Review of SEDAR 69

Atlantic Menhaden Stock Assessment

and Ecological Reference Points

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The Science Center for Marine Fisheries (SCeMFiS) requested technical assistance to review the SEDAR 69 Benchmark Stock assessment and Ecological Reference Points for Atlantic menhaden and provide a non-technical summary for stakeholders in the menhaden fishery to support science-based management of the fishery. SCeMFiS is a National Science Foundation Industry/University Cooperative Research Center that uses academic, recreational and commercial fisheries resources to address urgent scientific problems limiting sustainable fisheries and provides academic research products essential for the sustainable management of shellfish and finfish resources.

Background - I am a stock assessment scientist and have experience with the Atlantic menhaden fishery, ecology, stock assessment and management. Much earlier in my career I served on the Atlantic States Marine Fisheries Commission's Atlantic Menhaden Technical Committee and worked closely with scientists from the NMFS Beaufort lab and other states to sample the fishery, assess the resource and provide scientific advice for fishery management (e.g., Cadrin & Vaughan, 1997, Retrospective analysis of virtual population estimates for the Atlantic menhaden stock assessment, Fisheries Bulletin 95: 445-455). I have followed the subsequent advancement of the menhaden assessment and fishery management episodes. I am familiar with the Beaufort Assessment Model (BAM). As a review panel member and chair of several review workshops in the Southeast Data, Assessment, and Review (SEDAR) process and a member of the Southeast Council's Scientific and Statistical Committee, I have reviewed many applications of BAM to menhaden and other fisheries. I teach graduate-level classes in stock assessment and am active in the development of 'next generation' stock assessments (e.g., I co-chaired the 2013 World Conference on Stock Assessment Methods, and I am presenting a keynote address at the 2020 National Stock Assessment Workshop). I also have experience with multispecies models (e.g., I advised several graduate students who developed multispecies and full ecosystem models, and I am collaborating with NMFS scientists to host a workshop on Multispecies Modeling this June).

Both SEDAR 69 reports were reviewed below:

- SEDAR. 2020. SEDAR 69 – Atlantic Menhaden Benchmark Stock Assessment Report. SEDAR, North Charleston SC. 691 pp. available online at: http://sedarweb.org/sedar-69
- SEDAR. 2020. SEDAR 69 – Atlantic Menhaden Ecological Reference Points Stock Assessment Report. SEDAR, North Charleston SC. 560 pp. available online at: http://sedarweb.org/sedar-69

Summary

The updated and revised Beaufort Assessment Model (BAM) application to Atlantic menhaden is the best scientific information available for fishery management. The estimate of current fishing mortality is low relative, and the estimate of current stock size is high. The single-species assessment (BAM) includes much more information on size and age composition, fishery selectivity, and recruitment variability than the multi-species models that were developed, but all models provide similar perceptions of menhaden stock trends since the 1990s. The multi-species tradeoff analysis suggests that the single-species management target for menhaden performs relatively well for meeting menhaden and striped bass management objectives, but there is little apparent benefit to striped bass or other predators from fishing menhaden at a lower target fishing mortality. The multi-species analyses and the information provided in the report are not sufficient to support management decisions such as ecological reference points, because there are no cost-benefit analyses, does not account for some major sources of uncertainty, and appears to be less developed than alternative models.

Benchmark Stock Assessment

The Atlantic menhaden stock assessment is based on a long time series of well-estimated catch from the reduction and bait fisheries. Reduction landings peaked at 738,500 tons in 1956, averaged approximately 300,000 from the 1970s to the 1990s, and have been limited to approximately 200,000 tons since 2013. Bait landings were historically a small portion of the total catch (<10% in the mid-1980s) but have increased to about 20-25% of total landings recently. Recreational landings contribute a small portion of total catch. In 2017, reduction landings were 185,000 tons, bait landings were 44,000 tons and recreational landings were approximately 2,000 tons.

Age composition has been well-sampled in the reduction fishery since 1955 through a collaborative sampling program, and age composition of the bait fishery has been sampled since 1985. Sample data suggests a relatively stable age composition for the entire time series, with most of the catch composed of ages 1-3. The catch of old fish (age-6 and older) increased recently (since the 1990s in the south and since 2013 in the north).

Data from many fishery resource surveys (49) were considered in the assessment, ranging from Rhode Island to Florida, and multiple surveys were combined to derive five abundance indices for stock assessment modeling. An index of recruitment was derived from several state surveys and suggests that recruitment was relatively strong in the 1970s and lower since then. Three indices of adult abundance were derived for the southern area, Mid-Atlantic, and the northern area, each suggesting a variable stock without much trend since 1990. An index of egg production was derived from two plankton surveys, which also suggests a relatively stable stock since 1981. Despite the large number of surveys, none of them sample adults in the offshore areas, so an offshore hydroacoustic survey is recommended. The size distributions of menhaden in northern and Mid-Atlantic surveys were generally larger than the fishery size distributions, and size distributions in southern surveys were generally smaller than the fishery size distribution, but all surveys suggest a relatively stable size distribution over time.

The stock assessment is based on an updated and revised Beaufort Assessment Model (BAM) application. BAM is an integrated statistical catch-at-age model that fits to information from fishery and survey data with advanced statistical parameter estimation and formal measures of uncertainty. The BAM application to Atlantic menhaden has been refined and improved through several benchmark iterations. The BAM base run is structured by fleets (reduction and bait fisheries) and areas (northern and southern areas) and is fit to data from 1955 to 2017. Size-selectivity of each fleet was estimated for multiple periods, and the assumed form of selectivity allowed for old fish to have less than full vulnerability to the fishery (i.e., 'dome-shaped' selectivity), because older fish are further offshore, older fish tend to seasonally migrate into areas with less fishing, and the fishery targets large schools that are usually young fish. Extensive statistical diagnostics, sensitivity analyses, and simulation testing indicate that the model fits the available data well and the estimates of stock abundance and fishing mortality are reliable.

