A summary of the procedures applied to determine the amount of critical habitat needed for the recovery of the Atlantic salmon Gulf of Maine Distinct Population Segment

DRAFT
2008

Appendix B

Introduction

Statistical methods can be utilized to quantitatively estimate population growth, decline or extinction probabilities for a species. The size of a population and its corresponding growth rate are both important predictors of its future production as a population exhibiting long term continual decline will eventually go extinct. However, even if a population is not on average declining, there is still some probability that its future abundance will decline as a result of environmental variation and/or other processes. The probability of a population remaining above or below some abundance level is both a function of initial population size and productivity.

The simplest type model to perform these assessments is referred to as a simple Population Viability Analysis (PVA). A simple PVA quantitatively estimates information related to population growth and extinction probabilities for a single population (Dennis et al. 1991). A simple PVA is a stochastic exponential growth model of population size which is equivalent to a stochastic Leslie-matrix projection with no density dependence. These types of models are best used with census data where the sampling variability is small compared to the population or environmental variability (Dennis et al. 1991). It should be noted that long-term predictions about the productivity of any species is likely to be academic because the predictions generally assume that environmental factors remain unchanged. This leaves the reality of shorter term predictions being generally more reliable (Hanski 2002).

More complex PVA approaches have been developed whereby life history characteristics are accounted for within the model, such as the age distribution within the abundance measure. In addition, a modified approach has been developed where different life history processes are compartmentalized within the model allowing for the incorporation of such things as juvenile survival rates, adult survival rates, habitat limitations/degradation, age specific fecundity or migration rates (Beissinger 2002, Legault 2005). The forecasts generated from these PVA models can be used to explore the potential effects of management actions in light of unknown future conditions and the variability surrounding input assumptions and data (Samson 2002).

The simple PVA is a quantitative approach for estimating extinction probabilities whereas complex PVA models are more appropriate for comparing the effects from different management options. Simple PVA models are being widely used to evaluate the conservation status of many Pacific salmon Evolutionary Significant Units (Matthews and Waples 1991).

We developed a simple PVA model to simulate the Gulf of Maine Distinct Population Segment (GOM DPS) future performance based on observed past performance during a period of decline. The projections produced by this model were used to evaluate the proportion of trajectories falling below a pre-defined abundance level (i.e. threatened status) under different initial abundance levels. This process estimated the population size needed to remain above a given threshold for the foreseeable future, given a period of significant decline. The amount of critical habitat needed for recovery of the species can then be determined based on the estimated abundance level. It should be noted that this model does not take into account the possibility of catastrophic events or any genetic effects which could influence the interpretation of these results and the long term sustainability of the modeled population.

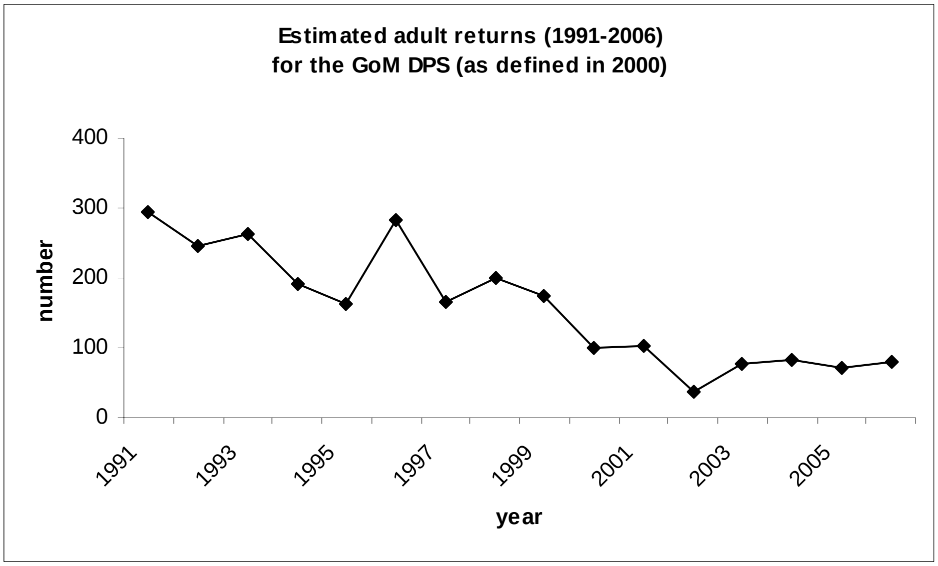
Input data

GOM DPS (as defined in 2000) adult returns (1991-2006)

Spawner estimates for the GOM DPS (as previously defined in 2000) were obtained for the time period 1991-2006 (*see figure below*). These estimates are for the GOM DPS, as previously defined in 2000, and are based on an adult return-redd count linear regression model (USASAC 2007). These data were used to calculate the population growth parameters necessary for the PVA. This data set was considered to be the most appropriate for this exercise for numerous reasons:

