NOAA Fisheries
Northwest Regional Office

The Viability Risk Assessment Procedure & Rebuilding Exploitation Rates

NOAA Fisheries analyzes the effects of harvest on salmon populations using both quantitative and qualitative analyses. The Viable Risk Assessment Procedure (VRAP) is a quantitative risk assessment method used primarily to analyze harvest impacts on Puget Sound Chinook salmon. The VRAP method provides estimates of population-specific exploitation rates, also called rebuilding exploitation rates or RERs. These rebuilding exploitation rates are consistent with a population's survival and recovery requirements under the Endangered Species Act. Proposed fisheries are evaluated, in part, by comparing the RERs to rates that can be anticipated as a result of the proposed harvest plan. NOAA Fisheries considers the harvest plan to present a low risk to the population when the impacts of the proposed plan are less than or equal to the rebuilding exploitation rates. The risk to a species associated with an individual population must also be considered within the broader context of other information such as recovery plan guidance on the number, distribution, and life-history representation within regions and across the species; the role of associated hatchery programs; observed population status and trends; and the practical effect of further constraints on the proposed harvest action. The results of this comparison, together with more qualitative considerations for populations where RERs cannot be calculated, are used to make a jeopardy determination for the species as a whole.

A summary of VRAP and how it is used to estimate rebuilding exploitation rates is provided below. A more detailed explanation and an example of how it has been applied to Puget Sound Chinook harvest evaluations is available in a report that describes NOAA Fisheries' approach to making Endangered Species Act determinations for harvest actions.

Summary of the Viable Risk Assessment Procedure

The Viable Risk Assessment Procedure:

- Quantifies the risk to survival and recovery of individual populations compared with a zero harvest scenario;
- Accounts for total fishing mortality throughout the migratory range of a species;
- Incorporates management, data, and environmental uncertainty; and
- Isolates the effect of harvest from mortality that occurs in the habitat and hatchery sectors.

The result of applying the VRAP methodology to an individual population is an RER which is the highest allowable ("ceiling") exploitation rate that satisfies specified risk criteria. Calculation of RERs depends on the selection of two abundance-related reference points (referred to as critical and rebuilding escapement thresholds (CET and RET), and two risk criteria that define the probability that a population will fall below the CET and exceed the RET.

For analytical purposes, the selection of risk criteria is a policy decision, but they are chosen within the context of the jeopardy standard.[1] They measure the effect of the proposed action against the baseline condition, and require that the proposed action not result in a significant negative effect on the status of the species over the conditions that already exist. The baseline condition assumes zero harvest. In previous VRAP applications, NOAA Fisheries determined appropriate risk criteria to be: (1) the percentage of escapements below the CET differs no more than 5% from baseline conditions; *and* (2) the RET must be met 80% of the time, *or* the percentage of escapements less than the RET differs no more than 10% from baseline conditions. These criteria seek to identify an exploitation rate that will not appreciably increase the number of times a population will fall below the critical threshold and also not appreciably reduce the prospects of achieving recovery.

As described above, VRAP uses critical escapement and rebuilding escapement thresholds as benchmarks for calculating RERs. Both thresholds are measured using natural-origin spawners. The CET represents a boundary below which uncertainties about population dynamics increase substantially. The RETs, as used in VRAP, are a level of spawning escapement associated with rebuilding to recovery, consistent with current environmental and habitat conditions. It is important to recognize that the RET is not an escapement goal but rather a threshold level that is expected to be exceeded most of the time (greater than 80%). There often is confusion about the relationship between RETs used in the VRAP analysis, and abundance related recovery goals. For most populations, the RET are significantly less than recovery goals that are specified in recovery plans. However, achieving these goals under current environmental and habitat conditions is a necessary step to achieve recovery. As the productivity and capacity of the habitat improves, the VRAP analysis will be adjusted to reflect those changes. Thus, the RET serves as a step toward recovery, which will occur as the contributions from recovery actions across all sectors are realized.

There are two phases to the VRAP process for determining a population's RER. The first phase uses data from the target population, or a representative indicator population, to fit a spawner-recruit relationship representing the performance of the population over the time period analyzed.

[1] Regulations implementing the Endangered Species Act jeopardy standard as: to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of the species.

Population performance is modeled as:

$R = f(S, \mathbf{e}),$

where S is the number of fish spawning in a single return year; R is the number of adult equivalent recruits[2]; and **e** is a vector of environmental, density-independent indicators of annual survival.

Several data sets are necessary for the first phase of this analysis: a time series of natural spawning escapement, a time series of total recruitment by cohort, and a time series for the environmental correlates of survival. In addition, it is necessary to assume a functional form for the spawner-recruit relationship. Given the data, it is possible to estimate the parameters of the assumed spawner-recruit relationship to complete this phase.

The data are fitted using three different models for the spawner-recruit relationship: the Ricker (Ricker 1975), Beverton-Holt (Ricker 1975), and Hockey stick (Barrowman and Meyers 2000). The simple forms of these models can be augmented by the inclusion of environmental variables correlated with brood year survival. The VRAP is flexible in that it facilitates result comparisons depending on assumptions between production functions and any environmental co-variates. Equations for the three models are as follows:

$$R = (aS\mathrm{e}^{-bS})(M^{c}\mathrm{e}^{dF}) \quad \text{[Ricker]}$$

$$R = (S/[bS + a])(M^{c}\mathrm{e}^{dF}) \quad \text{[Beverton-Holt]}$$

$$R = (\min[aS, b])(M^{c}\mathrm{e}^{dF}) \quad \text{[hockey stick]}$$

In the above, M is the index of marine survival and F is the freshwater correlate.

The second phase of the analysis, or projection phase, involves using the fitted model in a Monte Carlo simulation to project the probability distribution of the near-term performance of the population assuming that current conditions of productivity continue. Besides the fitted values of the parameters of the spawner-recruit relationships, estimates are required of the probability distributions of the variables driving the population dynamics, including the process error of the spawner-recruit relationship itself and each of the environmental correlates.[3] Also, since fishing-

[2] Equivalently, this could be termed "potential spawners" because it represents the number of fish that would return to spawn absent harvest-related mortality.

[3] Actual environmental conditions may vary from the modeled 25-year projections due to such things as climate change, restoration actions, development, etc. However, it is difficult to anticipate exactly how conditions might be different for a specific population which is the focus of the VRAP analysis. Incorporation of the observed uncertainty in each of the key parameters in the VRAP analysis, the use of high probabilities related to abundance thresholds and periodic revision of the RERs on a shorter time frame (e.g., 5-10 years) in the event that conditions have changes serve to mitigate this concern.

related mortality is modeled in the projection phase, one must estimate the distribution of the deviation of actual fishing-related mortality from the intended ceiling. This is termed "management error" and its distribution, as well as the others, is estimated from available recent data.

During the projection phase the population is repeatedly projected forward for 25 years using a stepped series of exploitation rates. The purpose of the analysis is to find the highest exploitation rate that satisfies the risk criteria. From the simulation results we compute the fraction of years in all runs where the escapement is less than the critical escapement threshold and the fraction of runs for which the final year's escapement is greater than the RET. Exploitation rates for which the first fraction is less than 5% and the second fraction is greater than 80% (or 10% from baseline) satisfies the identified risk criteria and can be used to define the population specific RER for harvest management.

The graphic below shows an example of the derivation of a rebuilding exploitation rate.