DRAFT OFL CV Decision Criteria Table for Atlantic Mackerel, July 2021

Decision Criteria	**Summary of Decision Criteria Considerations**	**Assigned OFL CV Bin** (60/100/150)
Data quality	**Surveys** *Synoptic surveys are available but recent low index values contribute imprecision to estimates of SSB. Survey and landings catch-at-age data showed cohort progression of the 2015 year-class.* • The assessment relies heavily on an SSB index derived from egg surveys in both Canadian and US waters. Estimated egg production declined >90% from the 1980s to the 2010s. Since 2010, egg production has remained at historically low levels with a slight increasing trend in recent years. Since 2000, spawning habitats have contracted remarkably in both the US and Canada (DFO 2017; Richardson et al. 2020). During this period, low egg incidence in surveys, and persistently low index values contribute uncertainty to inferences on low magnitude changes. • The assessment considers separate NEFSC spring bottom-trawl time series for the RV Albatross (1975-2008) and the RV Bigelow (2009-2019). Albatross index values exhibited a trend opposite to the SSB index, but analyses suggest that model results are relatively insensitive to the Albatross series. The Bigelow series exhibited abundance and age structure trends consistent with a strong 2015 year-class. • In both vessel series, strong cohorts progressed across years as expected, but cohort progression was occasionally inconsistent for weaker year-classes. **Landings and discards** *Landings data are of moderate certainty. High certainty in US and Canadian commercial landings is offset by unexpected trends in the revised MRIP data and unknown Canadian discards and bait and recreational catches.* • Canadian discards, bait and recreational catches are unknown but likely a relatively substantial fraction of combined Canada-US catch in recent years. A recent MSE (Van Beveren et al. 2020) concluded that this was a chief source of uncertainty in rebuilding the Northern contingent. • Revised MRIP estimates of recreational catches and discards in the MT assessment resulted in higher estimates especially in recent years; revised estimates increased nearly two-fold for the period 2008-2019. During 2015-2019, recreational catch comprised 34.7% of total US harvests. MRIP estimates and associated error now have a large influence on overall landings data. **Mortality** *Natural mortality is unknown and likely age- and time-variable for this pelagic forage species.* • In the assessment natural mortality is computed based on longevity (life table approach) at M=0.2, invariant with age and over years.	

	• The MT assessment included a likelihood profile analysis that indicated small likelihood differences between M=0.20 and M=0.30, with highest likelihood at M=0.25. The continued use of age-invariant mortality was justified based on a simulation exercise on hypothetical stocks (Deroba and Schueller 2013). • Justification for a time-invariant M was the scarcity of mackerel in the NEFSC Food Habitat Database throughout the series and the lack of predation estimates for the northern contingent, especially given the dominance of the northern contingent to overall stock size. Still, demersal predation as indexed by the NEFSC bottom trawl survey may be rare for this pelagic species. Overholtz and Waring (1991) suggested that pilot whales and common dolphins are important predators of adult mackerel. These and other mackerel predators have likely undergone decadal changes in abundance in the NW Atlantic.	
Model appropriateness and identification process	*A single age-structured model supports the assessment. Diagnostics and sensitivity runs indicate moderate deviations associated with parameter errors.* • ASAP is the primary assessment model in the MT. In SAW 64, two alternative age-based models were considered (SAM, CCAM), which yielded similar stock trajectories. The ASAP model met peer review standards for both the benchmark and MT assessments. • Cohort progressions are apparent in both survey and field data, indicating age determinations are likely accurate in support of the ASAP. • Two contingents with origins in Canada and US waters were combined into a single unit stock, supported by evidence of extensive contingent mixing within US winter and spring fisheries. • In SAW 64, over 150 model configurations of the ASAP model were evaluated in a logical progression for model identification and sensitivity.	
Retrospective analysis	*Moderate retrospective patterns occurred with some anomalous patterns in retrospective peels. Bridge runs showed overall consistency between the benchmark and MT assessments.* • Retrospective patterns in SSB and recruitment were greater in the MT assessment in comparison to the benchmark, with deviating directional bias in 5- year peels for SSB and F. Still, the retrospective-adjusted values for the terminal year fell within the 90% confidence intervals of the unadjusted estimates so a retrospective adjustment in the MT assessment was not warranted. • Bridge runs between the benchmark and MT assessments indicated a negligible change in SSB historical trends and a modest increase F since 2010 owing to the revised MRIP estimates. Bridge runs for the recruitment series continued to support the perception of a strong 2015 year-class.	
Comparison with empirical measures or simpler analyses	*Simpler analyses or empirical measures were not included in the benchmark or MT assessments, but stock trends are supported by ancillary information.* • Catch curve analysis (MT assessment) showed a 2-3 fold increase in total mortality 2000-2015 in comparison to 1975-1999, consistent	

