Bigeye tuna in the eastern Pacific Ocean: 2024 benchmark assessment

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Outline

1. Fishery definitions
2. Data - catch, index of abundance, and size compositions
3. Model assumptions - growth, natural mortality, recruitment, and selectivity
4. Bridging analysis
5. Reference models – hypotheses for the risk analysis
6. Model results
7. Stock status

Model overview

- An integrated age-structured length-based assessment model based on Stock Synthesis (v3.30.22.beta)
- One stock of bigeye in the EPO – using the "areas-as-fleets" approach
- Two sexes are included in the model – only natural mortality is sex-specific
- Model 1979-2023 with a quarterly time step
- The assessment model is fit to:
  - A longline index of relative abundance
  - Length compositions from both longline and purse-seine fisheries
  - Catches from both longline and purse-seine fisheries

Model files and results are available online

Agenda +

Meeting documents ⓘ +

Informational documents ⓘ +

Annual summary reporting - scientific observers for longline vessels (Resolution C-19-08) +

Background documents ⓘ

Bigeye tuna: Stock Synthesis files

1. Fishery definitions

Fisheries are defined by fitting a regression tree to length compositions

<table>
<tr><th>Fleet Number</th><th>Fleet type</th><th>Fleet name</th><th>Gear</th><th>Set type</th><th>Area</th><th>Catch data</th><th>Unit</th></tr>
<tr><td>1</td><td rowspan="7">Fishery</td><td>LL-n-A1</td><td rowspan="7">LL</td><td rowspan="7">-</td><td>1</td><td rowspan="7">Retained catch only</td><td rowspan="7">1,000s</td></tr>
<tr><td>2</td><td>LL-n-A2</td><td>2</td></tr>
<tr><td>3</td><td>LL-n-A3</td><td>3</td></tr>
<tr><td>4</td><td>LL-n-A4</td><td>4</td></tr>
<tr><td>5</td><td>LL-n-A5</td><td>5</td></tr>
<tr><td>6</td><td>LL-n-A6</td><td>6</td></tr>
<tr><td>7</td><td>LL-n-A7</td><td>7</td></tr>
<tr><td>8</td><td rowspan="7">Fishery</td><td>LL-w-A1</td><td rowspan="7">LL</td><td rowspan="7">-</td><td>1</td><td rowspan="7">Retained catch only</td><td rowspan="7">tons</td></tr>
<tr><td>9</td><td>LL-w-A2</td><td>2</td></tr>
<tr><td>10</td><td>LL-w-A3</td><td>3</td></tr>
<tr><td>11</td><td>LL-w-A4</td><td>4</td></tr>
<tr><td>12</td><td>LL-w-A5</td><td>5</td></tr>
<tr><td>13</td><td>LL-w-A6</td><td>6</td></tr>
<tr><td>14</td><td>LL-w-A7</td><td>7</td></tr>
<tr><td>15</td><td rowspan="6">Fishery</td><td>OBJ-A1</td><td rowspan="6">PS</td><td rowspan="6">OBJ</td><td>1</td><td rowspan="5">Retained catch + discards (inefficiency)</td><td rowspan="5">tons</td></tr>
<tr><td>16</td><td>OBJ-A2</td><td>2</td></tr>
<tr><td>17</td><td>OBJ-A3</td><td>3</td></tr>
<tr><td>18</td><td>OBJ-A4</td><td>4</td></tr>
<tr><td>19</td><td>OBJ-A5</td><td>5</td></tr>
<tr><td>20</td><td>OBJ-disc-EPO</td><td>1-5</td><td>Discards (size-sorting)</td><td>tons</td></tr>
<tr><td>21</td><td rowspan="2">Fishery</td><td>NOADEL-A1</td><td rowspan="2">PS</td><td rowspan="2">NOA+DEL</td><td>1</td><td rowspan="2">Retained catch + discards (all)</td><td rowspan="2">tons</td></tr>
<tr><td>22</td><td>NOADEL-A2</td><td>2</td></tr>
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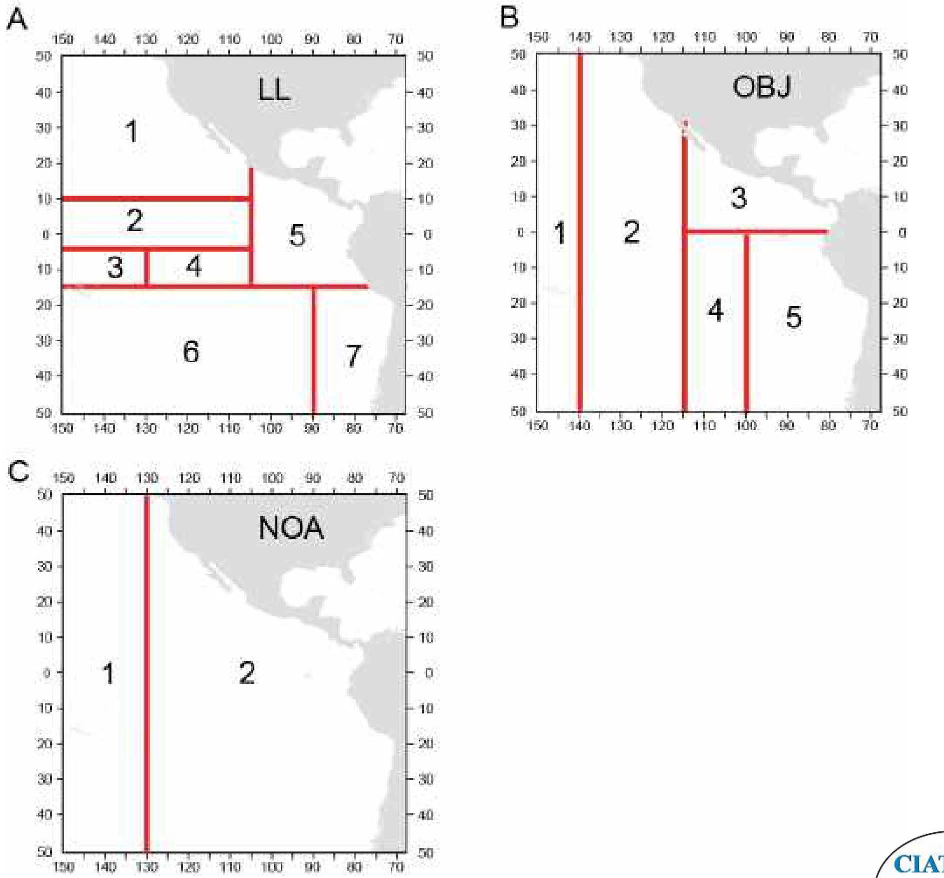

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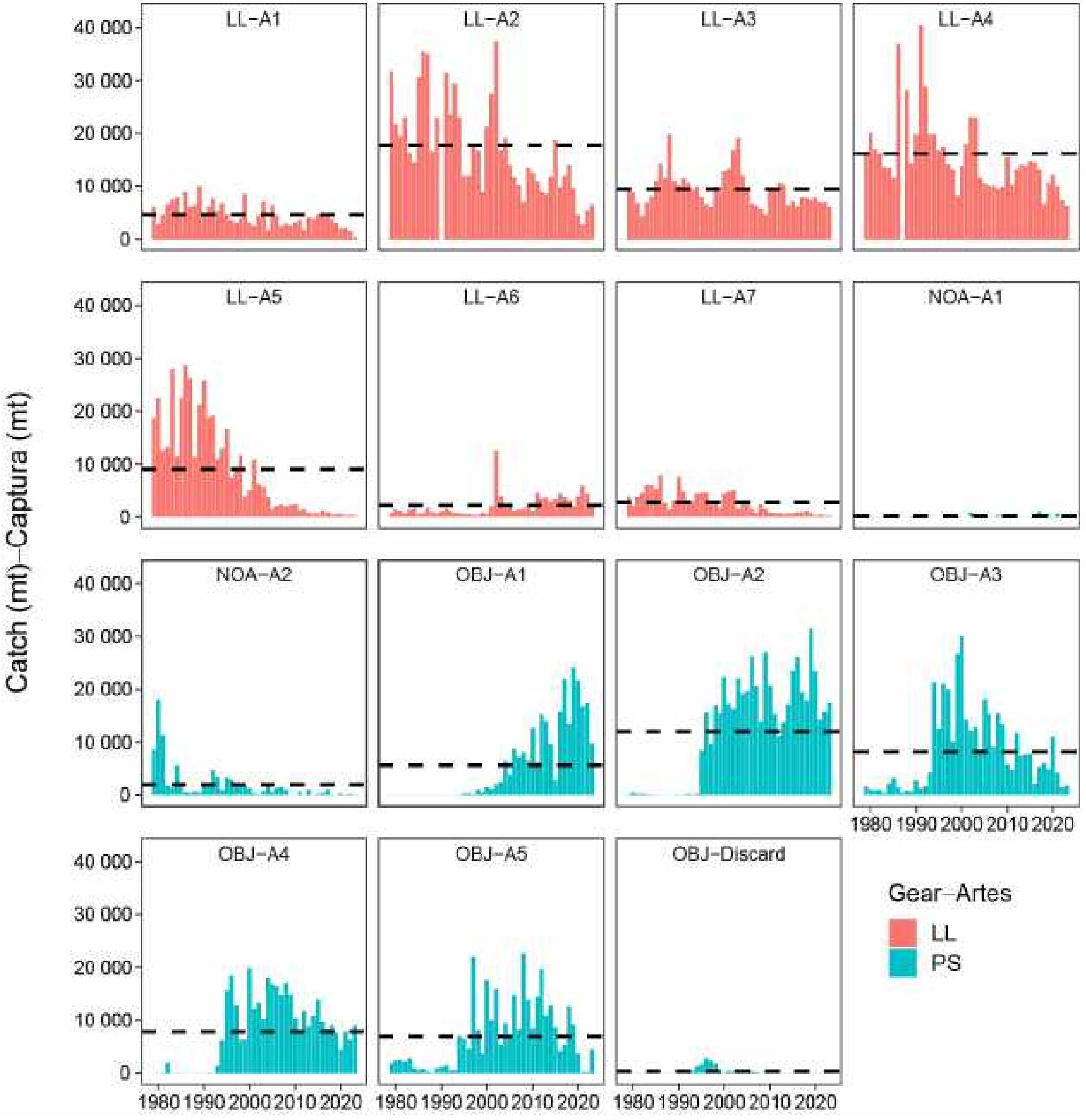
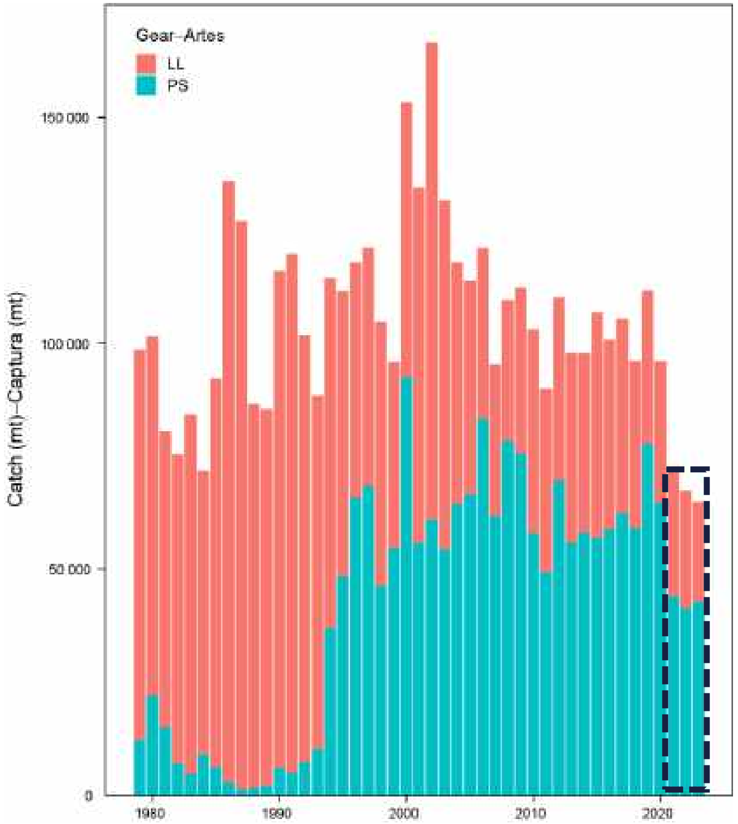
2. Data – catch



- Before 1994, catch was primarily taken by the LL fishery; after 1997, the OBJ fishery caught more bigeye than the LL fishery

- The total catch in 2021-2023 reached the lowest level since 1979

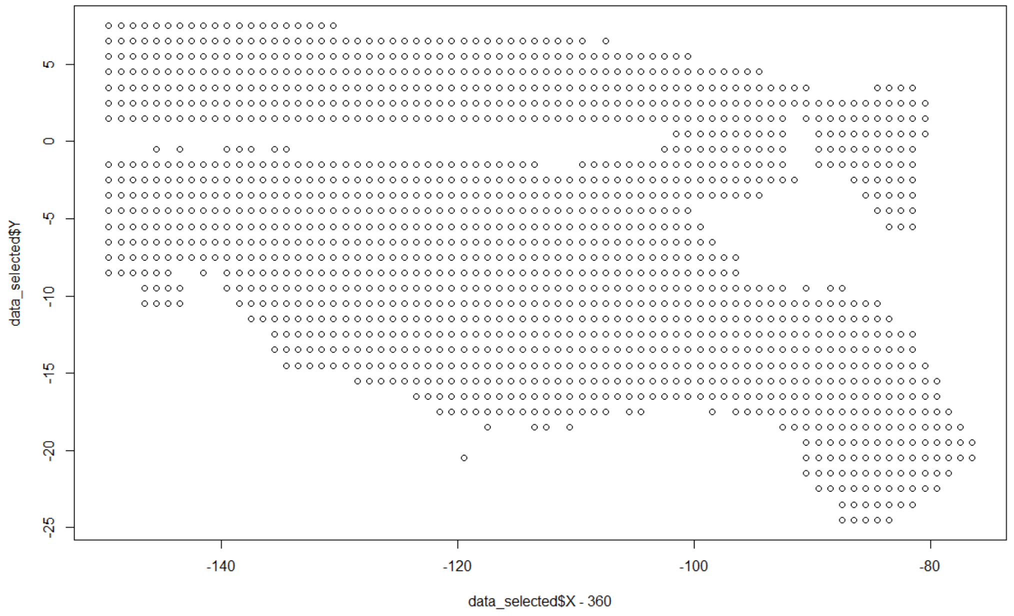


2. Data – longline index of relative abundance

- In Stock Synthesis: a “survey” is modeled as a fleet that has data, such as indices of abundance and age/length compositions, but takes no catch.

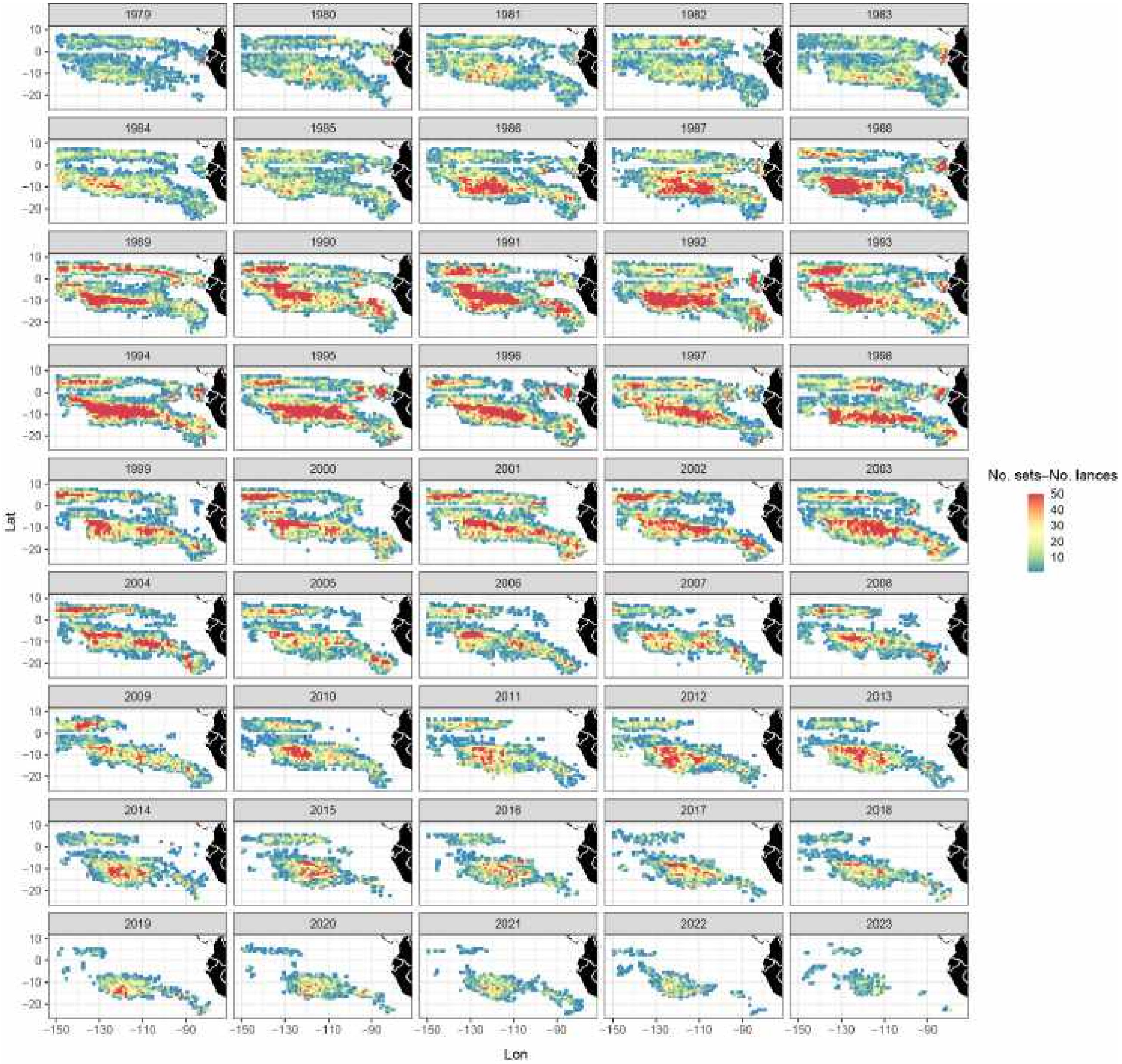
- The survey fleet includes:
  - A longline index of abundance
  - Longline length frequencies from Japanese (fishers and observers) and Korean (observes)