- A "regime shift" has been described for Atlantic salmon populations in the North Atlantic starting in 1991 (Chaput et al. 2005). This "regime shift" represents a decrease in productivity for Atlantic salmon in the Northwest Atlantic and has likely resulted from a change in marine survival that occurred in the early 1990's and has persisted to date. This time series is representative of a period of poor survival resulting in precipitous declines that have helped us get to our current status.
- This time period eliminates the major of the rod kill that occurred within the GOM DPS(as previously defined in 2000). Rod killed adults represent individuals that likely would have spawned and contributed to future generations, but were removed from the river prior to spawning. During the 1980's and early 1990's, with decreasing abundance and increasing catch and release being practiced, the number of rod killed fish in the GOM DPS (as previously defined in 2000) declined and reached zero (1995) as mandatory catch and released was instituted.
- Although there has been variation in the numbers and life stages stocked into the GOM DPS (as previously defined in 2000) since 1991, compared to historical stocking the effort has remained relatively consistent. The river-specific hatchery program was initiated in 1991 and since that time, river-specific fry have been the primary hatchery product stocked into the GOM DPS(as previously defined in 2000).
- The Penobscot River time series was not included even though it is part of the newly defined GOM DPS. This decision was due to large variations in stocking practices within the Penobscot River in terms of numbers and life stage stocked over the time series being considered. There have also been changes for the GOM DPS (as previously defined in 2000), but these changes have been mostly at the fry stage as opposed to the parr and smolt stages for the Penobscot. Changes in parr and smolt stage stocking will have large impacts on adult returns, as these stages have higher return rates compared to fry stocking. These effects would be independent of the prevailing marine conditions and therefore would artificially

bias the growth parameter estimation. In addition, the PVA is reliant on an estimate of population growth (i.e. trend in abundance), not on the absolute numbers of returns. Given that the Penobscot River and the GOM DPS (as previously defined in 2000) have declined in a similar fashion in recent times, coupled with the changes in stocking practices, the Penobscot time series was excluded from the estimation of the population growth parameters.



Methods

There are two steps to the PVA. The first step is to estimate the population growth rate and variance from the input data. The second step is to simulate future population growth using these parameters and to evaluate the proportion of trajectories falling below a pre-defined abundance level.

Estimating Population Growth Rate

The population growth rate is calculated according to the following formula:

$$Ln(returns_{t+1}/returns_{t})$$

These data can be expressed as the mean annual rate of increase (or decrease) in the population (>0=increase, <0=decrease and =0 flat). The variance around the population growth is calculated from the time series of the population growth. Both parameters are on a log normal scale.

A summary of the GOM DPS (as previously defined in 2000) population growth and its associated variance is presented below:

Time series	**mean population**	**standard deviation**

	growth	
1991-2006	-0.088	0.434

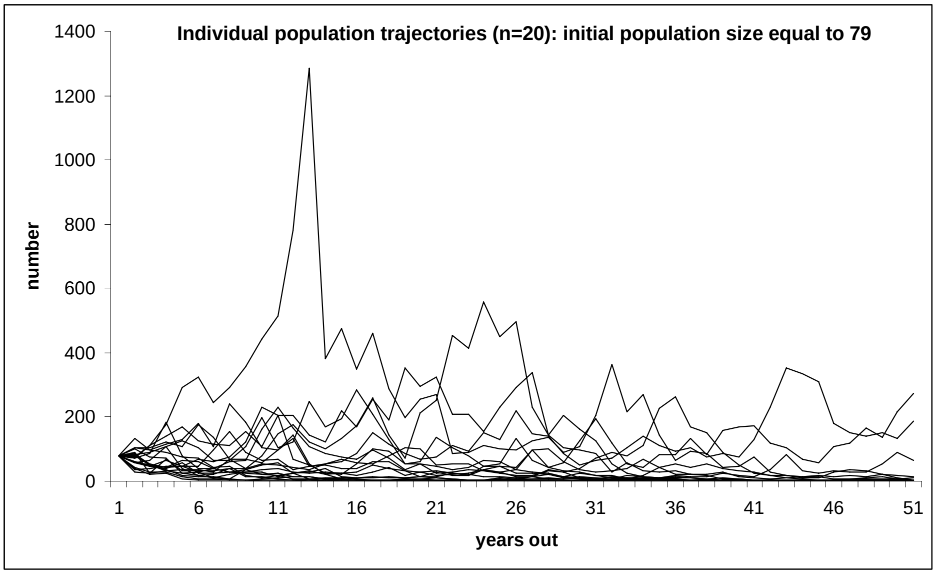
The population growth parameter provides some indication as to the status of the population under analysis. Low values equal a higher probability of decline and require larger improvements in population growth (e.g. survival/fecundity) or larger initial population size to avoid falling below a pre-defined threshold. Small initial population sizes exacerbate this process as there is a shorter time to wait until the population falls below this threshold (Holmes 2001). The trend is for negative population growth over the 1991-2006 GOM DPS(as previously defined in 2000) time series.

