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An analysis of monitoring future responses of salmon productivity to climate change in the North Pacific

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Extended Abstract

Forecasts of future sea-surface temperatures (SST) on the west coast of North America suggest that salmon (*Oncorhynchus* spp.) populations inhabiting the Northeastern Pacific Ocean will face warmer ocean conditions than in the past (IPCC 2007). However, the effect of this change on sockeye salmon (*O. nerka*) populations is unclear. This uncertainty exists in part because historically, *increases* in SST have been associated with (1) *decreases* in productivity (recruits per spawner) for central and southern British Columbia (BC) sockeye populations, and (2) *increases* in productivity of sockeye in the north (Alaska, plus Skeena and Nass in BC) (Mueter et al. 2002). It is also unclear whether, under changing ocean conditions, salmon productivity will continue to respond to SST as in the past, or whether that response will change due to processes such as altered associations between SST and salmon food supply, or natural selection and/or phenotypic plasticity (Crozier et al. 2008). Better understanding of mechanisms that drive changes in salmon thus requires a synthesis of data collected from numerous monitoring programs located across large areas. The more coordinated the design of these monitoring programs is, the more likely data will be high-quality and compatible across regions, thereby helping scientists to better understand mechanisms in the future.

In our simulation study, we examined how alternative monitoring designs affect the ability to answer large-scale questions about the relative contributions of climate-driven factors to changes in salmon productivity in the North Pacific Ocean. We tested alternative monitoring designs across a wide range of scenarios about future changes in ocean conditions and salmon responses to these changes, and we evaluated those designs in the presence of confounding anthropogenic impacts occurring on local scales. We did

this by comparing the known, "true" parameters, which were user-defined in a stochastic salmon dynamics model, with estimates that emerged from applying different monitoring designs. We explored a range of "what-if" scenarios about (i) future changes in SST, (ii) response of salmon populations to those forecasted changes, and (iii) simultaneous occurrence of stock-specific declines in productivity through increases in mortality due to anthropogenic impacts on freshwater habitat. We also examined optional methods for conducting stock assessments on the resulting data.

Our simulation model consisted of four main modules. (1) The "salmon populations" module was parameterized based on historical data for 37 sockeye salmon populations from 1950-1999 (Dorner et al. 2008). It projected spawner-recruit time series stochastically for different scenarios of climate change and salmon response to environmental conditions. Scenarios of future coastal SSTs by location, which were generated by Global Climate Models, were obtained from Nate Mantua's research group at the School of Aquatic and Fisheries Sciences, University of Washington, Seattle (personal communication, 26 June 2009). (2) The "data collection" module of our simulation model implemented a range of sampling protocols. (3) The "stock assessment" module emulated the process of fitting a mixed-effects stock-assessment model to data obtained from simulated monitored stocks. (4) Finally, the "performance evaluation" module calculated indicators to illustrate our ability to estimate salmon productivity and distinguish climate-driven changes in productivity from changes caused by more localized anthropogenic activities.

We found that hypothetical changes in salmon responses to SST (including changes in productivity in response to environmental conditions and changes in carrying capacity) had the largest impact on indicator values of bias and precision of parameter estimates. Introducing changes in salmon response that were parameterized based on historical relationships and observed natural variation produced average increases of 100% to 200% for some indicators. The primary focus of this analysis was an indicator that measured the ability to separate the effects of large-scale changes in the ocean environment from more localized anthropogenic impacts. It was one of the indicators most strongly affected by changes in salmon response to SST, indicating that distinguishing between sources of change will be a substantial challenge in the future given the current network of monitoring sites. There also was considerable interdependence among salmon response, sampling protocols, fitting options, and SST scenarios.

In summary, our findings imply that changes in salmon response to climate changes could make future stock assessment, and hence future salmon management, considerably more difficult. Although careful choice of a sampling and model-fitting protocol can help somewhat to improve parameter estimates, there was no combination that was optimal under all circumstances. As well, the relative benefits of choosing the optimal sampling and fitting options were by far outweighed by the potential effects of changing salmon response to ocean conditions, especially when the main concern is the ability to separate effects of climate change in the ocean environment from local anthropogenic activities.

This "extended abstract" is a shortened version of a longer manuscript that will be submitted to a journal. Please contact the lead authors for more information (bdorner@driftwoodcove.ca, kendra.holt@dfo-mpo.gc.ca, or peterman@sfu.ca).

References

Crozier, L.G., A.P. Hendry, P.W. Lawson, T.P. Quinn, N.J. Mantua, J. Battin, R.G. Shaw, and R.B. Huey. 2008. Potential responses to climate change in organisms with complex life histories: evolution and plasticity in Pacific salmon. Evolutionary Applications 1:252-270.

Dorner, B., R.M. Peterman, and S.L. Haeseker. 2008. Historical trends in productivity of 120 Pacific pink, chum, and sockeye salmon stocks reconstructed by using a Kalman filter. Canadian Journal of Fisheries and Aquatic Sciences 65(9):1842–1866.

IPCC (Intergovernmental Panel on Climate Change). 2007. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland, 104 pp. Available at http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm (accessed 31 May 2010).

Mueter, F.J., R.M. Peterman, B.J. Pyper. 2002. Opposite effects of ocean temperature on survival rates of 120 stocks of Pacific salmon (*Oncorhynchus* spp.) in northern and southern areas. Canadian Journal of Fisheries and Aquatic Sciences 59(3):456-463 plus the erratum printed in that same journal, volume 60:757.

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