2 June 2010

Assessment of regional conservation status of Pacific salmon based on multiple objectives: a simulation study

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Extended Abstract

When scientists design regional monitoring programs for spatially dispersed populations such as Pacific salmon (*Oncorhynchus* spp.), simulation modeling can be useful for examining trade-offs between sampling cost and the ability to achieve monitoring objectives. In this study, we use Monte Carlo simulation to demonstrate how the choice of best sampling design or method of data analysis depends on the monitoring objective and specific indicator used to reflect that objective.

The level of conservation concern for Pacific salmon populations is typically determined by estimating status and time trends in spawner abundance. However, an increasing need to assess biological diversity requires identification and evaluation of indicators of spatial population structure. A preference toward having spawning salmon spread across several different habitats, rather than concentrated within one or two streams (McElhany et al. 2000, DFO 2005), suggests several distributional indicators, including the proportion of spawning sites with abundance below some critical level, and the proportion of spawning sites that have experienced decreases in abundance more than some critical amount.

Given these new types of indicators, it is important to determine which sampling designs and/or methods of data analysis would be most appropriate, especially given limited budgets for monitoring. Sampling designs or analysis methods that maximize statistical performance for indicators of ***average*** regional abundance (i.e., the average across sites within an Evolutionarily Significant Unit in the United States or a Conservation Unit in Canada) may not be the best designs or analysis methods for indicators of the ***distribution*** of abundance and time trends in abundance ***among sites within that region***. We hypothesized that rotating panel temporal sampling designs and hierarchical estimation models could improve estimation of distributional indicators compared to annually sampling the same subset of sites and estimating site-specific indicators independently (i.e., individual estimation models). Rotating panels allow a larger number of sites to be sampled within a region with the same total effort (Urquhart et al. 1998), whereas hierarchical modeling of the sample data allows data poor sites to "borrow information" from more data-rich sites within the same region (Clark and Gelfand 2006).

To test these hypotheses, we considered a range of eight monitoring objectives and three sampling designs. Monitoring objectives covered all combinations of two statistical performance measures (minimize bias or root mean square error) and four

conservation indicators for spawners (average abundance, average time trend in abundance, proportion of spawning sites with abundance below 25% of the historical baseline, and proportion of spawning sites with a rate of decrease in abundance more than 30% over the last 3 generations). The three sampling designs differed in their temporal frequency of spawning site sampling, but had the same total sampling effort over the long term. Those sampling designs were: (1) index-sites that were assumed to reflect status of a larger number of salmon stocks in a region, (2) a two-year rotating panel in which a portion of sites within a region were designated to be in one of two panels and each panel of sites was visited every second year, and (3) a three-year rotating panel, where each site was visited every third year. We used field data on coho salmon (*O. kisutch*) spawner abundances to parameterize a Monte Carlo simulation model that generated realistic temporal patterns of change in spawner abundance. Within each simulation trial, data were generated at each of 60 spawning sites over a 10-year period. We then fit the resulting time series using two different approaches to linear regression -- individual models fit to time-series data from individual sites and hierarchical models fit simultaneously to all time-series data sets in the region. We then evaluated the bias and root mean square error of estimated conservation status of the simulated salmon populations. This entire process was repeated for a hypothetical situation in which the agency's monitoring budget was severely reduced, as has been the case on the west coast of North America.

We found that the best combination of sampling design and data analysis method depended on the indicator used to assess conservation status (e.g., current abundance, time trend in abundance, or distribution of those two across sampling sites within the region). The ranking also depended on whether statistical performance was measured in terms of bias alone or a combination of bias and precision (i.e., root mean square error). More generally, this example shows how Monte Carlo simulations can be used to evaluate the ability of various monitoring plans, including those with substantially different budgets, to meet specific monitoring objectives.

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

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(ExtendedAbstract-Holtetal-1June2010)