Projecting future status

The PVA uses the estimated population growth rate, its standard deviation and an initial abundance level to project into the future a user defined number of years for a user defined number of projections. The forward projection involves taking the natural log of returns for the year prior and adding to it the mean population growth rate and a random selection from the normal distribution of the population growth rate (as defined by its mean and standard deviation). This value is then exponentiated to bring it back to normal scale (i.e. adult abundance). This process is then repeated until the user defined time frame is completed and the user defined number of projections has been accomplished. The proportion of trajectories where the estimated abundance level falls below a user defined threshold abundance level is then recorded.

All simulations consisted of 10,000 iterations projecting forward 50 years. The abundance threshold was set at 500 individuals and the extinction threshold was set at 1 individual. If the abundance level fell below 1 individual, then no reproduction can occur and the population was considered extinct. There was no upper limit set for three reasons. First, we were only concerned with the number of iterations that remained above a pre-defined threshold (magnitude of difference doesn't matter). Secondly, the number of iterations resulting in extremely large estimates remained very low for all simulations (<3% of the interations exceeded 10,000 individuals after 50 years with an initial abundance of 2,000). Finally, without accurate habitat information or historical knowledge on the performance of a fully functional GOM DPS, any upper ceiling estimate would be a best guess at best and pure speculation at worse.

An example of the results from these simulations showing the variability of the projections is shown below. Note that with an initial population size set at 79 individuals and the population growth rates observed from the input data set, the majority of the trajectories go extinct within 50 years.



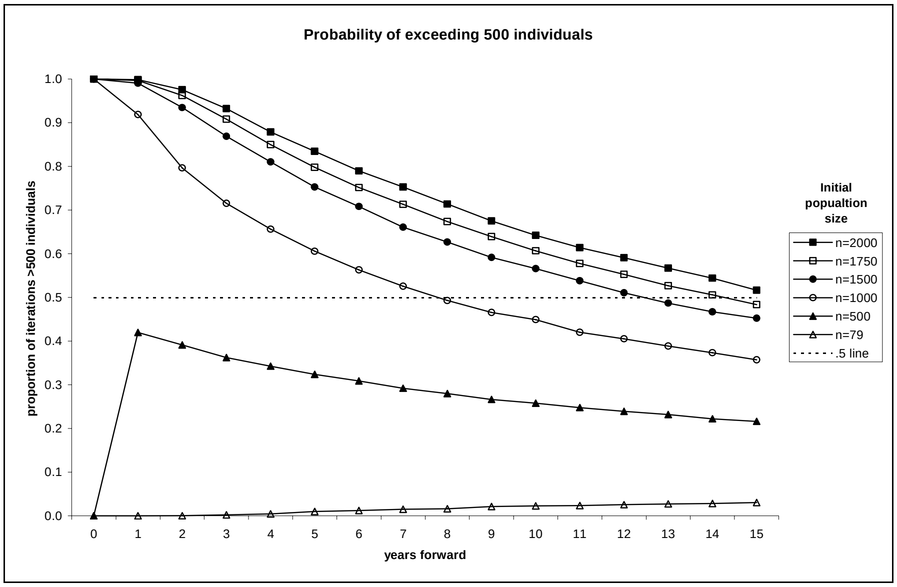
Threshold abundance level, likely, and foreseeable future

The threshold abundance level evaluated via this method was set according to the proposed recovery criteria, which states that a recovered population is a population that is likely to remain above 500 individuals for the foreseeable future. The term likely was interpreted as to having a greater than 50% chance of occurring whereas the foreseeable future was interpreted as equaling 15 years or 3 generations. Therefore for each simulation, the initial abundance level was varied to find the level at which the population remained above the 500 individual threshold level greater than 50% of the projections for 15 years into the future. The number of projections that fell below the extinction threshold was also counted.