Spatial coverage of the “survey” fleet



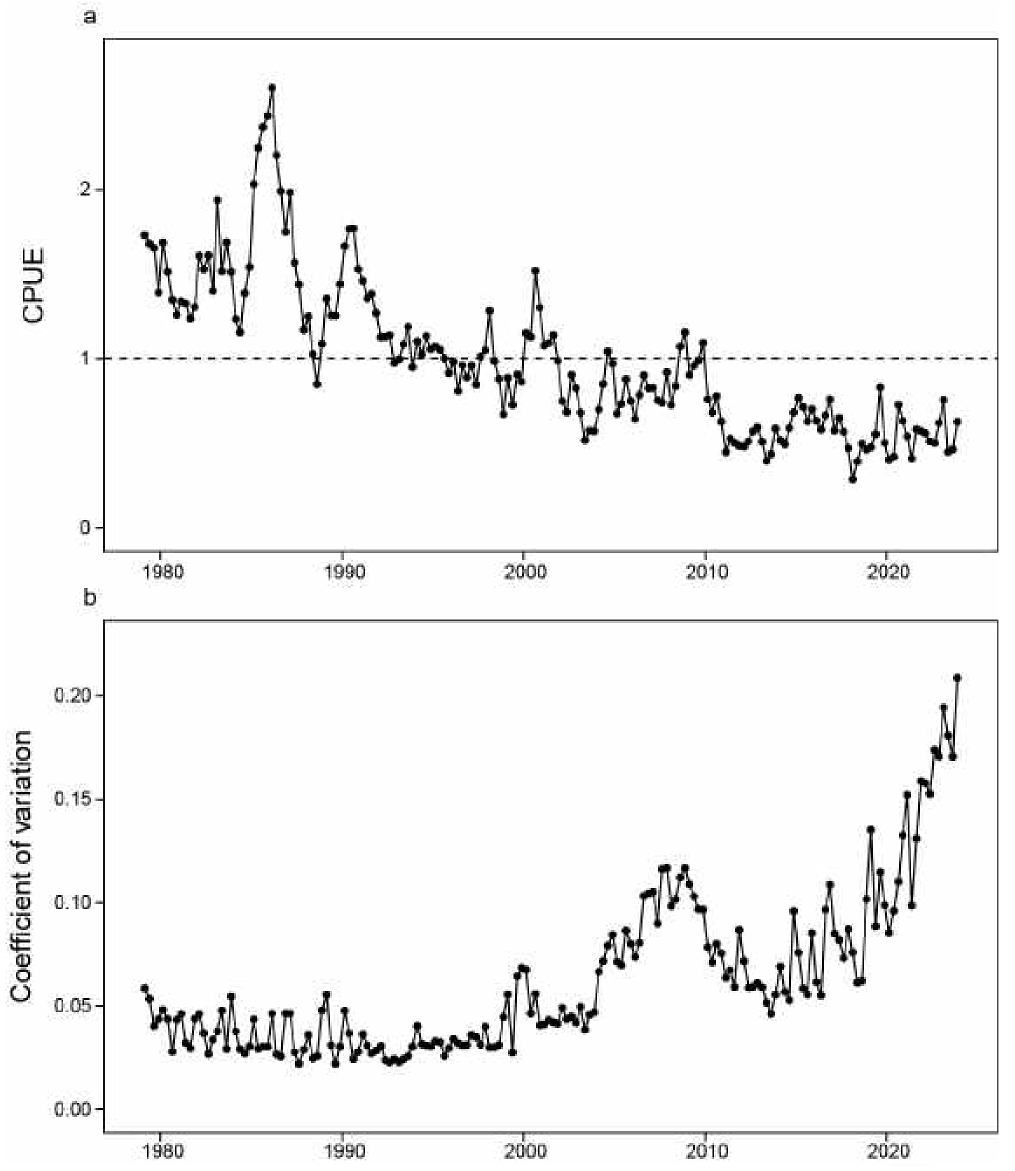
2. Data – longline index of relative abundance

- The longline index of relative abundance is based on Japanese operational catch and effort dataset
- This dataset is fitted to a spatiotemporal model to produce standardized index of abundance
- The key issue associated with this index of abundance is the shrinking fishing ground
- The dataset now covers a small proportion of the EPO, making the index of relative abundance for recent years being highly uncertainty

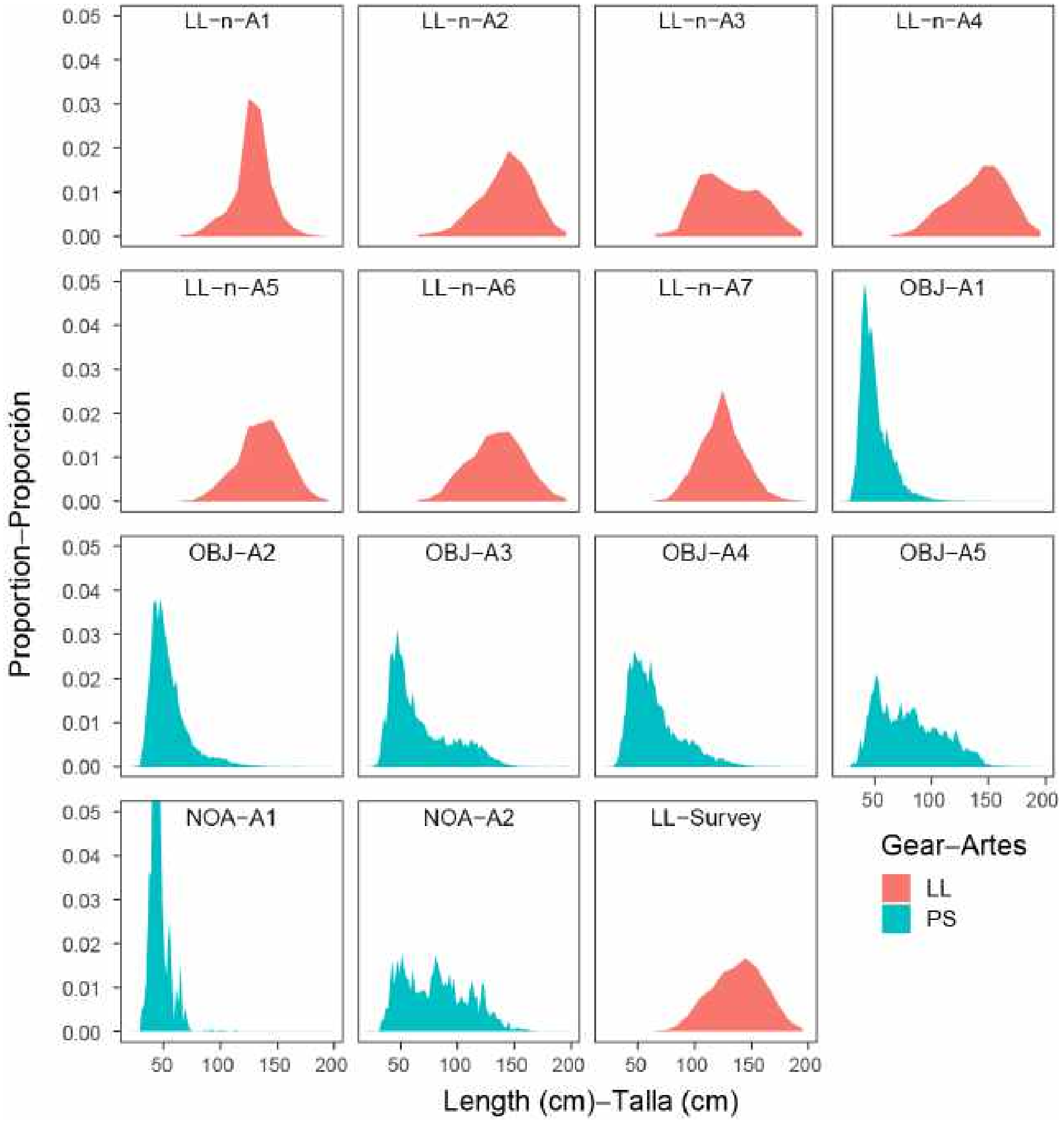


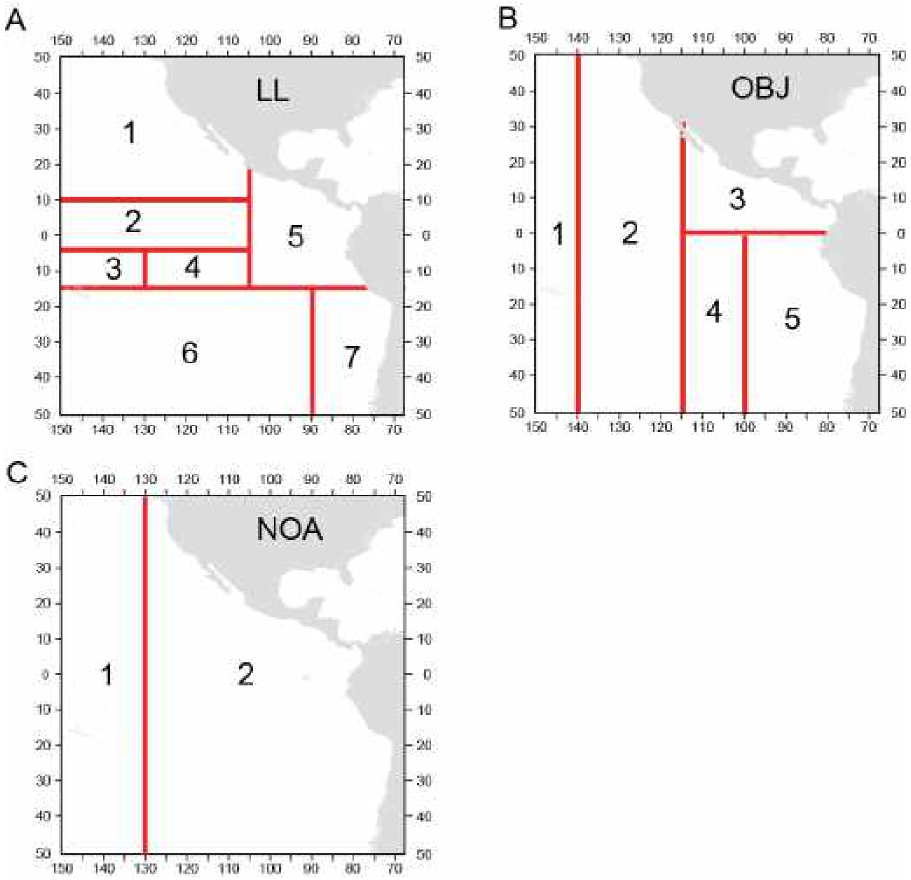
2. Data – longline index of relative abundance

- The spatiotemporal model accounts for vessel effects and the impact of hooks-between-floats on catchability
- The model fits better to the operational data (this assessment) than the aggregated data (previous assessments) based on the QQ-plot
- The index suggests that the abundance of large bigeye decreased continuously from 1979 to about 2010 and has remained low since 2011 without a notable long-term trend
- The coefficient of variation of the index has increased rapidly since 2020 due to the shrinking fishing ground



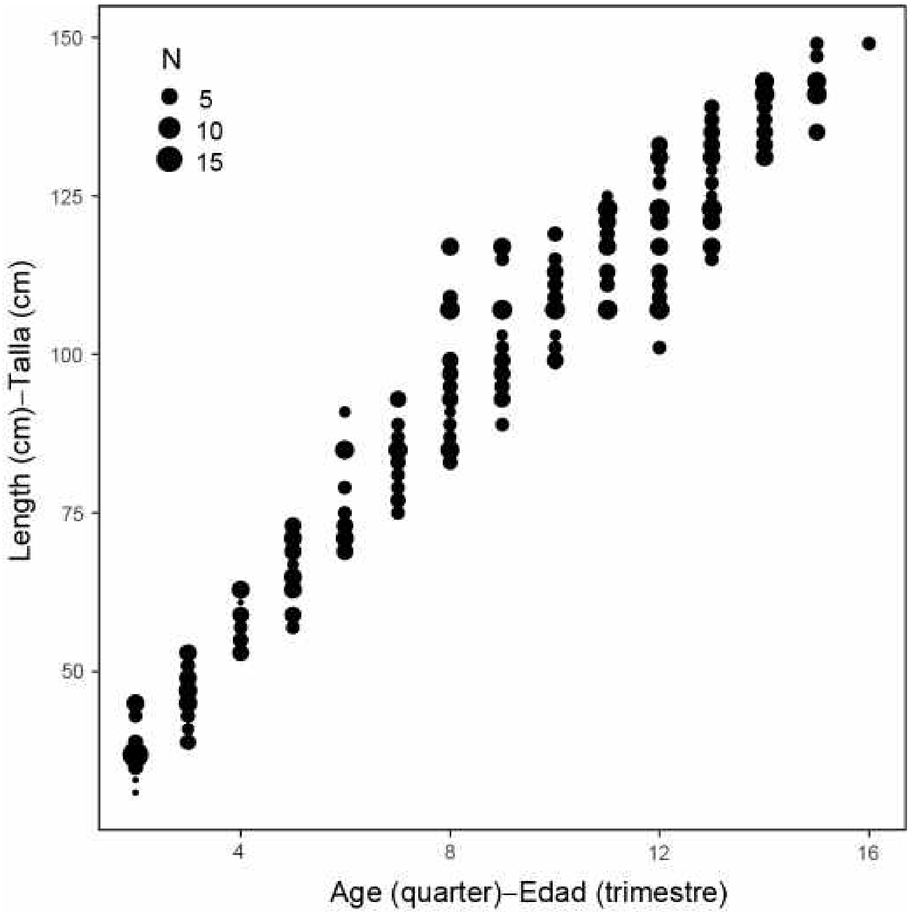
2. Data – size compositions





2. Data – conditional age at length

Age at length data is available for the OBJ fishery
in the third quarter of 2002

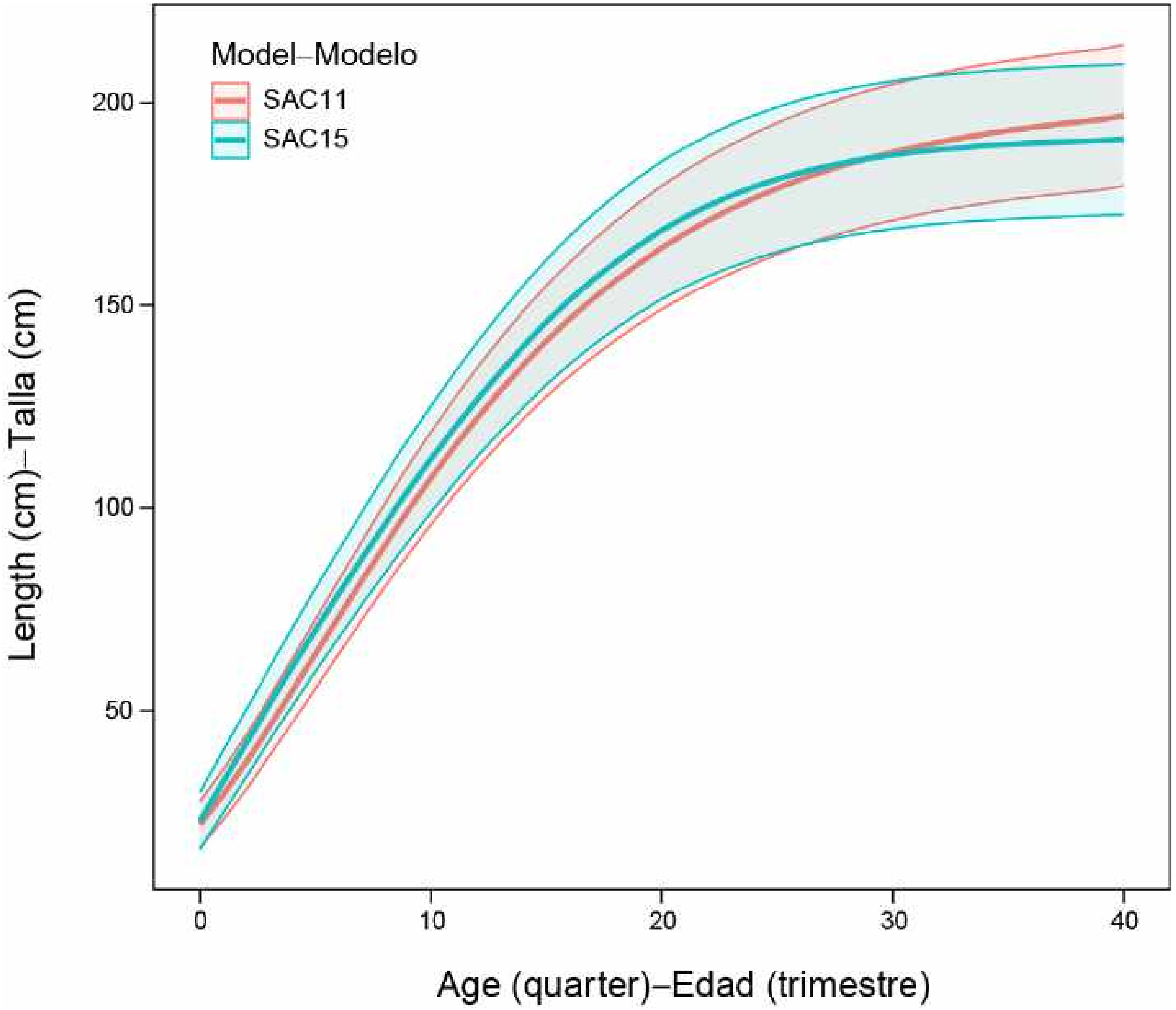


- The age at length data is only included in the reference models where growth is estimated

