Discussion of Alternative Minimum Stock Size Threshold for use in SEDAR Stock Assessments

NMFS Southeast Fisheries Science Center

28 February 2011

BACKGROUND

This report is the SEFSC's second and final contribution to the request (18 January 2011) from SERO titled "Data Analyses Request for Amendment 24 to the Fishery Management Plan for the Snapper-Grouper Fishery of the South Atlantic Region," addressing the portion of that request relevant to minimum stock size threshold (MSST) as defined in the National Standard 1 Guidelines. As agreed upon by SEFSC and SERO, this report discusses the NS1 definition and provides alternative MSST approaches, following discussions among scientists throughout the SEFSC (Beaufort, Miami, and Panama City).

Minimum Stock Size Threshold is used in assessments to determine stock status. If an assessment estimates current spawning biomass to be below MSST, the stock is considered overfished and a rebuilding plan is triggered. For SEDAR stock assessments, MSST has typically been related to natural mortality (M) and spawning biomass at maximum sustainable yield (S_{MSY}) according to the relationship,

$$\text{MSST} = cS_{MSY}, \text{ where } c = \max(1/2, 1-M). \quad (1)$$

This relationship was suggested by Restrepo et al. (1998) as part of a limit control rule that could serve as a default in the absence of more detailed analyses. The rationale for relating MSST to M was that "one would expect a stock fished at F_{MSY} to fluctuate around S_{MSY} on a scale related to *M* (small fluctuations for low *M* and large fluctuations for high *M*)."

The Restrepo et al. guidance was crafted more than a decade ago. Since then, the NS1 Guidelines have been revised. The current Guidelines state:

> The MSST or reasonable proxy must be expressed in terms of spawning biomass or other measure of reproductive potential. To the extent possible, the MSST should equal whichever of the following is greater: One-half the MSY stock size, or the minimum stock size at which rebuilding to the MSY level would be expected to occur within 10 years, if the stock or stock complex were exploited at the MFMT specified under paragraph (e)(2)(ii)(A)(1) of this section. Should the estimated size of the stock or stock complex in a given year fall below this threshold, the stock or stock complex is considered overfished.

The above definition is nearly identical to that in the previous NS1 Guidelines. Nonetheless, the current Guidelines have drawn renewed attention to MSST. Here we describe practical and technical shortcomings of the above definition of MSST. We then discuss several alternative approaches. Ultimately, the definition of MSST is a management decision, but the SSCs could make recommendations regarding scientific aspects of the decision.

PRACTICAL AND TECHNICAL SHORTCOMINGS

The current NS1 Guidelines suggest ("to the extent possible") a two-part definition, where MSST would be the greater of the two parts. The first part, one-half S_{MSY}, is a simple calculation. In fact, other regions currently use that definition of MSST. However, the second part ("the minimum stock size at which rebuilding …") is not a simple calculation. It implies the use of projection methods, raising several practical and technical considerations (described below). To our knowledge, no other region computes MSST by projection.

Projections to define MSST, as defined in the NS1 Guidelines, would require an optimization procedure. Although technically feasible, such projections raise questions of practicality. They would create an additional layer of analysis, requiring time and effort investments to develop and implement the necessary computer code during each assessment. Adding analyses to SEDAR is not a trivial consideration, as the process already consumes enormous resources. If the projection method were an improvement over existing approaches, the additional commitment of time and effort might be justified, but in our view, such projections would offer no improvement. Furthermore, the projections could only be run after the assessment model was fitted, such that determination of stock status would be a follow-up analysis. With simpler definitions of MSST, a determination is immediately available as output of the assessment model itself.

Computing MSST by projection raises two technical issues. First, S_{MSY} is an asymptotic concept. That is, if deterministic projections apply fishing at the level of F_{MSY}, spawning biomass eventually approaches S_{MSY}, but never actually achieves it. In the long term (number of years depends on the stock), spawning biomass will reach levels arbitrarily close to S_{MSY}, but will only reach it if granted some level of tolerance. In the short term (10 years as in the prescribed projections), population dynamics may still be transient and carrying momentum. In any case, it would be necessary to set a tolerance level for reaching S_{MSY}. How close is close enough? Within 1%? Within 10%? For deterministic projections, the tolerance level would need to be defined. Alternatively, the projections could be stochastic (e.g., variable recruitment), such that a stock fished exactly at F_{MSY} would be expected to fluctuate around S_{MSY}. In this case, spawning biomass would reach S_{MSY} in a probabilistic sense. However, this interpretation would simply reframe the question—what level of probability is appropriate?