Results

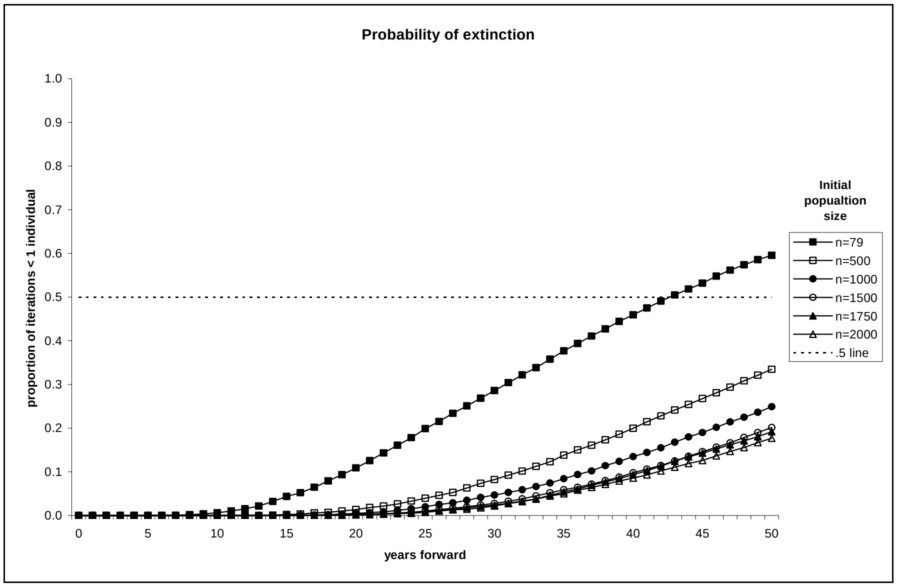
Results from the PVA suggest that an initial population abundance level of 2,000 adult returns is needed to have a likely chance (>50%) of remaining above 500 adults returns for the foreseeable future (15 years) given a downturn in survival as was experience from 1991-2006. Tabular and graphical results are presented below.

	>500 individuals
2,000	51.6%
1,750	48.4%
1,500	45.3%
1,000	35.7%
500	21.7%
79	3.1%



It should be noted that even with a large initial population size, there is still a probability of extinction over a longer time frame as a result of environmental variation and/or other processes. Although as Holmes (2001) warns, smaller initial population sizes greatly exacerbate the problem. Tabular and graphical summaries of the extinction risk under varying initial population size are presented below.

	Extinction
2,000	17.7%
1,750	19.2%
1,500	20.1%
1,000	24.9%
500	33.5%
79	59.6%



Discussion

The above results estimate that 2,000 individual adults are needed to likely weather another downturn in survival (post-recovery) and still remain above 500 adult returns for 15 years. This estimate is calculated from the historical dynamics and performance of the system as determined by the influences of various factors (environmental, natural and hatchery demographics, genetic…) during the time frame of the input data. There is no guarantee of future performance as there is no guarantee that future condition will mirror past conditions. In addition, even with an initial population of 2,000 individuals there is still a chance of the population going extinct as 18 percent of the projections fell below one individual. The habitat requirements for these 2,000 individuals can be calculated and this quantity can be considered during the critical habitat designation process. In addition, this modeling approach can be employed to determine the conservation status of the GOM DPS as recovery goals begin to be met. Forward projections based on past performance will give managers some estimation of the likely performance of a stock complex into the foreseeable future as it relates to listing and delisting criteria under the ESA.

Literature Cited

Beissinger, S. R. 2002. Population Viability Analysis: Past, Present, Future. *In* Beissinger, S. R. and D. R. McCullough. Eds. Population Viability Analysis. University of Chicago Press, pp. 5-17.

Chaput, G., Legault, C. M., Reddin, D. G., Caron, F. and Amiro, P. G. 2005. Provision of catch advice taking into account of non-stationarity in productivity of Atlanitc salmon (Salmo salar L.) in the Northwest Atlantic. ICES Journal of Marine Science. 62: 131-143.

Dennis, B., P. L. Munholland and J. M. Scott. 1991. Estimation of growth and extinction parameters for endangered species. Ecological Monographs. 61(2): 115-143.

Hanski, I. 2002. Metapopualtions of Animals in Highly Fragmented Landscapes and Popualtion Viability Analysis. *In* Beissinger, S. R. and D. R. McCullough. Eds. Population Viability Analysis. University of Chicago Press, pp. 86-108.

Holmes, E. E. 2001. Estimating risks in declining populations with poor data. Proceedings of the National Academy of Sciences of the United States. 98(9): 5072-5077.

Legault, C. M. 2005. Population Viability Analysis of Atlantic salmon in Maine. Transactions of the American Fisheries Society. 134:549-562.

Matthews, G. M. and R. S. Waples. 1991. Status Review for Snake River Spring and Summer Chinook Salmon. (U.S. Dept. Commerce, NOAA Technical Memorandum NMFS F/NWC-200).

Samson, F. B. 2002. Population Viability Analysis, Management and Conservation Planning at Large Scales. *In* Beissinger, S. R. and D. R. McCullough. Eds. Population Viability Analysis. University of Chicago Press, pp. 425-441.

USASAC. 2007. Annual Report of the U.S. Atlantic Salmon Assessment Committee Report No. 17 – 2004 Activities. Gloucester, MA. 151 pp.