- The data does not cover bigeye larger than 150 cm and older than 4 years

3. Model assumptions – growth

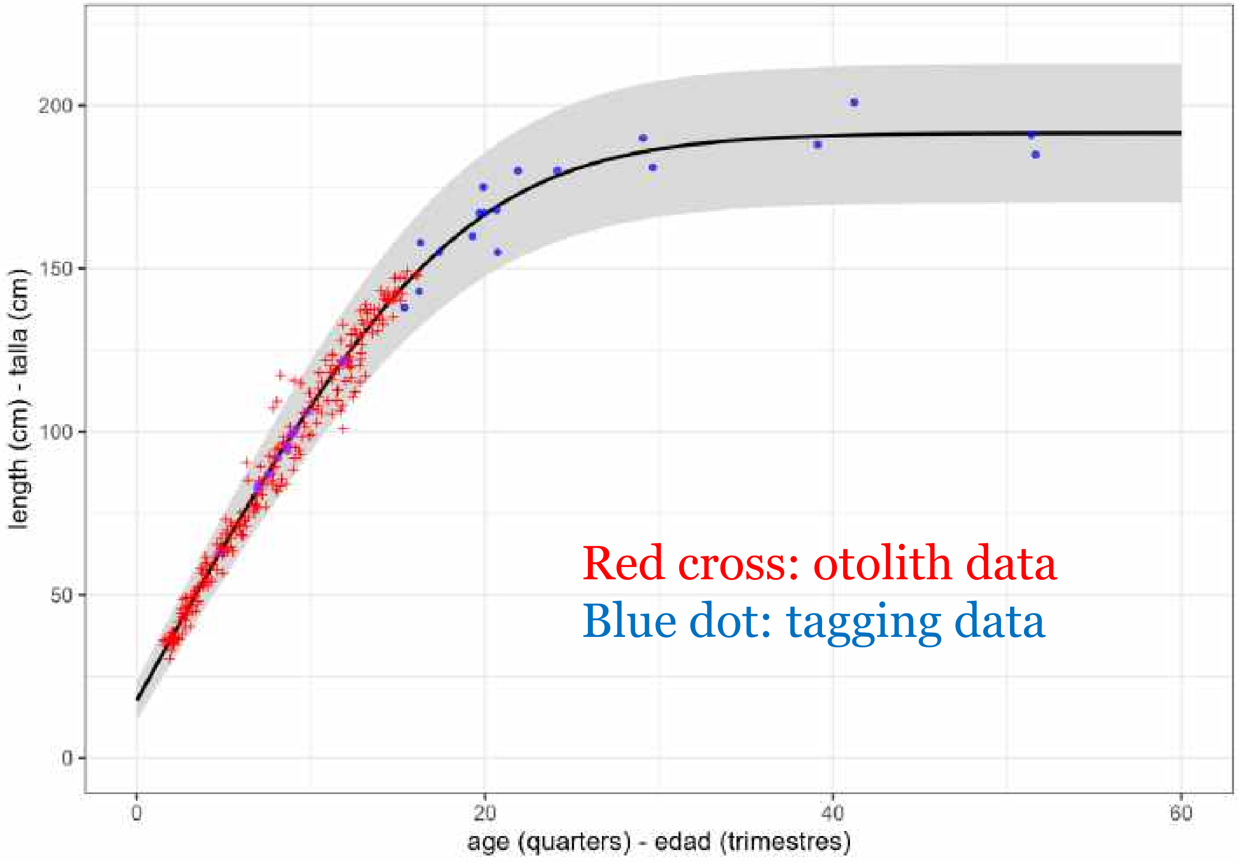
- The last benchmark assessment (SAC11) used a Richards growth curve
- This benchmark assessment (SAC15) uses a growth cessation curve



3. Model assumptions – growth

- The last benchmark assessment (SAC11) used a Richards growth curve
- This benchmark assessment (SAC15) uses a growth cessation curve

- The growth cessation curve has been found to fit better to the otolith + tagging data for bigeye in the EPO

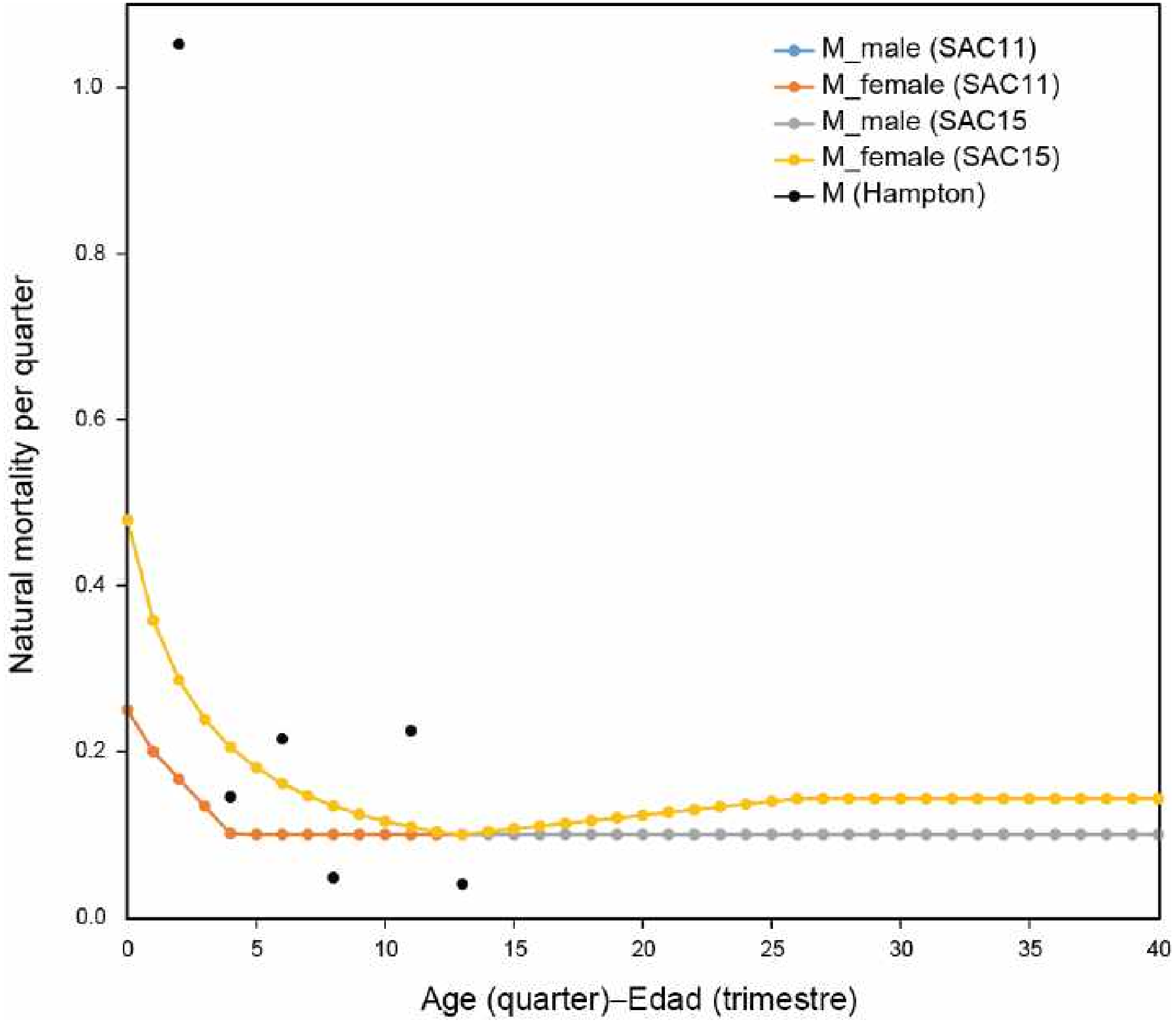


3. Model assumptions – natural mortality

- The last benchmark assessment (SAC11) used a broken-stick M curve
- This benchmark assessment (SAC15) uses the Lorenzen M curve for immature bigeye (smaller than the length at 50% maturity)

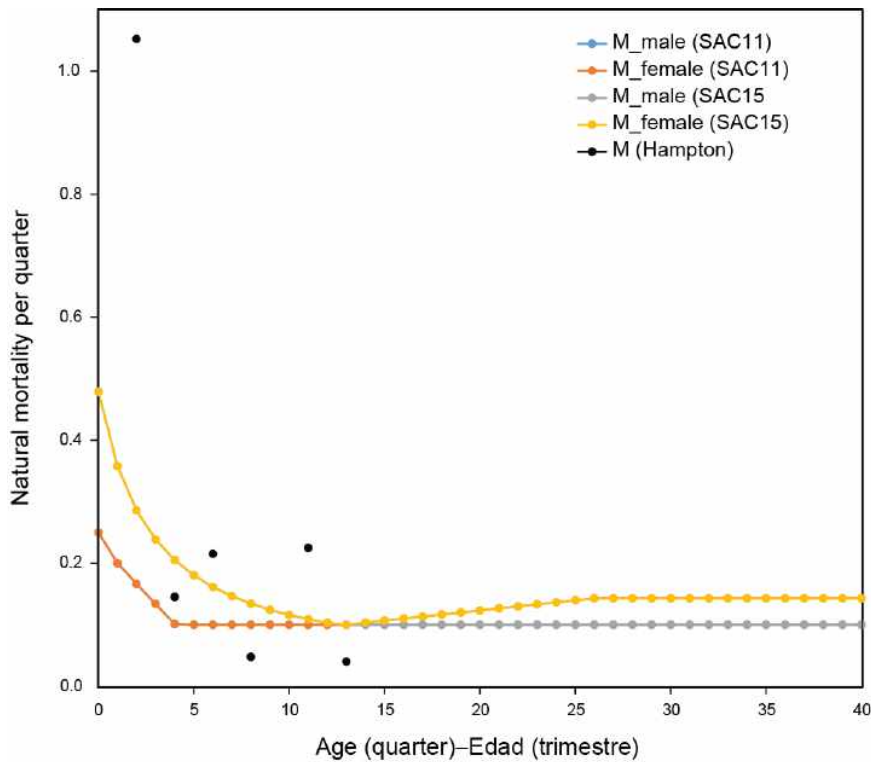
- The shape of the Lorenzen curve is based on Lorenzen's two recent publications in 2022:

$$M_l = M_{l50} \times \left(\frac{l}{l_{50}}\right)^{-1}$$



3. Model assumptions – natural mortality

- The staff tried to estimate the Lorenzen *M* curve using a cohort analysis approach with otolith and tagging data.
- The cohort analysis model was able to estimate the M for yellowfin, but it did not converge for bigeye mainly because the reporting rates for both longline fisheries and tagging data before 2020 are unknown.
- The Lorenzen M is considered to be more appropriate for immature bigeye because it follows the current good practice recommendation derived from scientific research and fits better to the M of Hampton (2000)

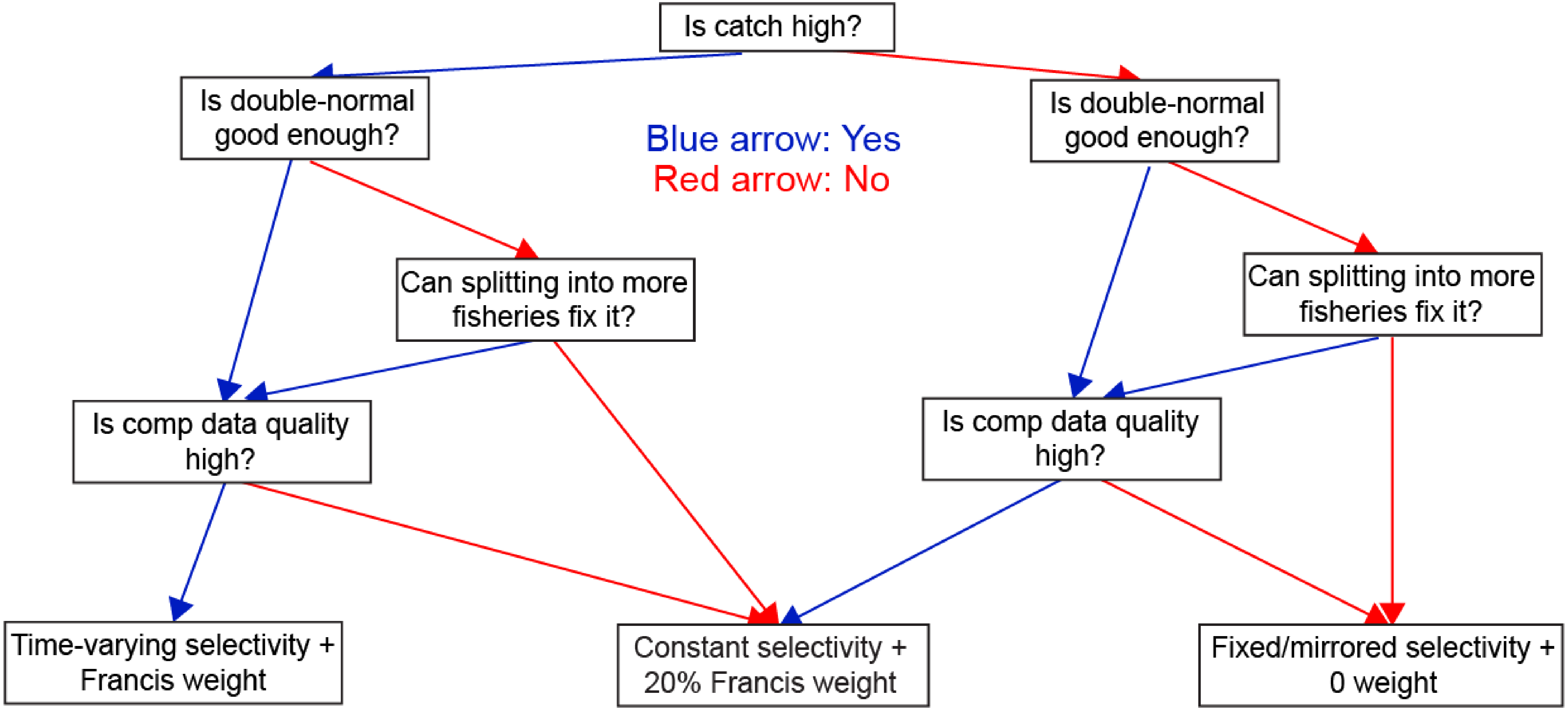


3. Model assumptions - recruitment

- Beverton-Holt stock-recruit relationship
- Recruitment is quarterly: use the quarter-as-year approach
- Three steepness (h) values are compared: 1.0, 0.9, 0.8
- No autocorrelation in recruit deviates
- Recruitment variability (σ_R) = 0.6 (quarterly)
- Bias adjustment follows Methot and Taylor (2011)

3. Model assumptions – selectivity and data weighting

A decision tree is developed for selectivity and data weighting



3. Model assumptions – selectivity and data weighting

Fleet number	Fleet type	Fleet name	Catch amount	Double-normal	Data quality
1	Fishery	LL-n-A1	Low	No	High
2		LL-n-A2	High	Yes	High
3		LL-n-A3	High	Yes	High
4		LL-n-A4	High	Yes	High
5		LL-n-A5	High	Yes	High
6		LL-n-A6	Low	Yes	High
7		LL-n-A7	Low	Yes	High
8	Fishery	LL-w-A1	Low	NA	NA
9		LL-w-A2	High	NA	NA
10		LL-w-A3	High	NA	NA
11		LL-w-A4	High	NA	NA
12		LL-w-A5	High	NA	NA
13		LL-w-A6	Low	NA	NA
14		LL-w-A7	Low	NA	NA
15	Fishery	OBJ-A1	Low	Yes	High
16		OBJ-A2	High	Yes	High
17		OBJ-A3	High	No	High
18		OBJ-A4	High	Yes	High
19		OBJ-A5	Low	Yes	High
20		OBJ-disc-EPO	Low	NA	NA
21	Fishery	NOADEL-A1	Low	Yes	Low
22		NOADEL-A2	Low	Yes	Low
23	Survey	LL-survey-EPO	NA	Yes	High

3. Model assumptions – selectivity and data weighting

Fleet number	Fleet type	Fleet name	Catch amount	Double-normal	Data quality	Selectivity	Time blocks	Weighting scaler
1	Fishery	LL-n-A1	Low	No	High	Fixed	NA	0
2		LL-n-A2	High	Yes	High	Estimated	1993; 2010	1
3		LL-n-A3	High	Yes	High	Estimated	NA	0.2
4		LL-n-A4	High	Yes	High	Estimated	1993; 2010	1
5		LL-n-A5	High	Yes	High	Estimated	1993; 2010	1
6		LL-n-A6	Low	Yes	High	Estimated	NA	0.2
7		LL-n-A7	Low	Yes	High	Estimated	NA	0.2
8	Fishery	LL-w-A1	Low	NA	NA	Mirror F1	NA	NA
9		LL-w-A2	High	NA	NA	Mirror F2	NA	NA
10		LL-w-A3	High	NA	NA	Mirror F3	NA	NA
11		LL-w-A4	High	NA	NA	Mirror F4	NA	NA
12		LL-w-A5	High	NA	NA	Mirror F5	NA	NA
13		LL-w-A6	Low	NA	NA	Mirror F6	NA	NA
14		LL-w-A7	Low	NA	NA	Mirror F7	NA	NA
15	Fishery	OBJ-A1	Low	Yes	High	Estimated	NA	0.2
16		OBJ-A2	High	Yes	High	Estimated	2000; 2010	1
17		OBJ-A3	High	No	High	Estimated	NA	0.2
18		OBJ-A4	High	Yes	High	Estimated	2000; 2010	1
19		OBJ-A5	Low	Yes	High	Estimated	NA	0.2
20		OBJ-disc-EPO	Low	NA	NA	Fixed	NA	0
21	Fishery	NOADEL-A1	Low	Yes	Low	Mirror F15	NA	0
22		NOADEL-A2	Low	Yes	Low	Mirror F19	NA	0
23	Survey	LL-survey-EPO	NA	Yes	High	Estimated	NA	1

