2023 Atlantic mackerel management track assessment

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July 2023
NW Atlantic mackerel seasonal migration patterns
(Sette 1950)

Spring Migration

Fall Migration
Background

- Last assessed and reviewed in July 2021
- Primary assessment model = ASAP
  - Ages 1-10+; Constant M = 0.2
  - One fishing fleet, time-invariant flat-topped selectivity (age 6+ = 1)
- Three fishery-independent surveys
  - Range-wide SSB index from egg surveys
  - Spring bottom trawl survey (ages 3+, dome-shaped selectivity)
    - Albatross years (1974-2008)
    - Bigelow years (2009+)
  - Long-term projections based on empirical CDF derived using recruitment estimates from 1975 onward
- BRPs: F40% as Fmsy proxy (0.22)
- Resulting stock status: overfished (24% of SSB msy proxy) with overfishing occurring (208% of Fmsy proxy)
  - Frebuild = 0.12 (F to rebuild stock by 2032, assuming two-stanza recruitment)
Term of Reference 1:
Estimate catch from all sources, including landings and discards

(Canada updated all input data for 2023 assessment)
- Reported Canadian catches represent a subset of total Canadian catch because the bait fishery, recreational fishery and commercial discards are not monitored.

- Canadian directed commercial and bait fisheries closed in 2022
U.S. catch (thousands mt)

- Comm landings
- Comm discards
- Recreational catch

Catch (thousands mt)

Year:
- 1992
- 1997
- 2002
- 2007
- 2012
- 2017
- 2022
Total catch-at-age (U.S. plus Canada)
Term of Reference 2:
Evaluate indices used in the assessment

(Canada updated all input data for 2023 assessment)
NEFSC spring survey: Bigelow years

Number-per-tow

Age

Year

Min=0.002  Mean=0.919  Max=9.549

Number

weight

median number

median weight

NEFSC spring survey: Bigelow years
Combined range-wide SSB index (egg and ecosystem surveys)
Contribution of the southern spawning contingent
Term of Reference 3:
Estimate annual fishing mortality, recruitment and stock biomass for the time series using the approved assessment method and estimate their uncertainty. Include retrospective analyses if possible (both historical and within-model) to allow a comparison with previous assessment results and projections, and to examine model fit.

Include bridge runs from the previously accepted model to the updated model proposed for this peer review.
Bridge runs:

2) 2020-2022
3) Maturity
4) WAA
Bridge runs:

5) Fishery catch
6) Egg index
Bridge runs:

7) Trawl survey
9) Increase egg index CV
ASAP estimates:

Spawning stock biomass (mt)

Recruitment (000s)
ASAP estimates:
R/SSB
ASAP estimates:
Fishing mortality
Retrospective analysis:
5 year peels 2017-2021

2021 MT
Mohns ρ estimates:
F = -0.093
SSB = 0.326
Rect = 0.431
Natural mortality

Graph showing the relationship between likelihood difference and natural mortality.
Historical retrospective

* 2009 TRAC did not pass peer review
Historical retrospective
Comparison with 2021 MT projections

SSB_{MSY PROXY} = SSB_{40\%} = 154,107 mt
2021 MT comparison with 2017 benchmark projections

ASAP estimates:
- 2017 Benchmark
- 2021 MT

Projections:
- 2017 Benchmark
  (Frebuild, 0.237)
- 2021 MT
  (Fmsy, 0.22)
Term of Reference 4:
Re-estimate or updated the BRP’s as defined by the management track level and recommend stock status. Provide qualitative descriptions of stock status based on simple indicators/metrics.
## Biological reference points

<table>
<thead>
<tr>
<th></th>
<th>2021 MT</th>
<th>2023 MT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_{MSY \ proxy}$</td>
<td>0.22</td>
<td>0.21</td>
</tr>
<tr>
<td>$SSB_{MSY \ proxy}$</td>
<td>181,090</td>
<td>154,107 (86,490-332,677)</td>
</tr>
<tr>
<td>$B_{MSY \ proxy}$</td>
<td>237,989</td>
<td>209,952 (118,636-432,417)</td>
</tr>
<tr>
<td>MSY proxy</td>
<td>34,103</td>
<td>30,460 (17,321-63,448)</td>
</tr>
</tbody>
</table>
Recommended stock status