One important revision in the SEDAR 69 assessment is applying tagging-based estimates of natural mortality, which are greater than previously assumed values. Over a million fish were tagged from Massachusetts to Florida in the 1960s, and 15-20% were recovered. An advanced statistical analysis of the tagging data provides relatively precise estimates of the natural mortality rate. These direct estimates of natural mortality rate from tagging are much more informative for stock assessment modeling than the conventional approximations derived from life history traits. This revised assumption has implications for the stock size estimates (larger) as well as the perception of productivity (greater) for reference points and the general consideration of menhaden as forage.

Management reference points for Atlantic menhaden are based on historical spawning potential. The SEDAR 69 Terms of Reference allow for either Maximum Sustainable Yield (MSY) reference points or proxies, such as those based on spawning potential. MSY reference points could not be estimated for Atlantic menhaden, because there is no evidence of weaker recruitment at low stock size, and there is no apparent reduction in long-term yield expected from fishing at high rates of fishing.

Estimates of fishing mortality suggest intense fishing from the 1950s to the 1980s, and a substantial reduction to relatively low fishing mortality since the early 1990s. The estimate of current fishing mortality (for 2017) is low relative to management reference points or the rate of natural mortality. Fishing mortality is 50% of the target spawning potential and 18% of the threshold reference points. The estimate of current fishing mortality is also much lower than the estimated natural mortality rate. The exploitation rate (% of deaths from fishing relative to total deaths including natural mortality) is 0% for age-0, 10% for age-3 and 1% for ages size and older.

Estimates of stock size peaked in the 1950s, decreased to relatively low abundance in the late 1980s and increased to relatively abundant stock sizes since the mid 1990s. The current stock size (2017 fecundity) is greater than the management target or threshold reference points. The current stock fecundity is 134% of the target and 178% of the threshold. Estimates of recruitment peaked in the 1950s, were relatively weak for the 1960s and early 1970s, then variable and moderate since the mid 1970s.

<u>Ecological Reference Points</u>

Several multi-species models were developed to evaluate the ecological role of Atlantic menhaden in the U.S. East coast ecosystem and to derive ecological reference points for conserving forage. The range of models included a time-varying intrinsic growth rate production model, a Steele-Henderson production model, a multispecies statistical catch-at-age model, and two Ecopath with Ecosim (EwE) models – one with moderate complexity and a full ecosystem EwE model. The simpler models included Atlantic menhaden and one to five predator species (striped bass, bluefish, spiny dogfish and weakfish). The more complex models included more predators and alternative prey species (e.g., Atlantic herring).

Information for the menhaden stock and fishery were from the SEDAR69 BAM model and information for other species were from recent stock assessments. Diet data were also included in models from several sampling programs along the entire east coast.

Among the alternative models, the two EwE models were the only options that could evaluate the effect of predators on menhaden as well as the effects of menhaden on predators. The EwE model with moderate complexity was selected for tradeoff analyses because the more complex model suggested that the simpler model included the predators that are most responsive to menhaden abundance. All models provided consistent perceptions of the trend in Atlantic menhaden stock since the 1990s, and those trends were also consistent with BAM estimates. Unlike the single-species assessment, the multi-species models estimated MSY reference points.

The multi-species tradeoff analyses (i.e., evaluating the effect of menhaden fishing on predator species) illustrates potential uses of multi-species models. The example tradeoff analysis suggests that the single-species management target for menhaden performs relatively well for meeting menhaden and striped bass management objectives. Model projections suggest that long-term expectations of fishing at the menhaden and striped bass fishing mortality targets maintain the striped bass stock above its threshold stock biomass and near its target stock biomass (Figure 144 page 371).

Overfishing is occurring in the striped bass fishery, and the long-term expectation of fishing at the current rate is that the striped bass stock will decrease to less than its management threshold - even with no fishing on menhaden. At the current rate of fishing mortality on striped bass, there is little change in the long-term expectation for the striped bass stock from fishing menhaden at a lower rate than the single species target. Therefore, the appears to be negligible benefit to bass from fishing menhaden lower than the single species target.

The tradeoff analysis is entirely focused on stock biomass consequences (and stock status relative to biomass targets and thresholds), but the consequences for yield are not reported. Long-term yield expectations from multi-species simulations suggest that fishing menhaden at the ecological reference point produces 65% of the yield expected from fishing at the target reference point and only 4% or 5% of the maximum sustainable yield for menhaden (from sim1.1 and sim3.5, respectively). A comprehensive tradeoff analysis should include relative costs and benefits, including economic costs of the ecological reference point.

Uncertainty in estimates from the selected multi-species model were evaluated through sensitivity analyses. However, the long-term projections from the selected multi-species model are deterministic and assume perfect understanding and control of predator-prey dynamics, perfect data, perfect assessments and perfect implementation of commercial and recreational menhaden and striped bass fisheries.

Results from EwE models are notoriously difficult to reproduce. The full ecosystem model has been refined through rigorous peer review and documentation, but the selected EwE model with moderate complexity has much less documentation and model development. For example, the section on balancing (13.2.2) only includes the general criterion for ecotrophic efficiency (EE<1) and does not include the other balancing criteria applied to the full ecosystem model (e.g., Section 14.1.4)