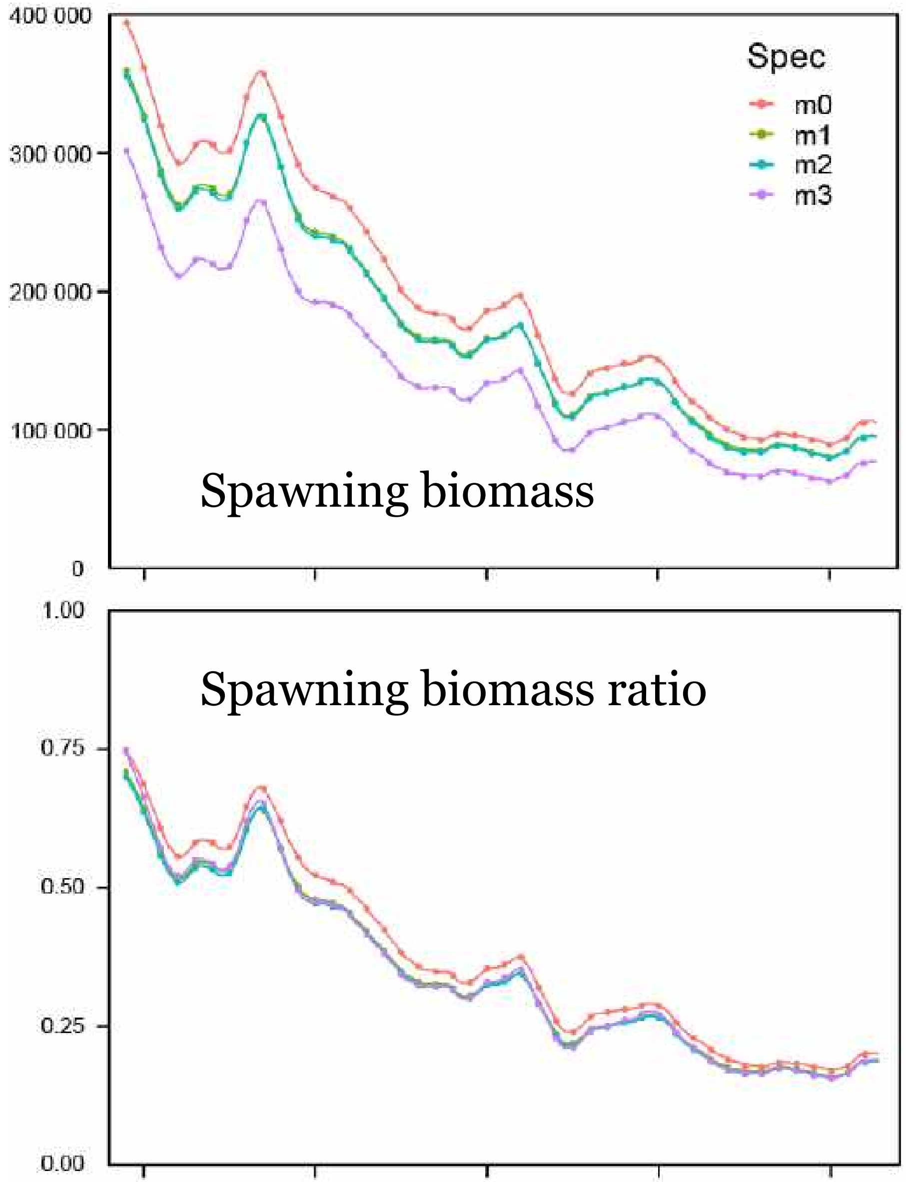
4. Bridging analysis

A bridging analysis is conducted to illustrate the impacts of each new change on model results:

- M0: the base reference model from the last exploratory assessment (SAC-14-05)
- M1: selectivity and data weighting are specified based on the new decision tree
- M2: the Richards growth curve is replaced by the growth cessation model
- M3: the broken-stick M vector for juveniles is replaced by the Lorenzen M curve

4. Bridging analysis

- The new selectivity and data weighting approach results in a slightly reduced scale of spawning biomass and spawning biomass ratio (M1 vs. M0).
- Updating the growth curve has a negligible impact on both spawning biomass and spawning biomass ratio (M2 vs. M1).
- Updating the *M* vectors leads to notably lower spawning biomass while almost identical spawning biomass ratio (M3 vs. M2).



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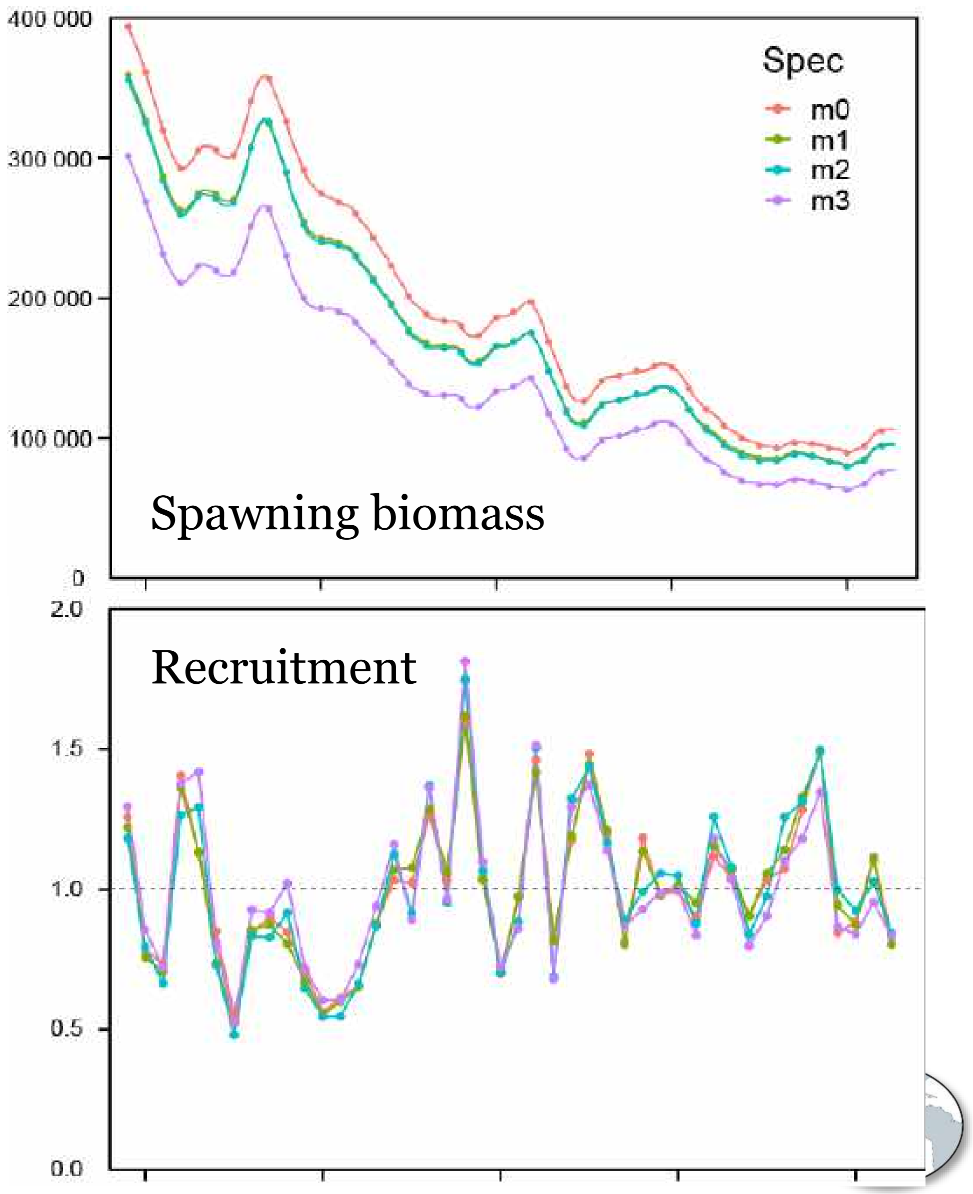
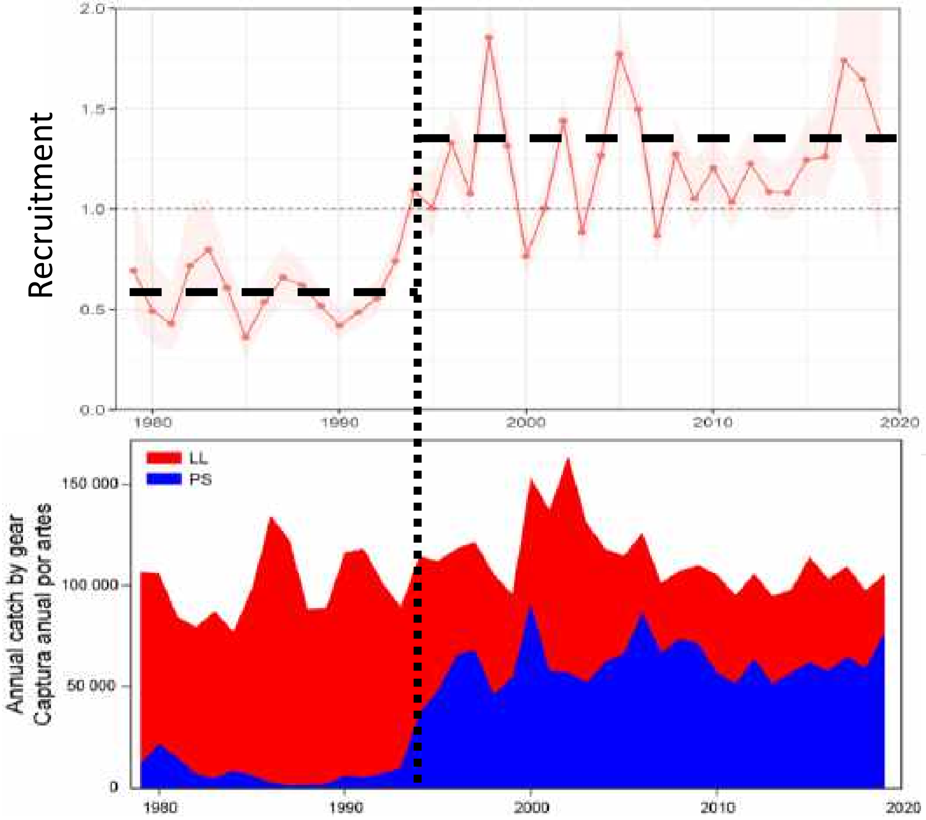
- Updating the growth curve has a negligible impact on both spawning biomass and spawning biomass ratio (M2 vs. M1).
- Updating the *M* vectors leads to notably lower spawning biomass while almost identical spawning biomass ratio (M3 vs. M2).
- Additional, updating the M vectors leads to a notable reduction in the degree of the regime shift in recruitment.



5. Reference models - hypotheses

Last benchmark assessment: the overarching hypothesis aimed to explain the apparent regime shift in recruitment that coincided with the expansion of the floating-object fishery



5. Reference models - hypotheses

Last benchmark assessment: the overarching hypothesis aimed to explain the apparent regime shift in recruitment that coincided with the expansion of the floating-object fishery

Why the previous model estimated a regime shift in recruitment?

- The expansion of the OBJ fishery in the EPO is expected to cause strong depletion signals in both longline index and length frequency
- Only weak depletion signals are observed in the longline fishery
- The model explains that discrepancy by producing more recruitment since 1994

5. Reference models - hypotheses

- This benchmark assessment: the degree of the regime shift is reduced greatly (SAC-11: 140% to SAC-15: 20%) for the base reference model, so the overarching hypothesis is not included in the risk analysis
- This significant decrease of the regime shift in recruitment results from the combination of changes made to the assessment.
- Among the changes, the three most influential ones are:

5. Reference models - hypotheses

1. Adding one more time block to the selectivity of longline fisheries in 2011
   - The selectivity for 1994-2010 is dome-shaped instead of asymptotic -> less depleted spawning biomass -> reduced expected impact of the OBJ fishery on population depletion
2. Improving the CPUE standardization model
   - Accounting for temporal correlations in spatiotemporal random effects -> a steeper decline in the longline index of abundance -> enhanced observed depletion signal caused by the expansion of the OBJ fishery
3. Updating the natural mortality curve for bigeye
   - Using the Lorenzen natural mortality -> higher natural mortality for juveniles -> reduced expected impact of the OBJ fishery (relatively to natural mortality) on population depletion

All three changes reduce the discrepancy between the observed and expected impact of the OBJ fishery on population depletion

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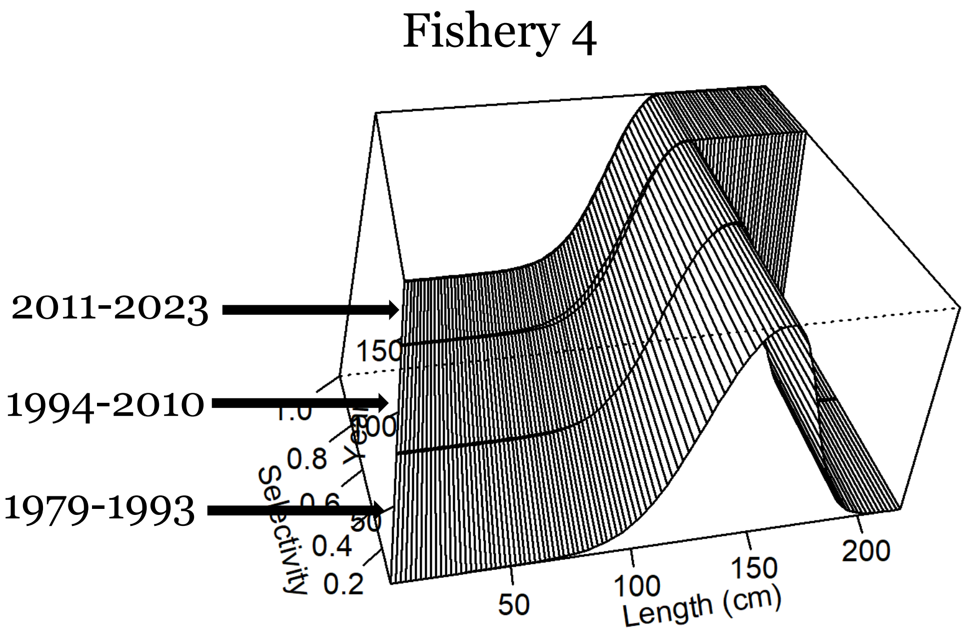
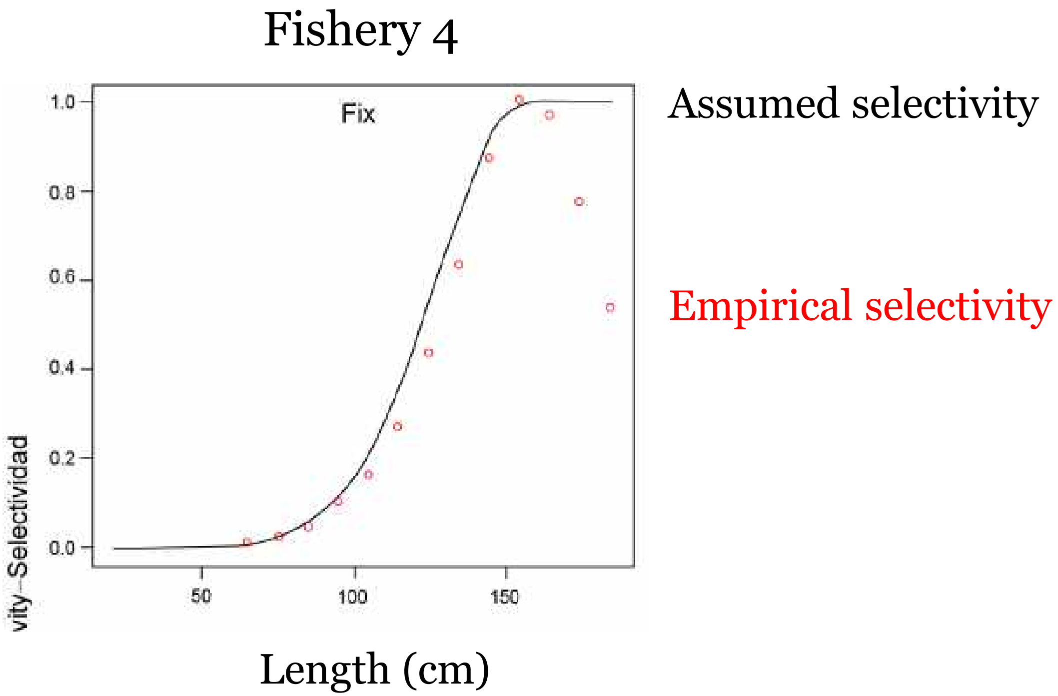
5. Reference models - hypotheses

Level 1 hypothesis: Four models are included to address the misfit to the composition data for the longline fishery that is assumed to have an asymptotic selectivity: (1) ignore the issue (Fix); (2) estimate the growth curve with a prior on L_{inf} (Gro) – use conditional age-at-length and L_{inf} prior from a external tagging analysis; (3) estimate a dome-shape selectivity curve for the longline fishery that is assumed to have asymptotic selectivity (Sel); and (4) estimate the scaler of the natural mortality vector (Mrt).

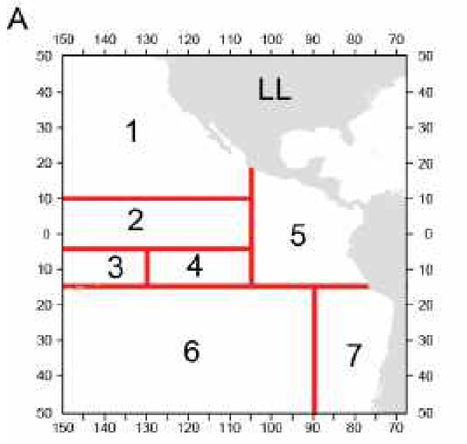




5. Reference models - hypotheses

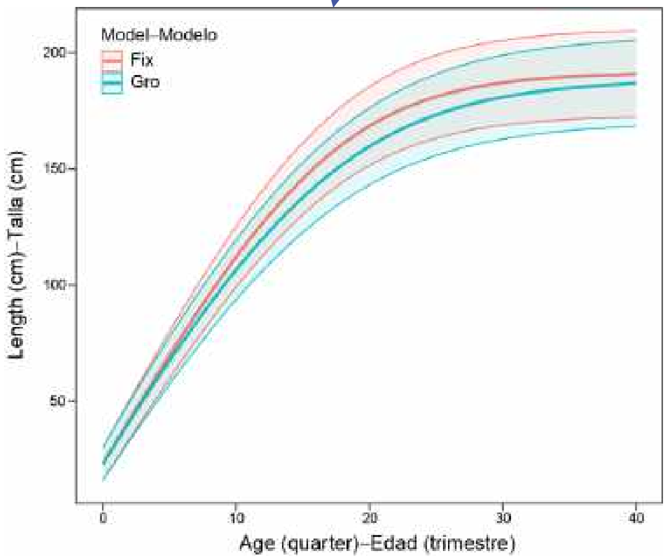
Why the longline selectivity of the last time block is asymptotic?

