factors acting at a broad spatial scale may explain the observed changes in productivity of North American Sockeye and Chinook. Monitoring programs collecting stock-specific data on distribution, survival, and production are critical to understanding the climate and oceanographic conditions effecting salmon production.

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