Overfished (12% of SSB msy proxy) but overfishing not occurring (86% of Fmsy proxy)

Due to change in overfishing status, will undergo peer review in Sept

Fishing mortality

2022 estimates:

F: 0.18
(0.003-0.35)

SSB: 19,017 mt
(1,835-36,199)

\[0.5 \times SSB_{40\%} = 0.5 \times SSB_{MSY \ PROXY} = 77,054 \text{ mt}\]

\[SSB_{40\%} = SSB_{MSY \ PROXY} = 154,107 \text{ mt}\]
Qualitative stock status metrics

- Age truncation apparent in fishery catches
  - Age-9 fish were observed in 2019-2021 fishery catches for the first time since 2012
- Range-wide SSB estimates from egg surveys have been below the time-series median since 2009
  - Southern contingent egg production has been an order of magnitude greater in since 2018 compared to the previous decade
- With the exception of the 2015 and 2021 year classes, recruitment estimates have been below the time-series median since 2008
- 2016 year class was the smallest estimate of the time series
2023 Canadian assessment of the northern contingent

- DFO revised the full suite of input data for the 2023 assessment (CAA, WAA, egg index, maturity, fecundity)
- SSB has been in or near the critical zone since 2011
- After reaching a time-series minimum in 2021, 2022 SSB was estimated to be 17,649 mt and 42% of the LRP (40% of SSB_{40\%})
- Fully selected fishing mortality was estimated to be 0.42 in 2022 and was below F_{40\%} for the first time since 1997
- Estimated recruitment (2012 onward) has been below the time-series median since 2009 and 2022 represented the 3rd lowest estimate of the time series
Term of Reference 5:
Conduct short-term projections
Short-term projections

- Following methodology of rebuilding plan, recruitment sampled from empirical CDFs derived assuming two recruitment stanzas
  - When $SSB < \frac{1}{2} SSB_{MSY}$, empirical CDF based on recruitment estimates from 2009 onward
  - When $SSB \geq \frac{1}{2} SSB_{MSY}$, empirical CDF based on recruitment estimates from 1975 onward

- Interim catch assumptions
  - 2023: 5,953 mt (2023 US ACL + 2022 Canadian catch (56 mt))
  - $F_{rebuild}$ defined as the $F$ that would result in a 61% probability of rebuilding the stock by 2032 ($F_{rebuild}$ updated from 0.12 to 0.11 with this MT)
  - Sensitivity analysis where 2022 recruitment estimate reduced to median of recent recruitment (2009 onward) due to poor projection performance ($F_{rebuild}$ reduced from 0.11 to 0.07)
Projections at Frebuild: SSB

<table>
<thead>
<tr>
<th>Year</th>
<th>Base</th>
<th>Reduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>2023</td>
<td>43,721</td>
<td>26,387</td>
</tr>
<tr>
<td>2024</td>
<td>69,870</td>
<td>42,756</td>
</tr>
<tr>
<td>2025</td>
<td>85,584</td>
<td>61,060</td>
</tr>
<tr>
<td>2026</td>
<td>96,586</td>
<td>75,584</td>
</tr>
<tr>
<td>2027</td>
<td>109,397</td>
<td>88,050</td>
</tr>
<tr>
<td>2028</td>
<td>121,447</td>
<td>101,857</td>
</tr>
<tr>
<td>2029</td>
<td>135,534</td>
<td>117,098</td>
</tr>
<tr>
<td>2030</td>
<td>151,543</td>
<td>135,003</td>
</tr>
<tr>
<td>2031</td>
<td>163,892</td>
<td>153,837</td>
</tr>
<tr>
<td>2032</td>
<td>175,493</td>
<td>172,040</td>
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</tbody>
</table>

SSB_{MSY\_PROXY} = SSB_{40\%} = 154,107 \text{ mt}
## Projections at Frebuild: Catch

