An Introduction to Backward and Forward Projection Stock Assessment Models

Backward and forward projection models represent two common approaches to assessing fish population trends. Virtual Population Analysis (VPA) is one type of backward projection model that has been used to assess ASMFC-managed species such as striped bass, summer flounder, tautog, and weakfish. Forward projection models, more commonly called Statistical Catch-at-Age models (SCAA), have been used to assess ASMFC-managed species such as Atlantic menhaden, croaker, and herring.

Age-structure. Backward and forward projection models differ from many simpler approaches in stock assessment in that they track changes over time in the number of fish in each age class (number of age 0s, age 1s, age 2s, etc.). Such age-structured models are often used when we want to answer age-specific questions about population trends such as "How many fish older than age 8 are there in the population?" or "Are there trends in recruitment (age 0s)?".

Input. Core data used in both forward and backward projection models are age-structured; in other words, these models require age information from scales, otoliths, or other aging structures. Catch-at-age data are estimated because it is not practical to age every fish landed. A subset of fish caught is aged and the proportions of fish in each age class are used to estimate the age structure of all landings.

Output. Although these models can be enhanced, the simplest VPA or SCAA will provide similar output, specifically estimates of historical annual abundance-at-age and annual estimates of the instantaneous fishing mortality rate (F) for each age class.

Backward projection. VPAs work on the principal that the minimum number of fish in the population in a given year is equal to the total number of fish that either were caught or died naturally. For a fish that lives to age 3, all fish hatched in 1997 are assumed dead by 2001 (see Figure 1). Given this assumption, total fishery catch-at-age, and an estimate of natural mortality (M; or age-specific natural mortalities), we can reconstruct historical abundance-at-age. Reconstruction is performed in an iterative ("trial and error") fashion. However, many fish hatched between 1998 and 2001 are still alive, so we cannot assume their abundance is zero in 2001. A process called "tuning" is used to reconstruct the population for younger fish in which assumptions are made about the rate of fishing mortality in the last year of the assessment. Alternatively, additional information such as survey data is used to estimate F in the final years of the assessment. In all cases, it is important to note that VPAs assume catch-at-age is known without error.

Forward projection. Forward projection models like SCAAs differ from most VPAs in that they estimate annual abundance-at-age starting with the first year of the analysis and ending with the most recent year (Figure 2). SCAAs estimate or make assumptions about abundance of the stock in the first year of the analysis and estimate annual recruitment in order to reconstruct population abundance-at-age. SCAAs inputs include catch-at-age data from the fishery, an estimate of natural mortality (or estimates of natural mortality-at-age), and an index of catch-per-unit-effort that is typically obtained from fisheries independent surveys. The model uses a series of short equations to estimate fishing mortality, abundance-at-age, survey catch, and fishery catch. To determine what levels of population abundance and fishing mortality would be most likely given the actual data, model estimates are statistically compared with the actual fishery catch and survey data. SCAAs admit error in the catch at age data and often require the level of uncertainty (variability) in catch records be specified. Basic SCAA models also assume that selectivity (the proportion of fish in each age class vulnerable to the fishery) does not change over time. A comparison of similarities and differences between the most basic forms of VPAs and SCAAs can be found in Table 1.

To read about retrospective bias, a common problem associated with backward and forward projection models, please consult the Science Highlight in the March 2007 issue of Fisheries Focus. This article is a synopsis of the Commissioner Stock Assessment Workshop during Summer Meeting Week 2007. For more information, please contact Genny Nesslage, Senior Stock Assessment Specialist 703.842.0740 or gnesslage@asmfc.org.

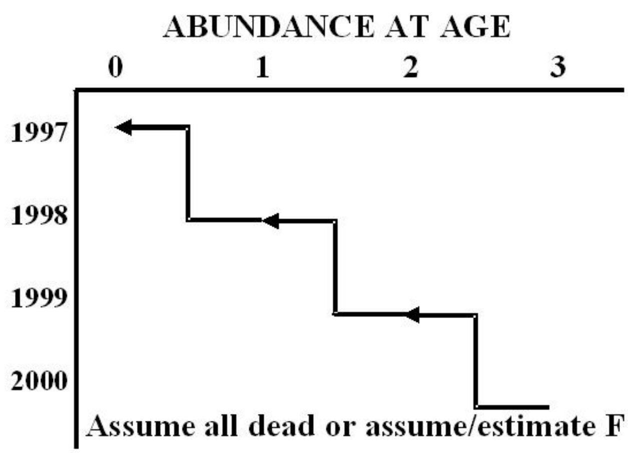

Figure 1. Diagram of a "backward projection" such as Virtual Population Analysis for a fish that lives to age 3. All fish hatched in 1997 are assumed dead by 2001. Arrows illustrate how the number of age 3 fish in 2000 is used to estimate the number of age 2s in 1999, number of age 1s in 1998, etc.

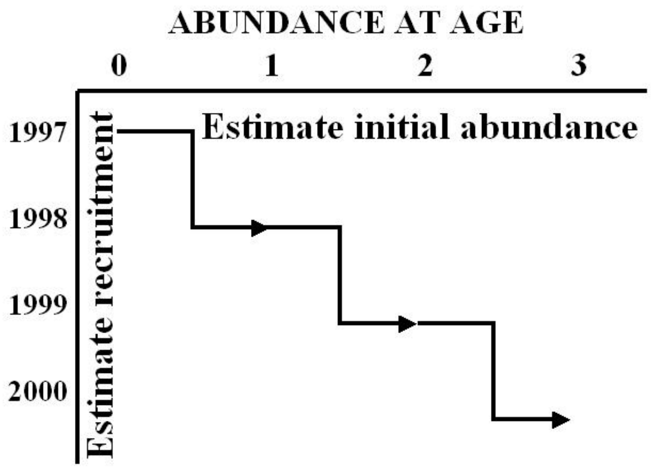

Figure 2. Diagram of a “forward projection” such as a Statistical Catch-at-age (SCAA) model for a fish that lives to age 3. SCAAs use a series of short equations to estimate abundance-at-age, fishing mortality, survey catch, and fishery catch. Arrows illustrate how estimated recruitment (age 0s) in 1997 is used to estimate the number of age 1s in 1998, number of age 2s in 1999, etc. Initial abundance-at-age and annual recruitment is estimated by the model.

Table 1. Similarities and differences between the most basic form of Virtual Population Analysis (VPA) and Statistical Catch-at-Age (SCAA) models.

DIFFERENCES	VPA	SCAA
	-Minimum data requirement = estimated catch-at-age -Iterative solution -Catch-at-age is known without error	-Minimum data requirement = estimated catch-at-age and catch-per-unit-effort index -Statistically fit -Error admitted in catch-at-age data -Selectivity constant over time
SIMILARITIES	-Both estimate historical annual abundance-at-age -Both assume constant rate of natural mortality (M) -Both estimate annual instantaneous fishing mortality (F) at age	