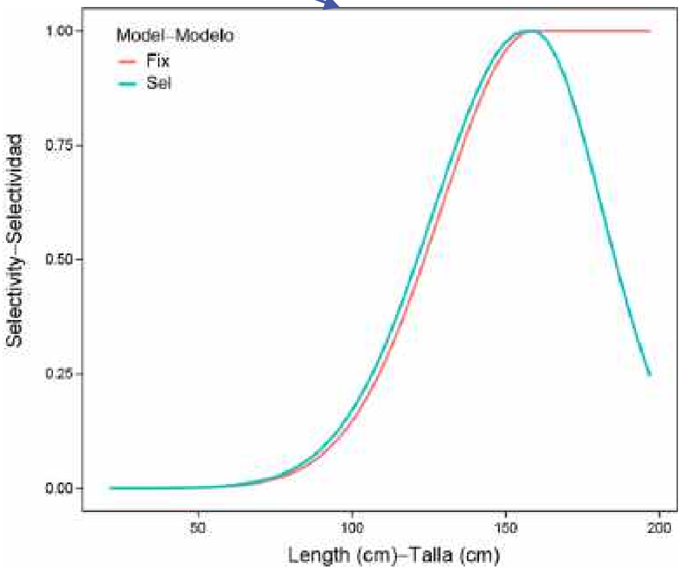
- The regression tree detects a significant change in Fishery 4's longline selectivity in 2011
- The last block for Fishery 4 has the highest proportion of large bigeye
- The change in the selectivity of this fishery can be caused by:
    1. The change in the spatial distribution of fishing ground (contraction to the places where bigeye are large)
    2. Inconsistent measurements between those from fishermen (before 2011) and observers (since 2011)
    3. The change in fishing gear/operation (e.g., using light sticks)

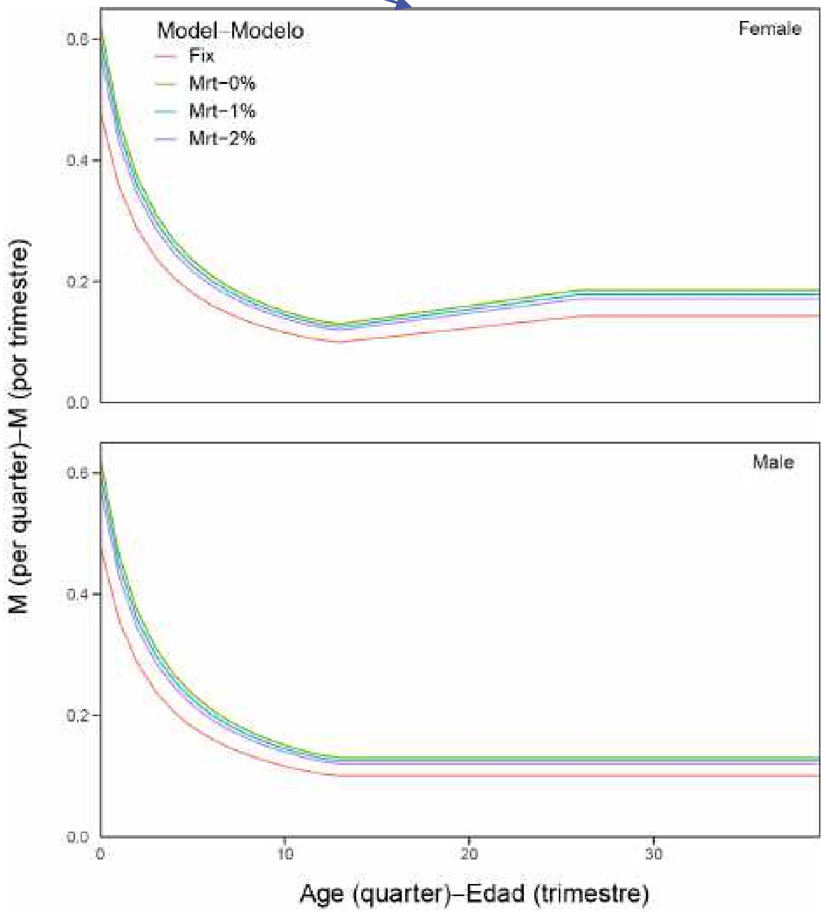


5. Reference models – estimated parameters

Level 1 hypothesis: Four models are included to address the misfit to the composition data for the longline fishery that is assumed to have an asymptotic selectivity: (1) ignore the issue (Fix); (2) estimate the growth curve with a prior on L_{inf} (Gro); (3) estimate a dome-shape selectivity curve for the longline fishery that is assumed to have asymptotic selectivity (Sel); and (4) estimate the scaler of the natural mortality vector (Mrt).





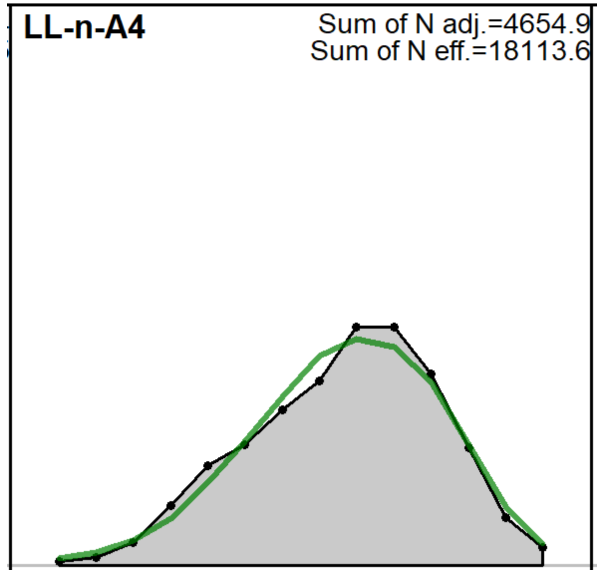


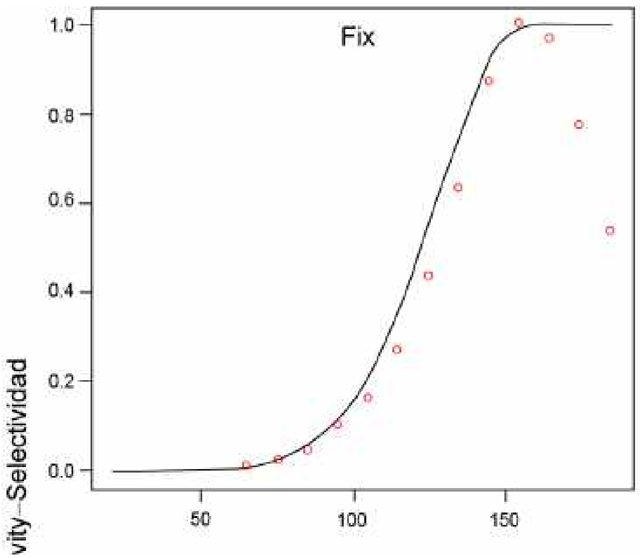
5. Reference models - hypotheses

Level 1 hypothesis: The four models are equally weighted. The decision to equally weight the four models is made based on the outcome of the two risk analysis workshops organized by the IATTC.

Why including Model Fix where the misfit is ignored?

1. The overall fit is not bad at large sizes
2. The review panel thinks the empirical selectivity diagnostic can be overly-sensitive to the largest individuals





Length (cm)

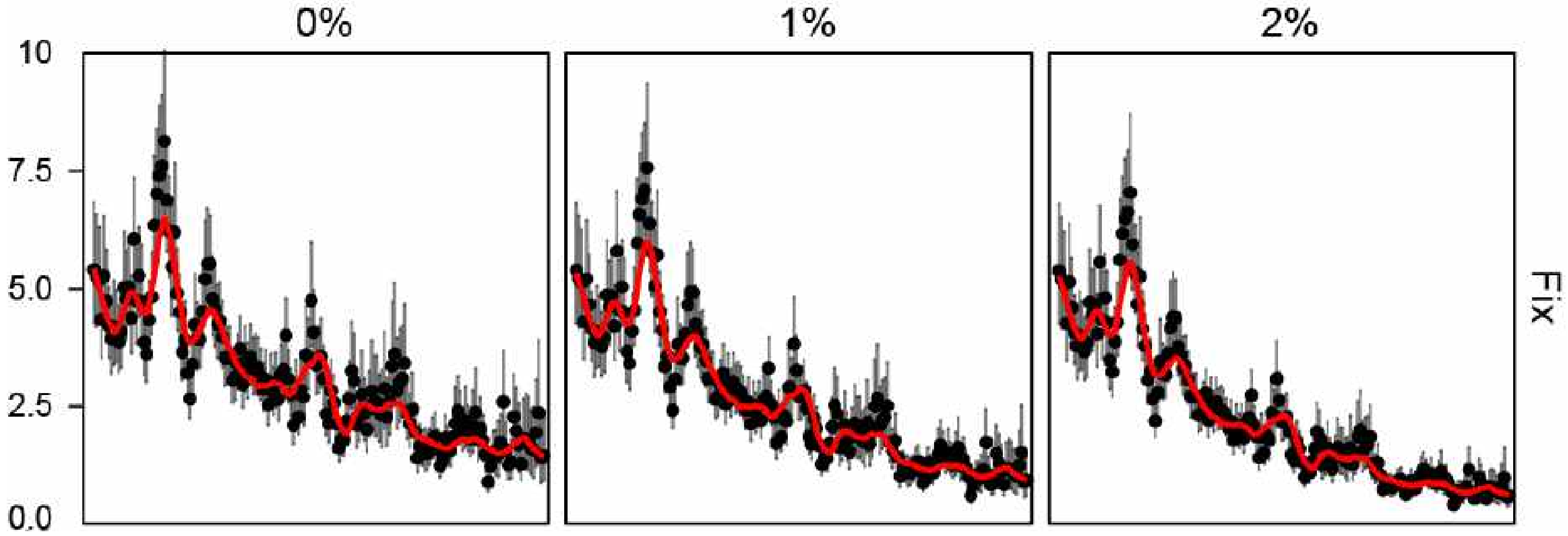
Assumed selectivity

Empirical selectivity

5. Reference models - hypotheses

Level 2 hypothesis: Various levels of annual increase in longline catchability are included to address the uncertainty in effort creep. Bigeye is the main target species of the Japanese longline fishery in the EPO - its catchability is expected to increase owing to advancements in fishing skill and technology.

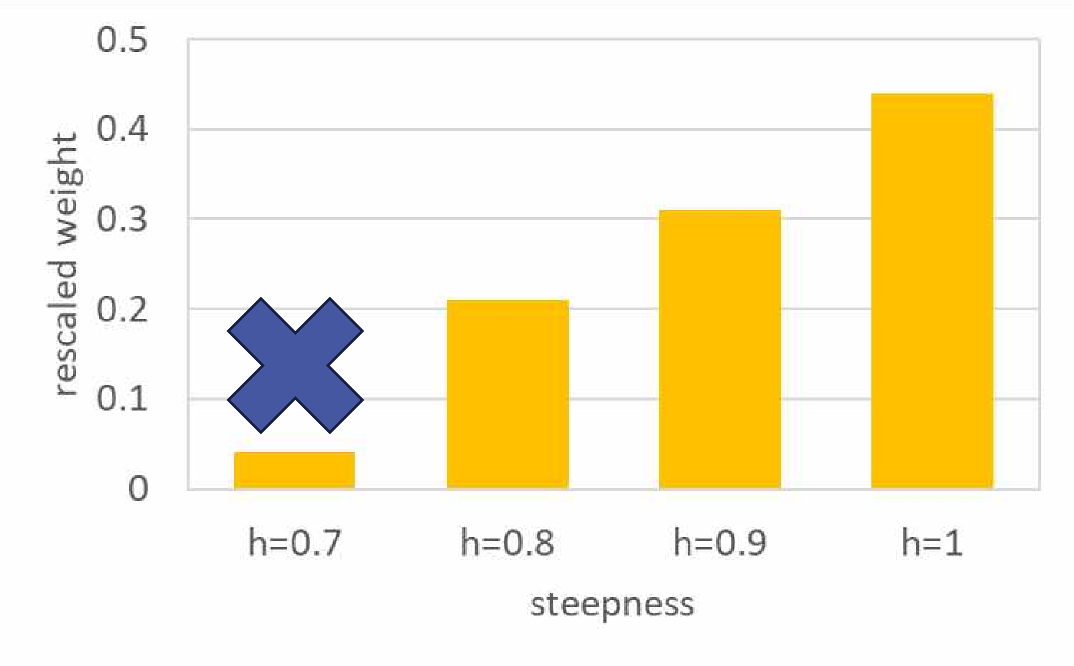
The review panel suggests considering a 1% annual increase in the catchability of bigeye in the longline fishery. Based on this recommendation, three annual increases (0%, 1%, and 2%) are considered to address this uncertainty, each equally weighted.



5. Reference models - hypotheses

Level 3 hypothesis: Three steepness values (1.0, 0.9, and 0.8) are included to address the uncertainty in the shape of the stock-recruitment relationship. The three steepness values are weighted based on expert judgement from the risk analysis for the last benchmark assessment:

- Weighted by each expert considering evidence regarding steepness
- Weights are combined across experts
- Those weights are unchanged in this assessment because no new evidence on steepness has been available