The second technical issue is that analysts would need to choose an initial age structure for the projection. We can think of several possibilities, but have difficulty recommending any of them. The population could be initialized using the estimate of age structure from the terminal year of the assessment. However, that estimated age structure is never in equilibrium, but instead reflects transient population dynamics. Thus, this approach would define the threshold as a transient concept, in stark contrast to the more typical equilibrium benchmarks, including the other component of this particular definition of MSST (one-half S_{MSY}). Furthermore, the projections as prescribed in the NS1 Guidelines would vary the initial stock size to find the minimum that meets the rebuilding criterion, yet that minimum stock size may not be consistent with the assessment's terminal-year estimate of age structure. For example, a truncated age structure might not be consistent with larger stock sizes, and conversely, a healthy age structure might not be consistent with lower stock sizes.

Another approach to initial age structure would be to use the equilibrium structure associated with MSY, but again, this age structure might not be consistent with the minimum stock size that meets the rebuilding criterion. Yet another approach would be to adjust the equilibrium age structure along with stock size, perhaps by applying various levels of fishing mortality. Other, perhaps innumerable, approaches could be constructed for initializing the age structure in these projections. It is not obvious whether any approach would be most logical, but it seems clear that the choice would have substantial effect on any MSST computed by projection.

ALTERNATIVE APPROACHES

The sentiment behind the NS1 Guidelines definition seems reasonable, namely that the more productive stocks have a lower threshold for being declared overfished. Indeed, that concept underlies the use of natural mortality in the Restrepo et al. definition. In SEDAR applications of Restrepo et al., many of the stocks are long-lived, and their correspondingly low values of M puts the biomass limit (MSST) very close to the biomass target (S_{MSY}). This feature may not have been envisioned when the Restrepo et al. advice was established. A larger buffer between MSST and S_{MSY} could be accomplished simply by generalizing equation (1) as follows,

$$\mathrm{MSST} = cS_{MSY}, \text{ where } c = \max[a, (1-M)b] \,. \qquad (2)$$

In equation (2), c would fall in the range [a, b]. The lower bound should not be below a=0.5, and the upper bound might appropriately be set at b=0.75. Equation (1) is a special case of equation (2) that occurs when a=0.5 and b=1.0.

The Restrepo et al. approach [equation (1) or (2)] is premised on a single value of M. In contrast, SEDAR stock assessments typically allow M to vary through time or, more commonly, across age or size. This difference between technical guidance and SEDAR implementation poses a practical consideration, although in our view, not a fundamental flaw. For computation of MSST, SEDAR assessments have applied a single value of M taken to be representative of the stock (e.g., average adult mortality, or M that would provide equivalent cumulative survival to the oldest age as would age-based mortality).

An alternative approach to adjust MSST for stock productivity would be to relate MSST to steepness (r), rather than natural mortality,

$$\mathrm{MSST} = cS_{MSY}, \text{ where } c = b - (b-a)(r-0.2)/0.8 \,. \qquad (3)$$

Because steepness scales between 0.2 and 1.0, the above definition would put c on the range [a,b], closer to the upper bound when steepness is high (more productive stock). Again, a reasonable range might be [a=0.5, b=0.75]. This definition has intuitive appeal, but we note that steepness can be difficult to estimate with accuracy. Furthermore, not all assessment models utilize the parameter of steepness.

Yet another approach would be to choose a constant value of c. For greatest simplicity, a single value could be applied to all stocks within a Fishery Management Plan. Alternatively, a single value could be applied to multiple stocks grouped by relevant criteria. Species might be grouped according to life-history characteristics or through such means as susceptibility and productivity analysis. Generic simulation analyses might guide appropriate choices of c for each group, with higher values assigned to those groups where low stock size carries more risk.

When specifying an appropriate buffer between the biomass limit and biomass target (e.g., defining a, b, and c above), it may be worth considering that biomass controls are the second tier of a two-tiered system. With reauthorization of the Magnuson-Stevens Act came stricter requirements on fishing mortality (the first tier) through the use of annual catch limits and accountability measures. The intent of ACLs and AMs is to end overfishing for all managed stocks. Their use is expected to help accomplish management objectives, including rebuilding stocks that are marginally below an optimal level. Thus, formal rebuilding plans may be less critical for conservation than they were prior to the reauthorization, and perhaps they should be triggered only for those stocks that are more severely depleted.

We note that an NRC review of rebuilding plans has been requested, and presumably MSST would be addressed by such a review. Afterward, MSST might be an appropriate topic for a SEDAR procedural workshop. The Restrepo et al. approach was intended as a "default for defining status determination criteria in the absence of more detailed analyses." Perhaps the time has come to do those detailed analyses.