<table>
<thead>
<tr>
<th>Year</th>
<th>Base</th>
<th>Reduced 2022 Rect</th>
</tr>
</thead>
<tbody>
<tr>
<td>2023</td>
<td>5,953</td>
<td>5,953</td>
</tr>
<tr>
<td>2024</td>
<td>6,864</td>
<td>2,726</td>
</tr>
<tr>
<td>2025</td>
<td>8,571</td>
<td>3,900</td>
</tr>
<tr>
<td>2026</td>
<td>9,830</td>
<td>4,866</td>
</tr>
<tr>
<td>2027</td>
<td>11,417</td>
<td>5,741</td>
</tr>
<tr>
<td>2028</td>
<td>12,710</td>
<td>6,760</td>
</tr>
<tr>
<td>2029</td>
<td>14,129</td>
<td>7,806</td>
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<tr>
<td>2030</td>
<td>15,764</td>
<td>8,976</td>
</tr>
<tr>
<td>2031</td>
<td>17,020</td>
<td>10,200</td>
</tr>
<tr>
<td>2032</td>
<td>18,197</td>
<td>11,386</td>
</tr>
</tbody>
</table>
Questions?
Comparison with 2021 MT projections

SSB \_MSY\_PROXY = SSB_{40\%} = 154,107 \text{ mt}

ASAP estimates:
2021 MT
2023 MT

Projections:
2021 MT
(Frebuild, 0.12)
2023 MT
(Frebuild, 0.11)
Recent 5-year averages for 2023 MT and 2021 MT

Age-1 = 0.04 (0.18)
Age-2 = 0.67 (0.71)
Age-3 = 0.99 (0.94)
SSB Weight-at-age
NEFSC spring survey: *Albatross years*

- **Number-per-tow**
  - Min: 0.002, Mean: 0.837, Max: 16.165

- **Weight-per-tow**
  - Min: 0.002, Mean: 0.837, Max: 16.165

**Graphs:**
- Number and weight trends over years.
- Median number and weight highlighted.

**Legend:**
- Number: solid line
- Weight: dashed line
- Median number: red line
- Median weight: red dashed line
ASAP diagnostics: Fit to fishery catch
ASAP diagnostics: Index RMSEs

![Graph showing Root Mean Square Error for Indices](image)
ASAP diagnostics: Fit to range-wide SSB index
ASAP diagnostics: Fit to Bigelow index (2009-2022)
ASAP diagnostics: Fit to *Albatross* index (1968-2008)
ASAP estimates: SSB and recruitment time series
ASAP estimates: Selectivity

Fleet 1 (Combined)

 Indices

Selectivity at Age

Selectivity at age

Age

Age
ASAP estimates: Terminal year estimates

**Annual Total SSB**

- **Biomass**: 2022
- **Probability Distribution**
- **Cumulative Distribution**

**Annual Total F**

- **Fishing Mortality**: 2022
- **Probability Distribution**
- **Cumulative Distribution**
Retrospective analysis:
Terminal year estimates with 90% CIs

Fishing mortality vs. years of evaluation

rho-adjusted

original
Long-term projections

- 100-year projections at $F_{40\%} \ (0.21)$ from 2000 numbers-at-age estimates for 2023 from MCMC simulations
- Recent 5-year averages used for weight-at-age and proportion mature-at-age estimates
- Age-specific fishery selectivity estimates from ASAP model
- Recruitment sampled from an empirical CDF derived from 1975-2019 recruitment estimates of the final ASAP model
- $M = 0.2$
2017 Benchmark rebuilding projections

5-year rebuilding scenario (rebuild in 2023)

F = 0.237

SSB$_{2016}$ = 43,519 mt

<table>
<thead>
<tr>
<th>Year</th>
<th>ssb (mt)</th>
<th>catch (mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>103,652</td>
<td>17,508</td>
</tr>
<tr>
<td>2018</td>
<td>138,968</td>
<td>21,898</td>
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<tr>
<td>2019</td>
<td>162,796</td>
<td>29,184</td>
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<tr>
<td>2020</td>
<td>176,538</td>
<td>32,480</td>
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<tr>
<td>2021</td>
<td>184,399</td>
<td>35,195</td>
</tr>
<tr>
<td>2022</td>
<td>190,926</td>
<td>36,365</td>
</tr>
<tr>
<td>2023</td>
<td>196,922</td>
<td>37,515</td>
</tr>
<tr>
<td>2024</td>
<td>200,853</td>
<td>38,375</td>
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<tr>
<td>2025</td>
<td>204,445</td>
<td>39,189</td>
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<tr>
<td>2026</td>
<td>206,283</td>
<td>39,674</td>
</tr>
<tr>
<td>2027</td>
<td>207,484</td>
<td>39,900</td>
</tr>
<tr>
<td>2028</td>
<td>208,316</td>
<td>40,123</td>
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