**Comments on CRI technical workshop III: Incorporating spatial processes into viability analyses for salmonids**

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As a population biologist with a mathematically abstract understanding of population growth, I appreciate the reality-check I received from the managers attending this workshop. Faced with simple management questions, I was unable to provide definitive answers. This dialog delineated the gap between general population theory and the guidelines necessary for managing salmonid populations. To bridge this gap, general theory must be interpreted in terms of salmonid life-histories, and translated at a level of precision relevant to the scales at which management decisions are made. This process will require theoretical work that is guided specifically by the day-to-day questions faced by managers.

Although it was clear from the presentations of NWFSC researchers that salmon-inspired models are being developed to answer relevant management questions, it was also clear that the managers in attendance need more specific guidelines than those offered by current theory. Current theory is spotty in its consideration of basic principles or assumptions underlying population growth. Imagine the entire set of population models that could be constructed if every potential aspect of population dynamics was varied while holding all others constant. Including the spatial interaction of individuals and populations adds several new dimensions to this parameter-space. The parameter-space is larger the less we know about a species—the less we can rule out dynamics that do not apply.

The need to understand all potential salmonid spatial dynamics is frustrated by real limits on time, scientist resources and the data required to parameterize many potential models. One of the most promising developments from the workshop is a plan to minimize the time and resources spent exploring the potential universe of salmonid dynamics, through judicious use of the models on hand.

*Comparative modeling to identify robust guidelines for salmonid management*:

The plan is to use several disparate models developed by NWFSC researchers and others in order to evaluate several specific management scenarios. When models with different assumptions about population response to specific conditions generate similar predictions about overall population response to a particular management strategy, we may assume the predictions are robust. Departures between model predictions identify specific effects of different assumptions and sometimes reveal cryptic assumptions embedded in certain models. At the very least, departures between model predictions identify where we need to explore the parameter space of model assumptions in greater detail.

A similar comparative modeling strategy is in use at the National Institute of Standards and Technology (NIST). NIST studies many complex problems, including the behavior of the magnetic storage materials used in the computer industry. The behavior of magnetic materials includes strong spatial interactions between individual charged particles, leading to diverse

models of dynamics that are as intractable as many population models. In order to determine how robust are the predictions of these models, NIST scientists are using several different models to analyze a set of 'standard problems'. For lessons that might be learned from this effort, contact Bob McMichael, chairman of NIST Materials Science and Engineering Laboratory (rmcmichael@nist.gov) or see the project website (www.ctcms.nist.gov/programs/profiles/mumag.html or search 'micromagnetics modeling' or 'mumag').

The idea of 'standard problems' is particularly relevant to salmonid management. It would be very useful if a group of managers could formulate a set of standard problems they face, including the relevant spatial scale of each problem and the amount of biological data at hand to inform their decisions. These standard problems could be used to determine the type of models that should be explored in the short term. Perhaps a future CRI workshop could focus on this effort.

*Defining populations for demographic management*:

NMFS has proposed a definition of population based on demographic independence, a population being a group of breeding individuals whose dynamics and extinction risk over a 100-year period are not substantially influenced by demographic exchange with other populations. This is a very useful definition for demographic management of populations, provided such independence can be determined (see below). In practice, there are many problems with identifying populations based on this criterion. Each of the metrics that can provide evidence for demographic independence between populations (patterns in alleles frequencies, correlations in abundance over time, spatial and temporal spawning distributions, mark/recapture data, and physical data on habitat environments) can also be confounded by processes that are not related to demographic independence. It was proposed that careful consideration of all metrics in tandem can improve the likelihood of making the proper judgement about demographic independence. An excellent example of this process is in the discussion section of Ford's (1998) work on alternative chinook migration models. There he uses a combination of genetic and demographic inference to suggest the most likely population dynamics. For another example of the combined use of genetic and demographic inference to reveal population dynamics in a small mammal, see Peacock and Ray (2000).

One goal of the workshop was to evaluate whether the rather subjective process of weighing several metrics would result in reliable estimates of demographic independence. As I recall, the plan for evaluating this reliability was similar to the 'standard problems' project outlined above: give the same data to different teams for analysis, to see if they come up with similar evaluations of demography. It is also possible that some metrics are more reliable than others, or some combination of metrics would reveal more about demographic independence. These patterns might not be revealed by independent teams working on a single or a few real data sets. I suggest these patterns could be revealed through a modeling exercise. A simple two-population model such as that of Hastings (1993)* could be expanded to include genetics and potentially correlated environments, and outputs from this model could be analyzed using the proposed metrics. (*The model presented at the workshop by Chris Jordan could also be modified for this purpose.) This

approach would reveal any potential match between the (known) type of internal/external population forcing and patterns in the different population metrics.

*Demographic independence and the rate of dispersal between populations*:

One breakout discussion group invoked Hastings' (1993) rule of thumb that demographic independence can be achieved if less than 10% of individuals are exchanged between populations. This rule is supported by some empirical work. However, I am concerned that there may be great temporal variability in exchange rates in response to processes both internal and external to populations. It may be very important to define populations based on exchange rates inferred from (past) data rather than predicted (future) exchange. If predictive models don't include all the forces that may alter exchange rates over time, predictions of population independence may be erroneous.

*Suggestions for future workshops*:

Above I suggested that the comparative modeling project would benefit from a list of standard problems generated by the managers themselves. Perhaps this list could be generated at a workshop where preliminary results from the comparative modeling project are also presented. A discussion of the modeling results should stimulate a refinement of the guidelines managers actually need.

In order to generate useful guidelines for management, modelers must eventually create a sort of key to model outcomes, based on model assumptions. In order to distinguish the model assumptions appropriate for particular populations, managers will need certain demographic data for each population. There should be a plan for generating these data. A related problem is the lack of essential data on exchange rates, needed for the modeling efforts themselves. Perhaps after a bit more modeling work, there will be enough information on critical model parameters to guide a workshop on 'necessary data and how to obtain it'. Modelers could address the first topic and managers the second.

Finally, future workshop participants should be apprised of the topics and results of previous workshops. Receiving a brief written summary would help invited speakers focus their contributions on gaps, or build on previous discussions.