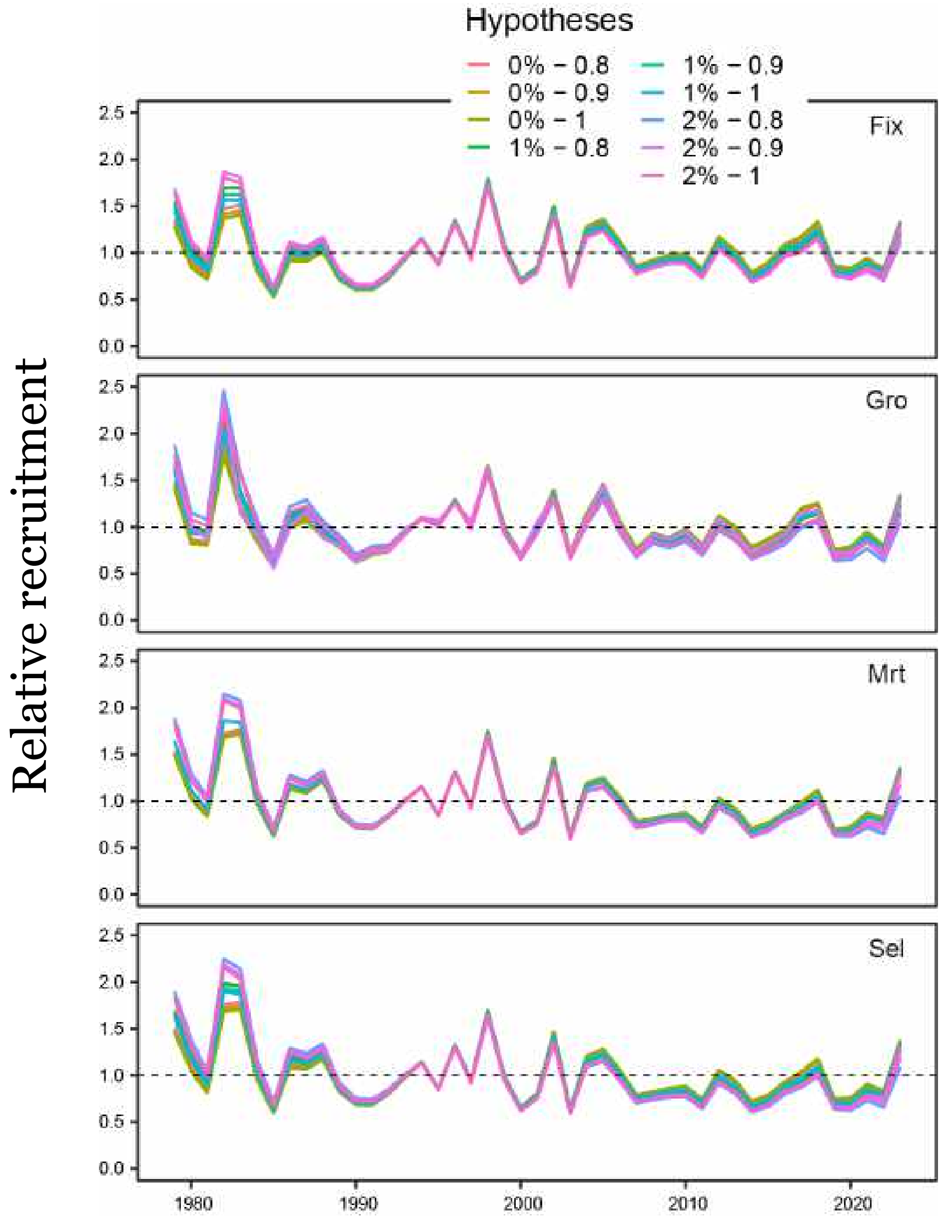


6. Model results - convergence

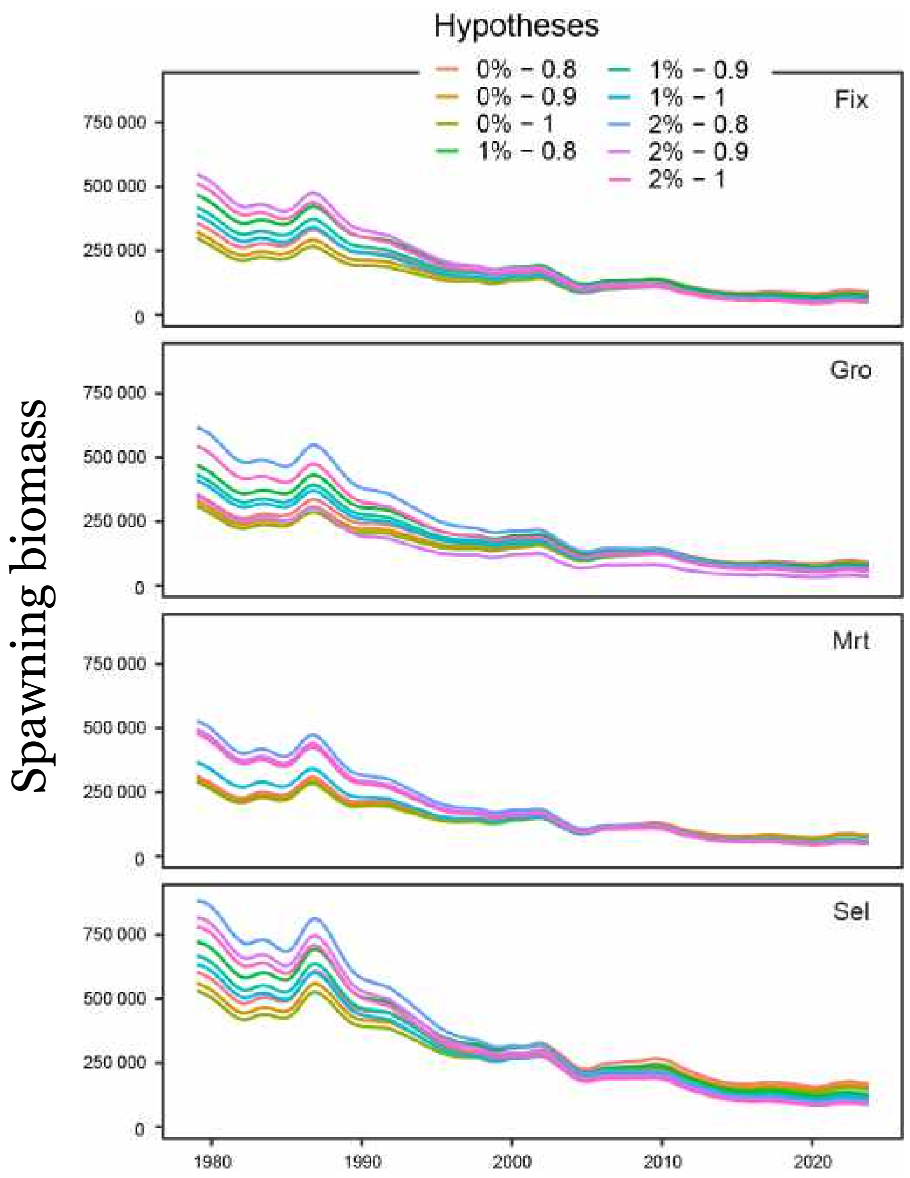
Level 1 hypothesis: Model Fix, Gro, Sel, Mrt
Level 2 hypothesis: 0%, 1%, 2% annual increase in longline catchability
Level 3 hypothesis: Steepness of 1.0, 0.9, 0.8

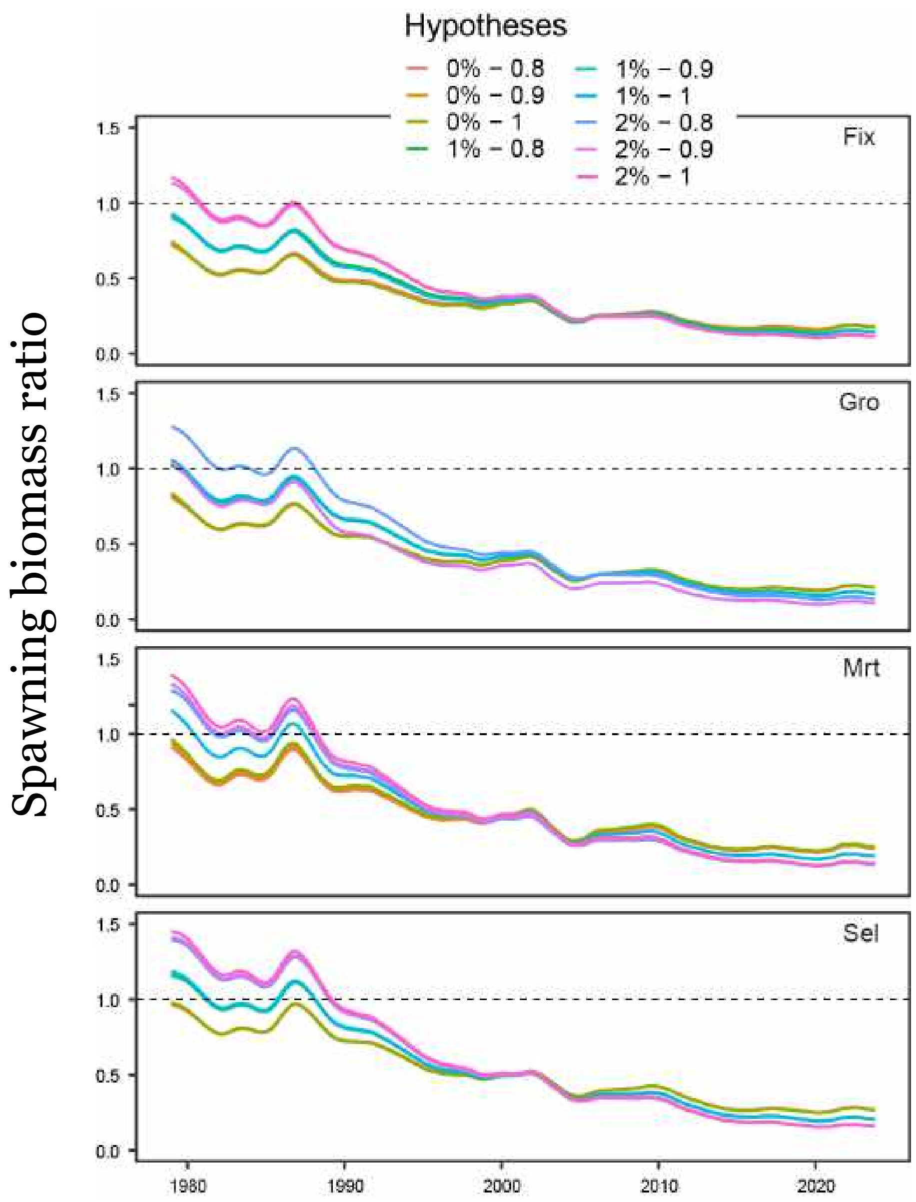
- The combination of the three hypothesis yields $4 \times 3 \times 3 = 36$ reference models
- The final weight of the reference model = $W_{level1}(0.25) * W_{level2}(0.33) * W_{level3}$
- 33 of the 36 reference models converge with positive definite Hessian matrices and pass the Jitter diagnostic
- Three reference models are rejected:
  1. Fix – 2% - 0.8
  2. Mrt – 1% - 0.9
  3. Mrt – 1% - 0.8

6. Model results – relative recruitment



6. Model results – spawning biomass





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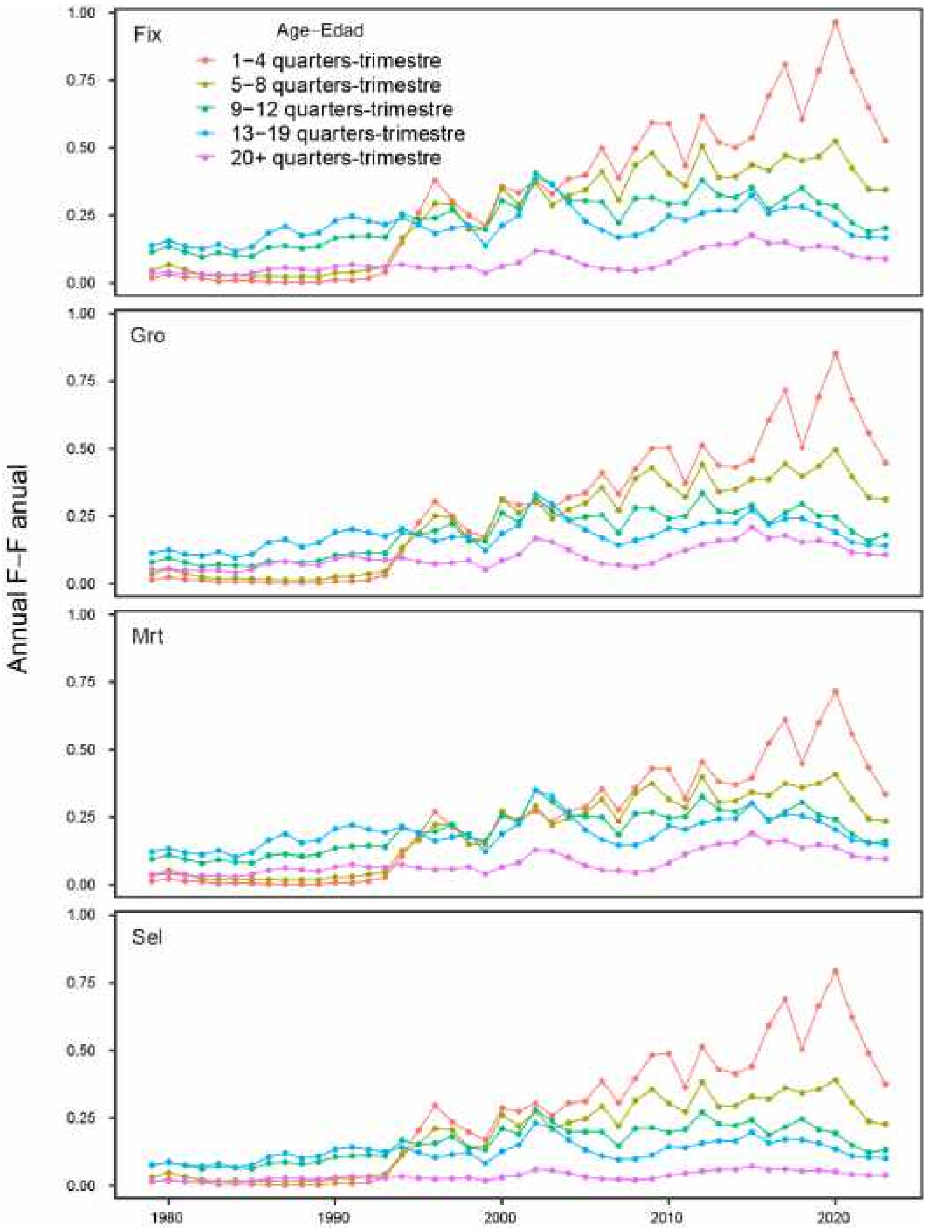
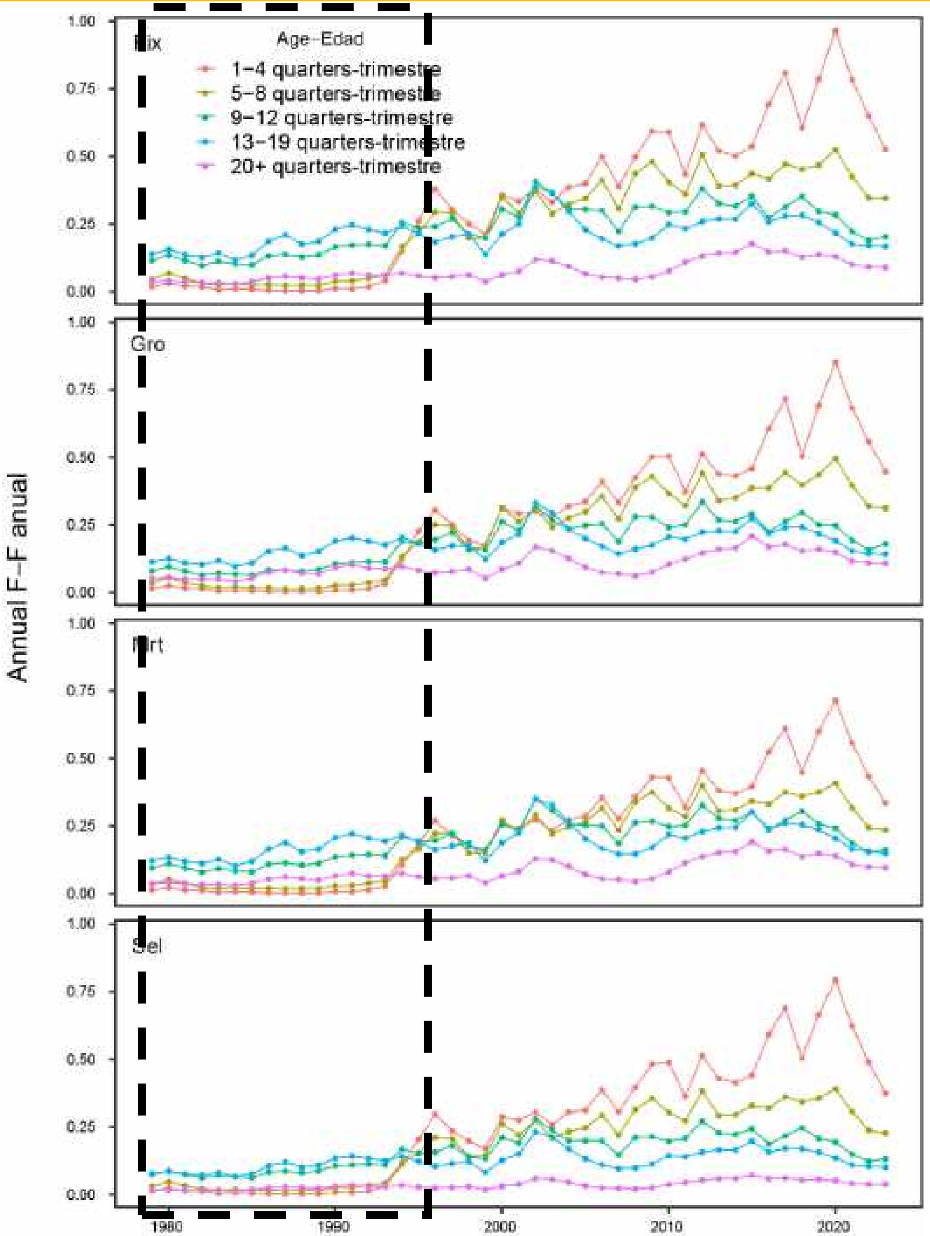
6. Model results – fishing mortality



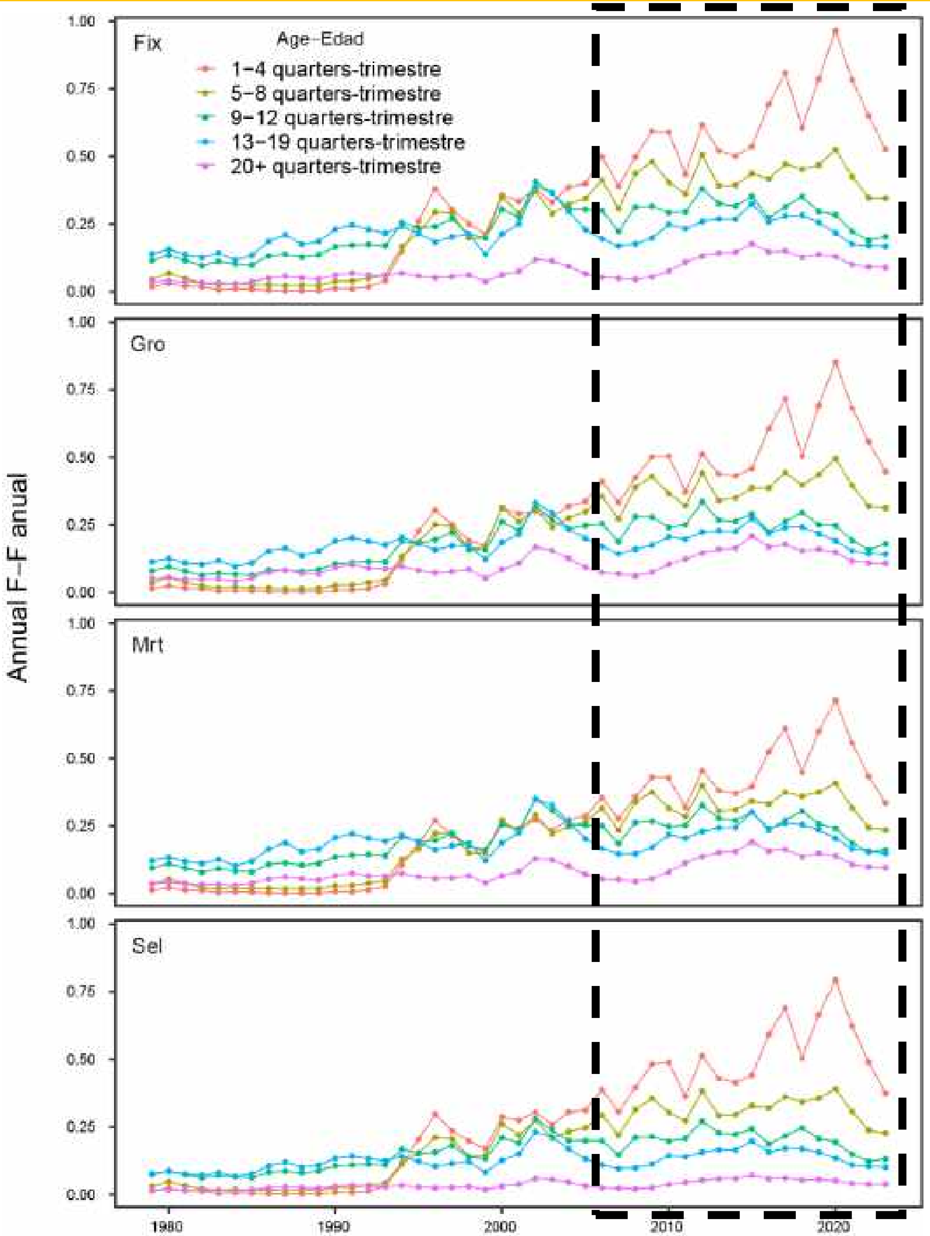
6. Model results – fishing mortality

- Before 1995: the fishing mortality for adult bigeye was higher than that for juvenile bigeye