	with higher Fs (or Ms) in the recent period. Severe age-truncation also supports perception of higher F (or Ms) during since 2010. • Decreases in egg incidence since 2000 (Richardson et al. 2020) is consistent with depletion in SSB observed for that same period.	
Ecosystem factors accounted	*Atlantic mackerel phase diagram suggests that stock productivity has changed since 2000. The current depleted state of Atlantic mackerel has unknown ecosystem causes. Large shifts in age structure and possible spatial behaviors have also affected stock productivity in unknown ways.* • The contribution of predation mortality to total mortality (M+F) is unknown. M is prone to age- and time-specific variation owing to predation by pelagic predators. • Although age-9 fish were observed in the 2019 catch, the stock has shown severe age truncation with ages >3 years scarce in catch and survey samples since 2010. Extreme age-truncation is expected to result in depressed recruitment, decreased population resilience, and increased sensitivity to environmental change (Hsieh et al. 2006; Secor et al. 2015). • US harvests are influenced by contingent mixing (contributions by the Northern contingent), which is dynamic over years and decades (Arai et al. 2021). • Lack of an apparent stock-recruitment relationship suggests recruitments are environmentally driven (Plourde et al. 2015). Larval habitat suitability has shown a long-term decline in major regions of the Southern contingent's historical range (McManus et al. 2018). • The NEFSC Climate Vulnerability ranking is "moderate" for Atlantic mackerel, with distributional vulnerability and climate exposure ranked high in part owing to the species' responsiveness to surface oceanographic conditions.	
Trend in recruitment	*Recruitments are without trend with dominant year-classes occurring every 15-20 years. High uncertainty in trends in recruitment centers on whether to use recent or historical time series in stock projections.* • The 2015 year class estimate from the MT assessment was 15% lower than the estimate from the 2017 benchmark. • In the benchmark assessment, the strong 2015 year-class provided short-term SSB projections that were biased high. Precaution is advised when short-term projections rely heavily on terminal year recruitment. • Alternative recruitment hypotheses support use of the historical series from 1975 onwards, the series from 1999 onwards, and the series 2009 onwards. • The lack of an apparent stock recruitment relationship causes uncertainty on whether BRPs should be derived for the entire historical series or for the selected recruitment time series used in stock projections.	
Prediction error	*Prediction error was not estimated in the benchmark or MT assessments, although bridge runs between the two assessments showed relatively good agreement in total catch, SSB and F trajectories despite revised MRIP estimates. The forecast error for rebuilding by 2023, derived from the 2018 benchmark assessment was high.*	

Assessment accuracy under different fishing pressures	*Historical high amplitude changes in catch levels follow expectations of stock trajectories, but since 2010 a period of stable low catches and SSB is seemingly unaligned with a period of high and declining F.* • Recent catch has been stable and consistently below quota. • The Atlantic mackerel stock status phase diagram shows that SSB is largely unrelated to F since 2010. • An alternative view is that SSB has shown significant increases in recent years (MT assessment indicates a 179% increase from 2014 (15318 mt) to 2019 (42,862 mt), which could drive the strong decline in F following the period of high exploitation prior to 2011.	
Simulation analysis/MSE	*No formal MSE-type analysis has been conducted for the entire stock. An MSE was conducted for the Northern Contingent (Canada's stock) and indicated high sensitivity of stock trajectories and rebuilding to unreported catch (Van Beveren et al. 2020).*	

Draft Narrative

The stock phase diagram indicates that SSB has been relatively insensitive to changes in F since 2010. Further, US catches have been stable and below quota for this period. These two elements contribute to uncertainty in the role of F in stock rebuilding and draw attention to the assumption of time- and age-invariant M. It is plausible that Atlantic mackerel are in a depleted state owing to unknown ecosystem causes leading to high uncertainty in the OFL specification. Uncertainty in specifying time stanzas for stock projections and BRPs also point to high uncertainty in ecosystem processes that have led to the recent period characterized by age-truncation, spawning ground contractions, and changed contingent composition.

The ASAP model and its inclusion of a stock-wide SSB index represented a remarkable advance in Atlantic mackerel assessment. In SAW 64, the ASAP model was corroborated against two alternative age-based models. The model is supported by expected cohort progressions and both the benchmark and MT assessments met peer review standards. In the MT assessment, moderate retrospective patterns occurred with some anomalous patterns in retrospective peels. Bridge runs showed overall consistency between the benchmark and MT assessments, albeit a large revision in MRIP estimates caused an increase in F since 2010.

In recent years, recreational catch comprised 35% of total US harvests, which translates to a greater contribution of error in MRIP estimates to total catch uncertainty. A missing component of catch — Canadian bait, recreational fisheries and discards — likely affects overall assessment accuracy, stock projections, and the effectiveness of stock rebuilding strategies (van Beveren et al. 2020).

A key uncertainty centers on what period of the stock's historical trajectory is relevant to stock projections and BRP determinations. Based upon the benchmark assessment, recent recruitments (inclusive of the strong 2015 year-class) were projected to achieve rebuilding targets by 2023. Projections from the MT assessment indicated much slower stock rebuilding over this period, calling attention to whether expectations for stock trends and/or rebuilding should be drawn from historical (1975-2019 or 1999-2019) or recent (2009-2019) recruitment time series. Changed stock productivity would justify the use of the more recent time series, but continued debate occurs on whether such a "regime" change should also apply in deriving BRPs for the more recent period. R/SSB, a proxy for changes in stock productivity, showed nil to a slightly increasing trend over the historical time series.

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