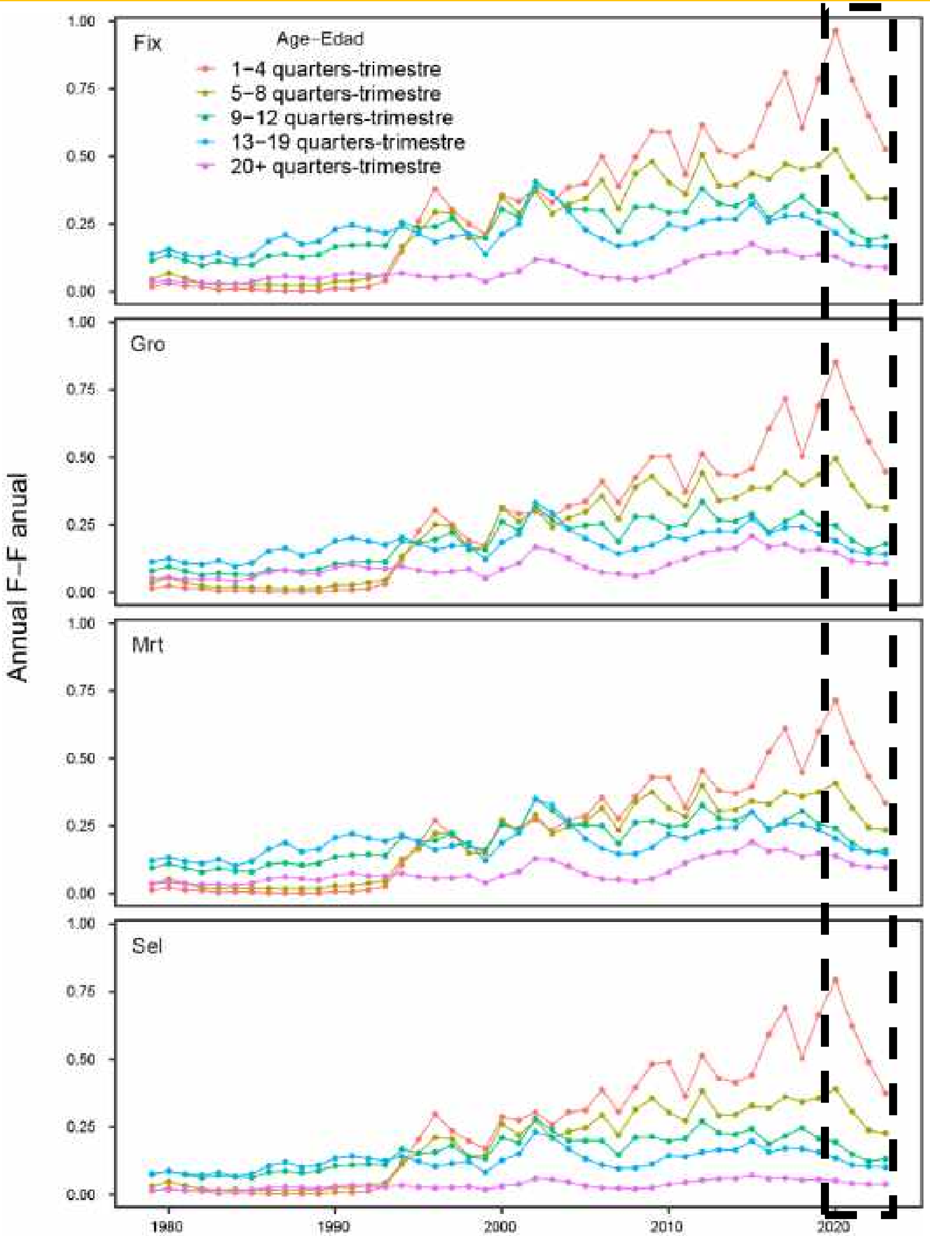
6. Model results – fishing mortality

- Before 1995: the fishing mortality for adult bigeye was higher than that for juvenile bigeye
- After 2005: the fishing mortality for adult bigeye was lower than that for juvenile bigeye

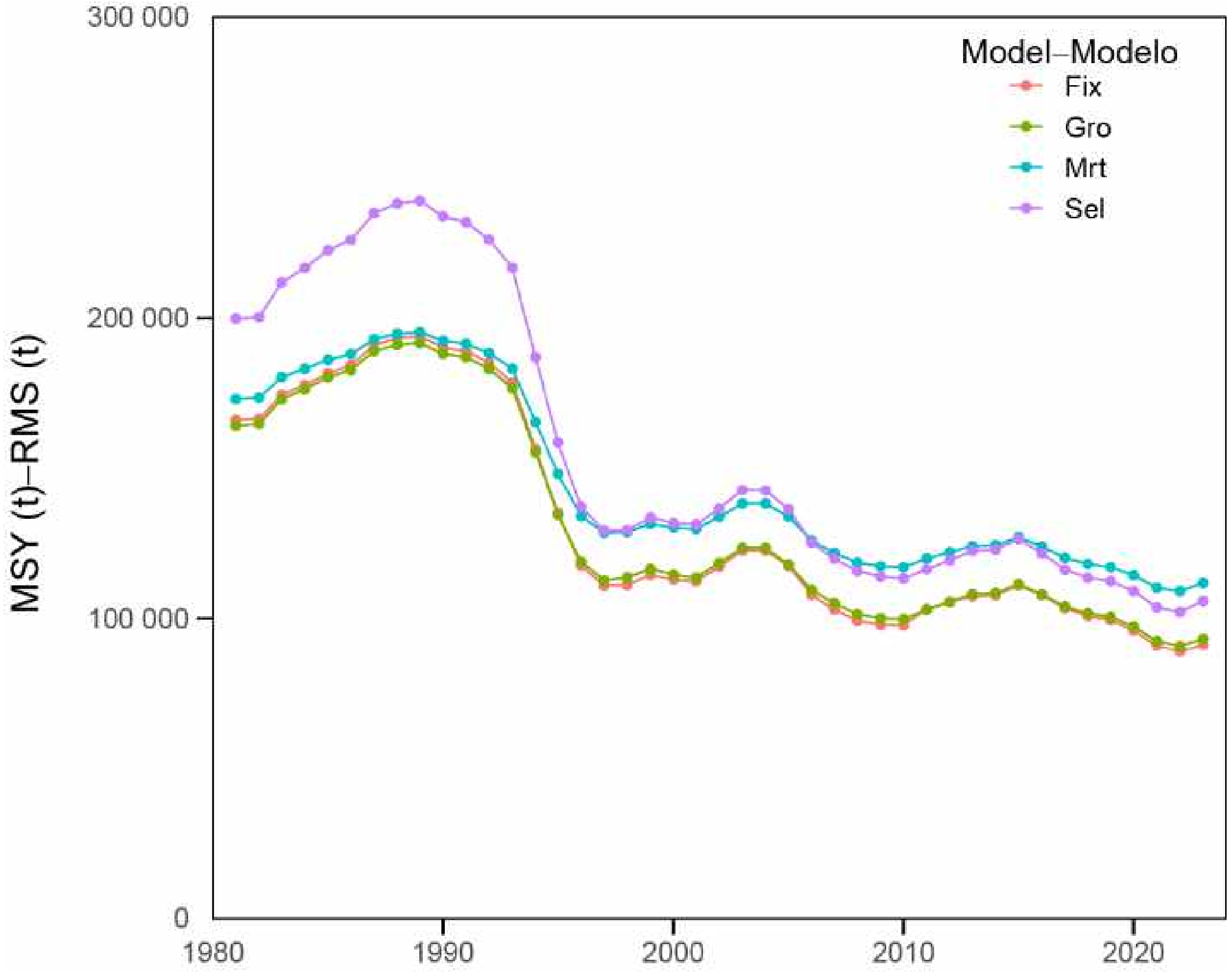


6. Model results – fishing mortality

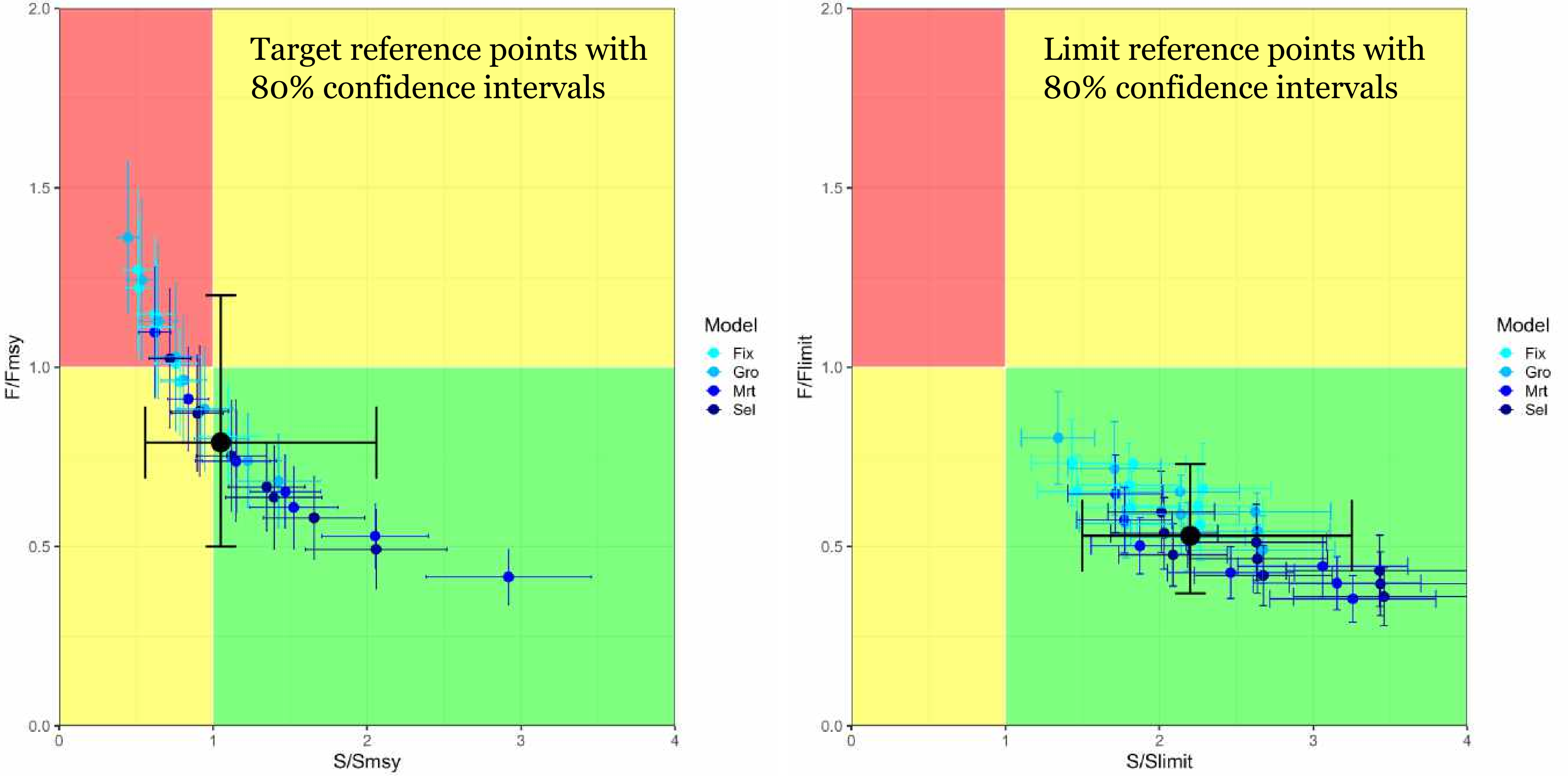
- Before 1995: the fishing mortality for adult bigeye was higher than that for juvenile bigeye
- After 2005: the fishing mortality for adult bigeye was lower than that for juvenile bigeye
- In 2021-2023: the fishing mortality for both juvenile and adult bigeye decreased, and the decreasing rate is higher for juvenile than adult bigeye
- The decreased fishing mortality in 2021-2023 is due to low longline and floating-object catches



6. Model results – maximum sustainable yield



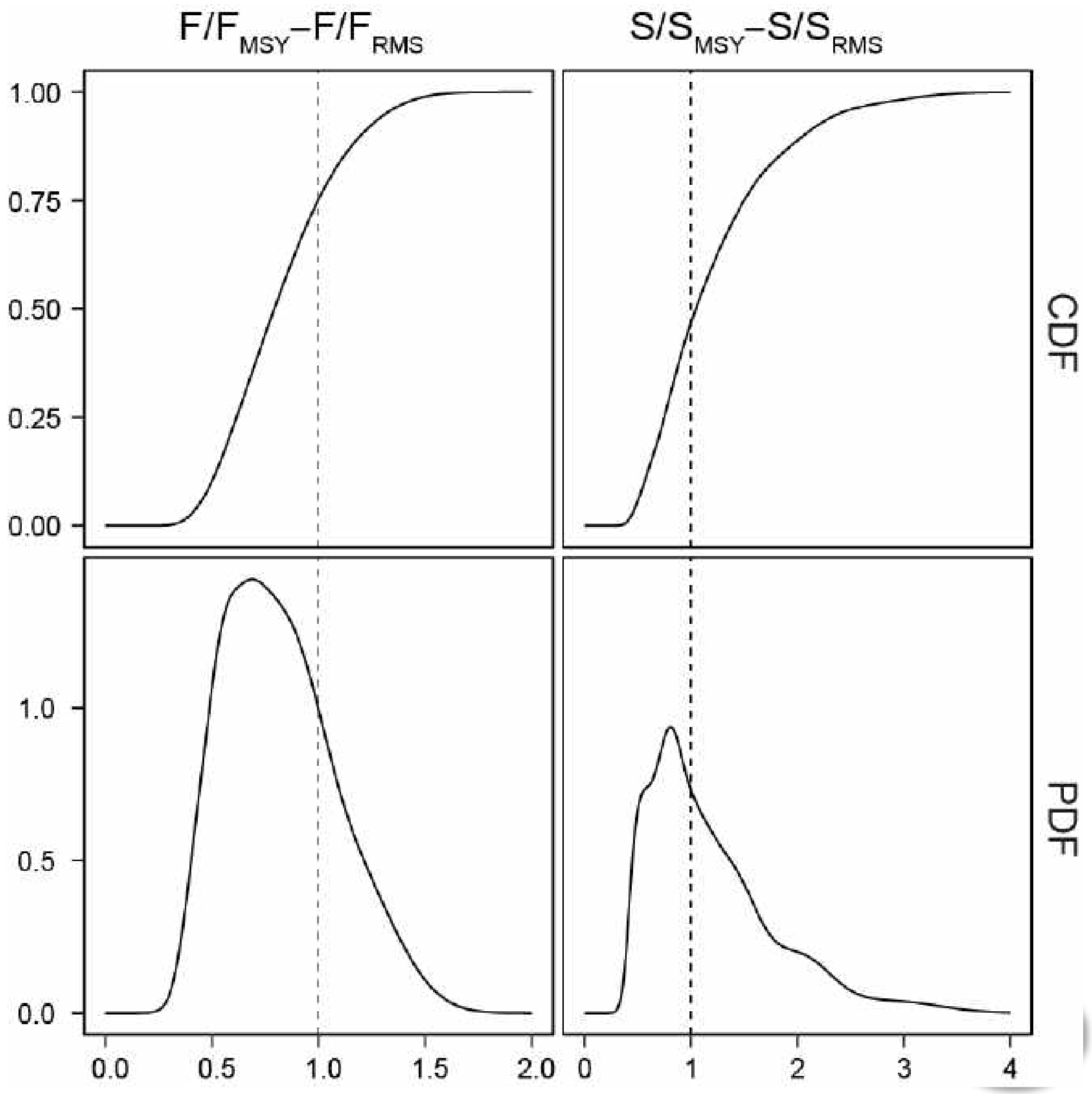
7. Stock status – Kobe plot



7. Stock status – target reference points

The overall results of the risk analysis, based on the thirty-three converged reference models, show unimodal probability distributions for management quantities. The risk analysis indicates:

- 46.6% probability that the spawning biomass at the beginning of 2024 is below the target reference point (S_{MSY_d})
- 24.7% probability that the fishing mortality in 2021-2023 is above the target reference point (F_{MSY})



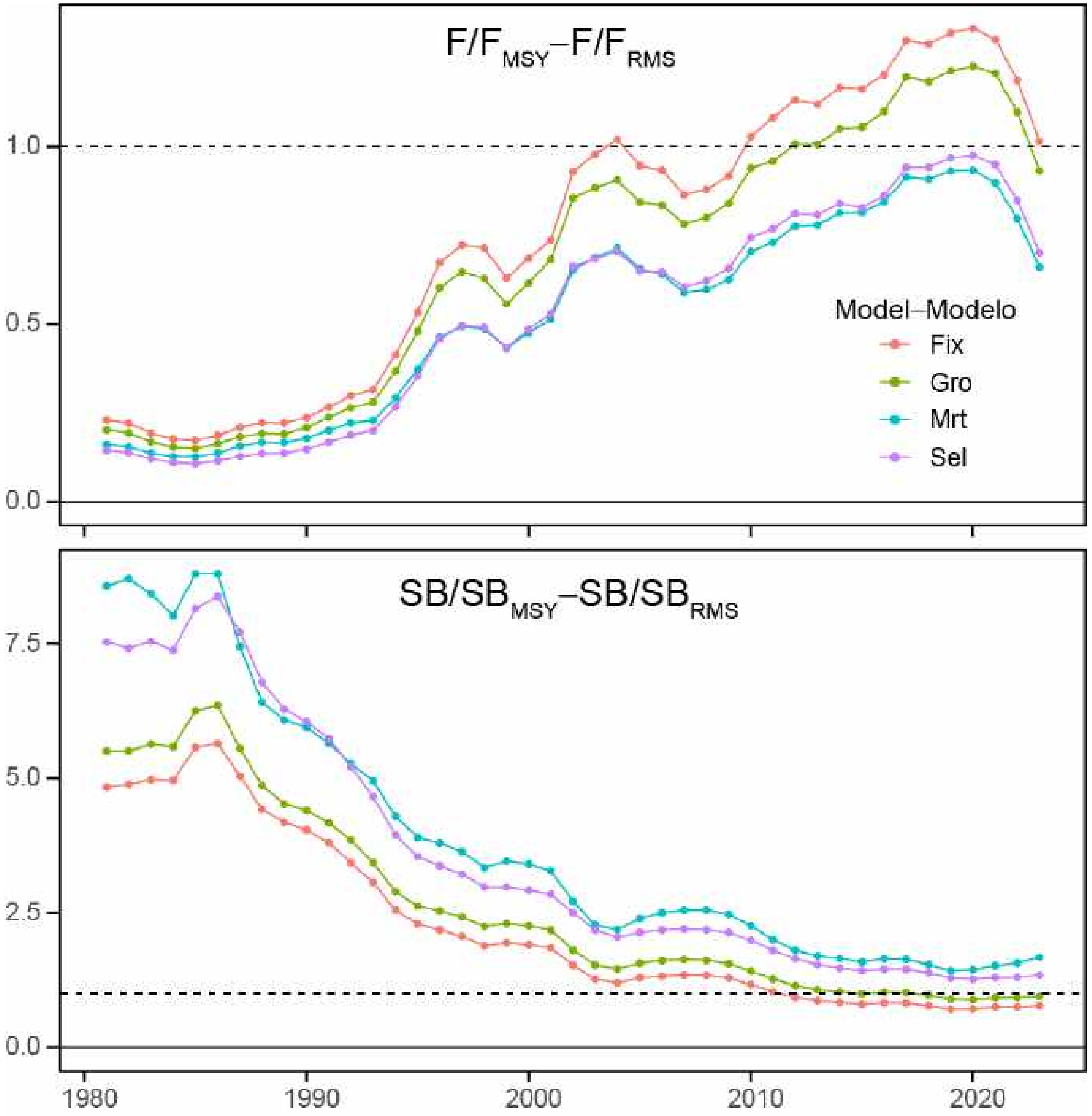
7. Stock status – target reference points

Models Fix and Gro:

- $F_{current}/F_{MSY}$ > 1 in around 2010, reached historically high levels in 2020, and decreased three years in a row to about 1 in 2023.
- $S_{current}/S_{MSY\_d}$ < 1 since about 2012 and recovered slightly after 2020 due to the decrease in $F_{current}/F_{MSY}$ during the same time, whereas it is still below 1 in 2023.

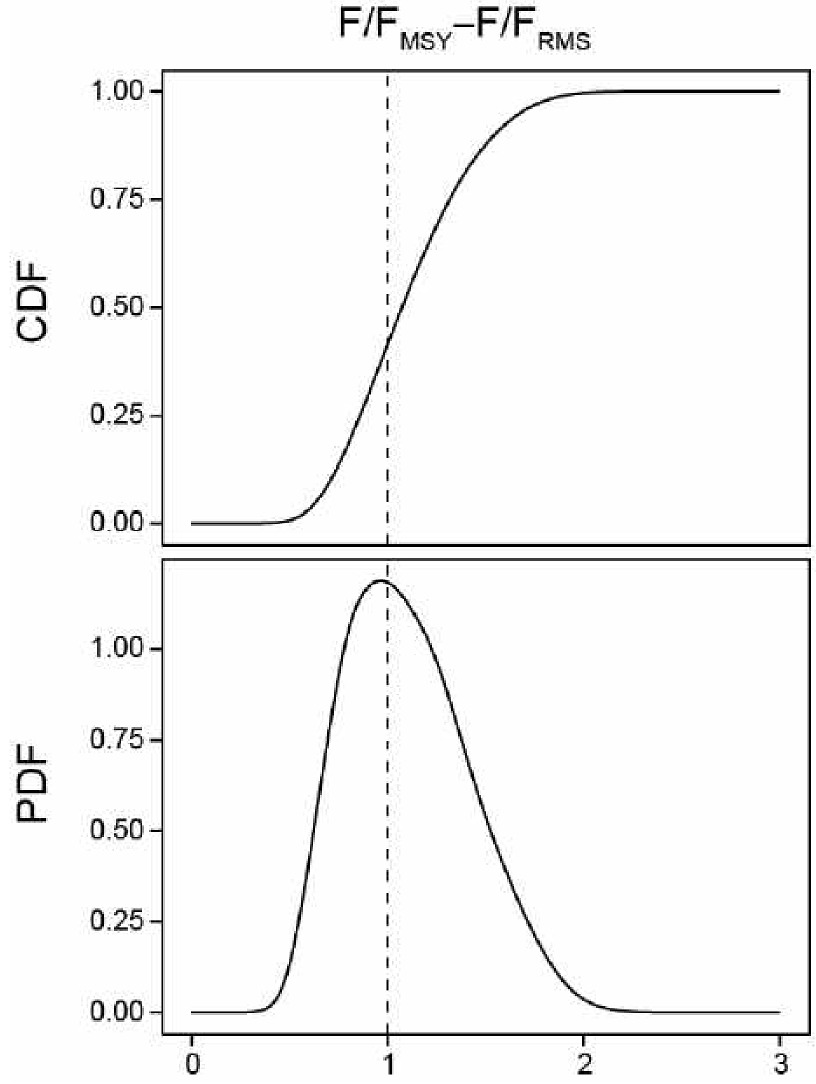
Models Sel and Mrt:

- $F_{current}/F_{MSY}$ reached historically high levels in 2020, which are slightly < 1, and decreased thereafter to < 0.7 in 2023.
- $S_{current}/S_{MSY\_d}$ decreased to historically low levels in 2020 (> 1) and increase thereafter to > 1.3 in 2023.



7. Stock status – target reference points (2017-2019)

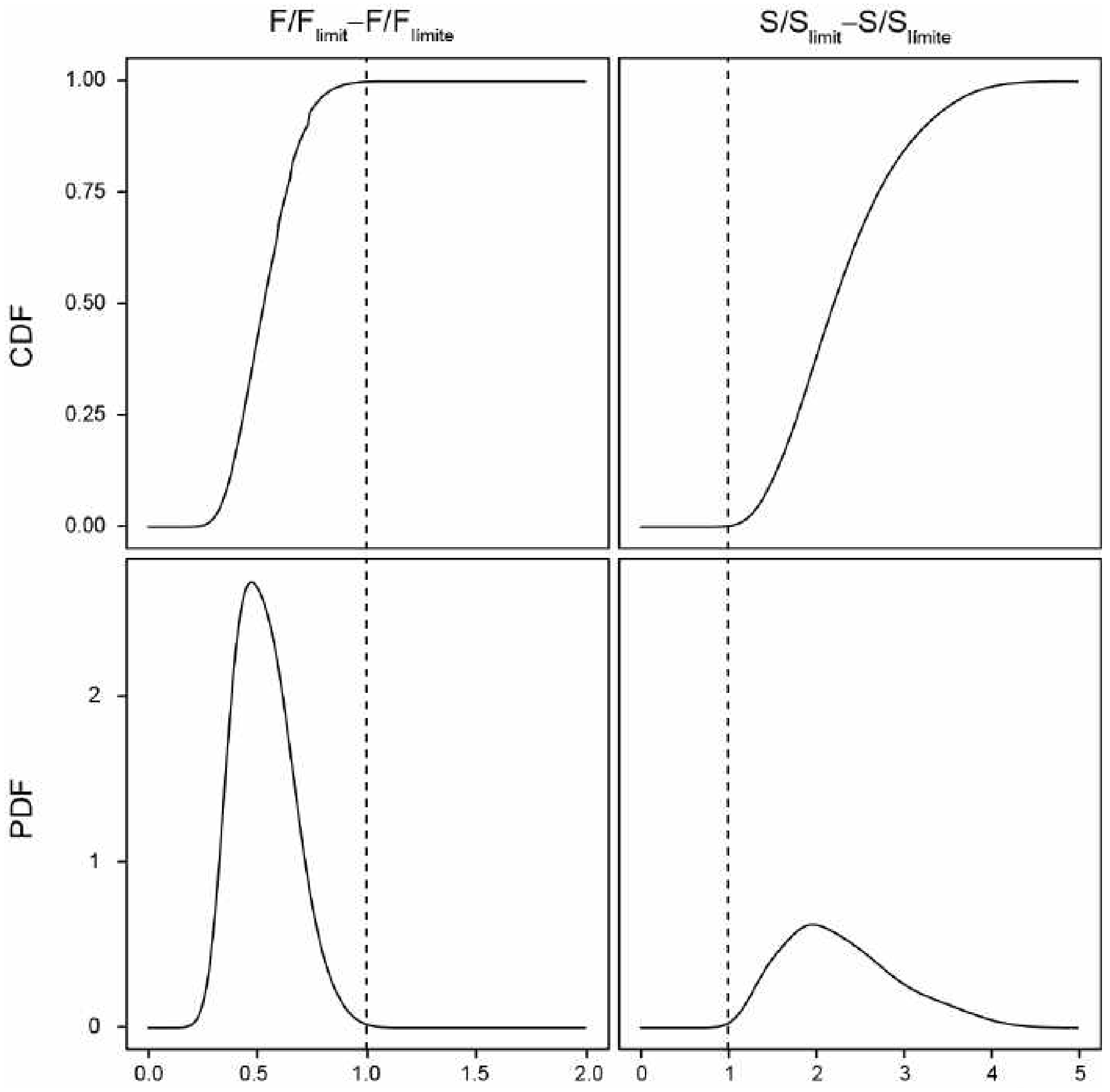
Based on the new reference models in this benchmark assessment, the joint distribution function for $F_{2017-2019}/F_{MSY}$ in the status quo period is unimodal and indicates that there is a 58.5% probability that the fishing mortality in 2017-2019 is higher than F_{MSY}



7. Stock status – limit reference points

The overall results of the risk analysis, based on the thirty-three converged reference models, show unimodal probability distributions for management quantities. The risk analysis indicates:

- 0.2% probability that the spawning biomass at the beginning of 2024 is below the limit reference point (S_{Limit})
- 0.1% probability that the fishing mortality in 2021-2023 is above the limit reference point (F_{Limit})

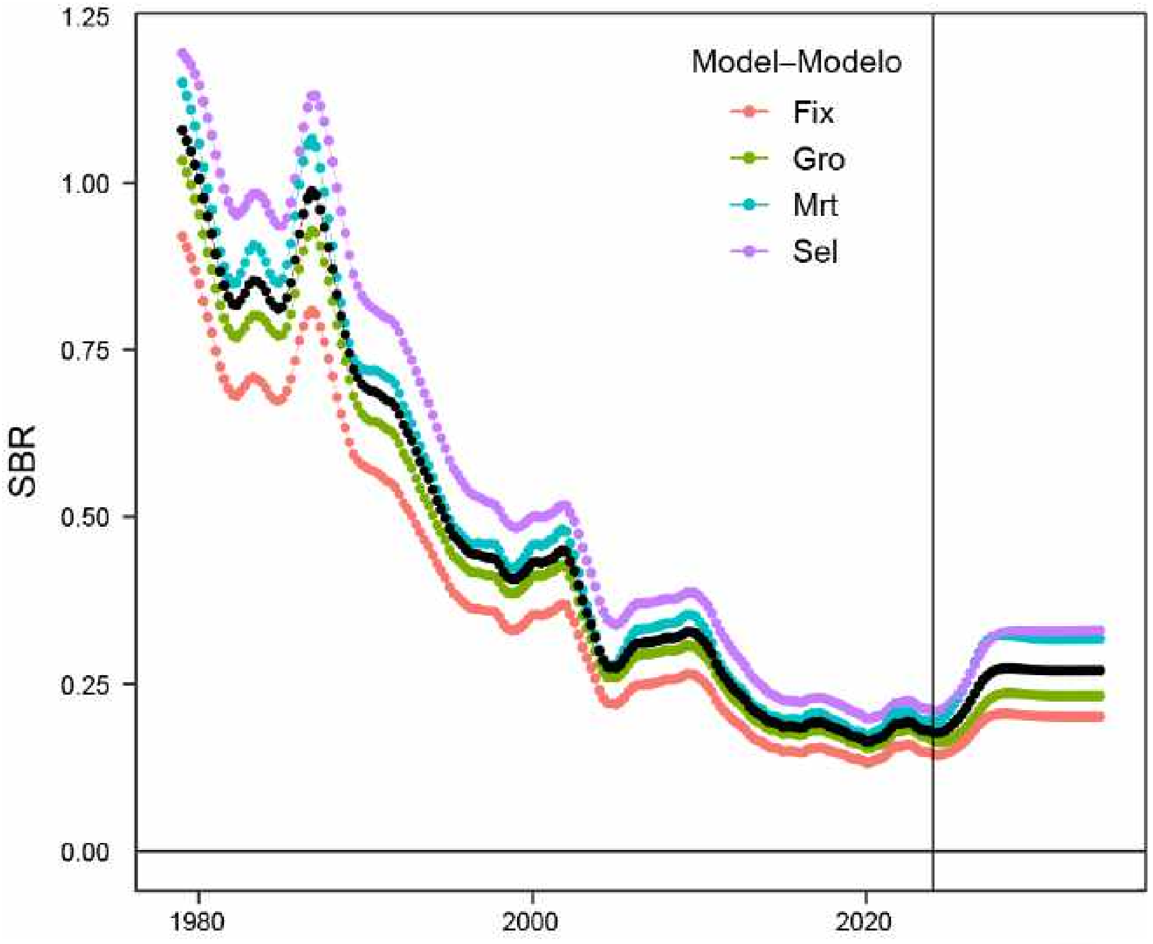


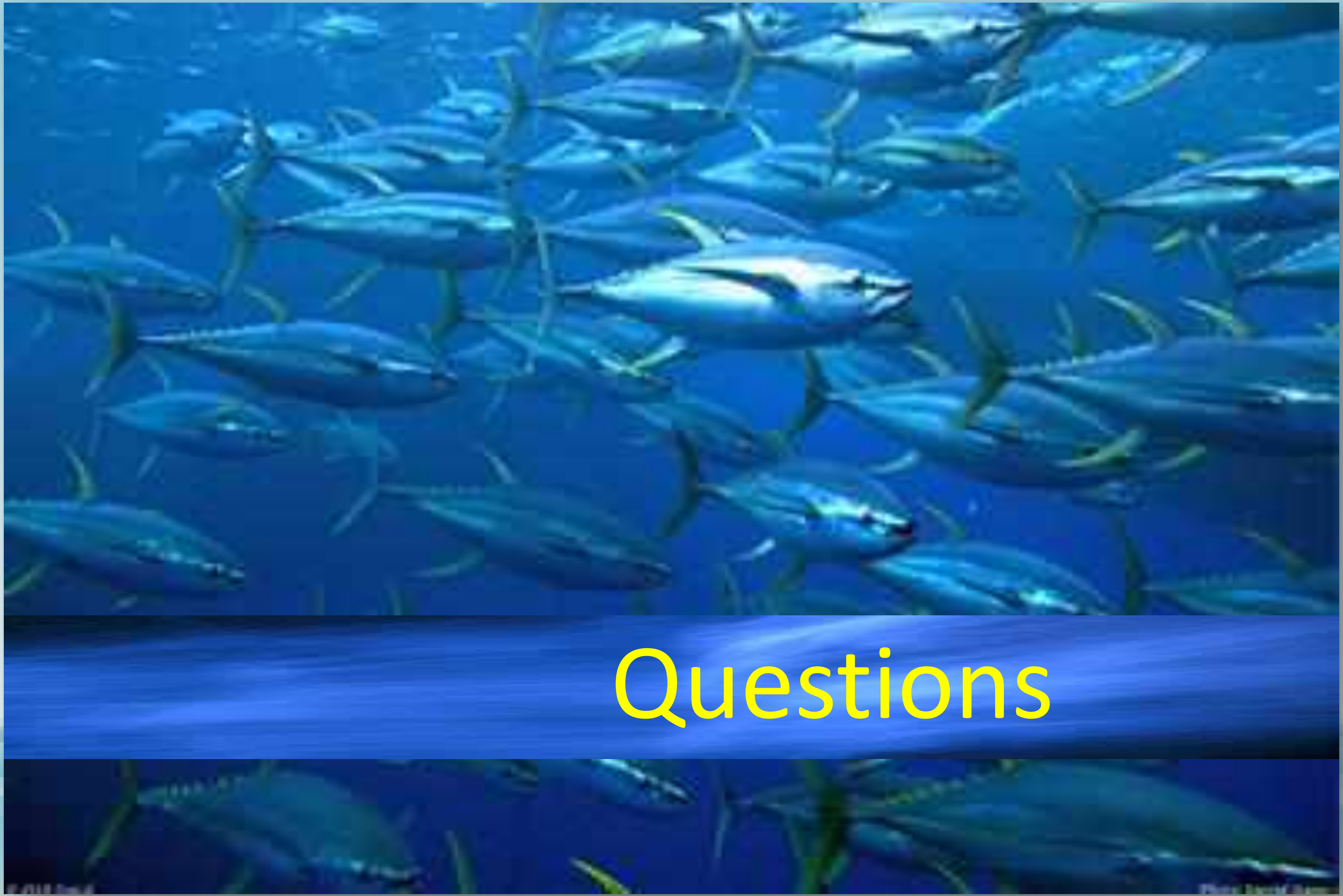
7. Stock status – 10-year projection

There is a 24.7% probability that the fishing mortality in 2021-2023 was above the MSY level, so the spawning biomass is expected to increase to be above the MSY level if future fishing mortality remains at the current level

The 10-year projections under the current fishing mortality:

- Models Fix and Gro: relatively pessimistic (0.20 and 0.23, respectively)
- Models Mrt and Sel: relatively optimistic (0.32 and 0.33, respectively)
- Weighed across all models: there is a 50% probability that the spawning biomass ratio at the beginning of 2034 will be above 0.27.




Questions