Comisión Interamericana del Atún Tropical
Inter-American Tropical Tuna Commission

Exploratory analysis for the stock assessment of bigeye tuna in the eastern Pacific Ocean

Haikun Xu, Mark N. Maunder, Carolina Minte-Vera, and Cleridy Lennert-Cody

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Outline

1. Introduction
2. Improvements made to the assessment model
3. Impact of the improvements on the new “base” model
4. Model diagnostics for the new “base” model
5. Effect of the improvements on assessment results
6. Future directions

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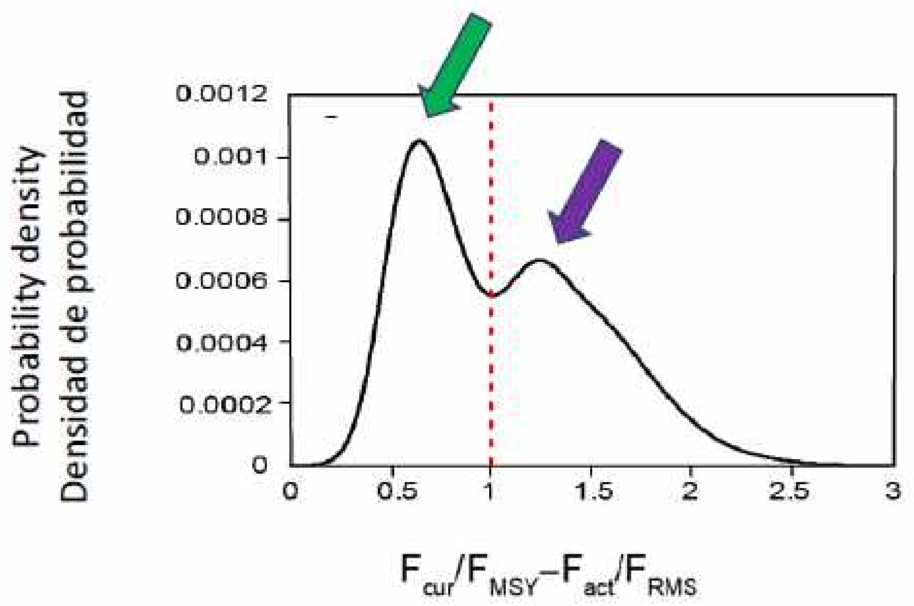
Introduction

- The last benchmark stock assessment for bigeye was conducted in 2020
- A new risk analysis approach was used to evaluate stock status: from using one base-case model to using forty-eight reference models
- The risk analysis for bigeye shows bimodal patterns in management quantities, making it challenging to provide management advice



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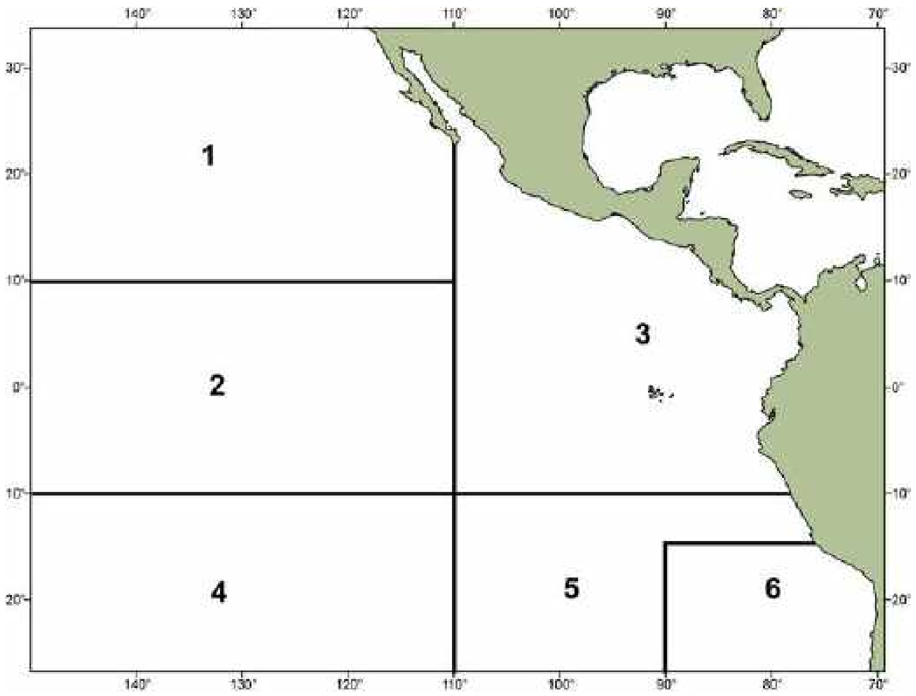
2. Improvements made to the assessment model

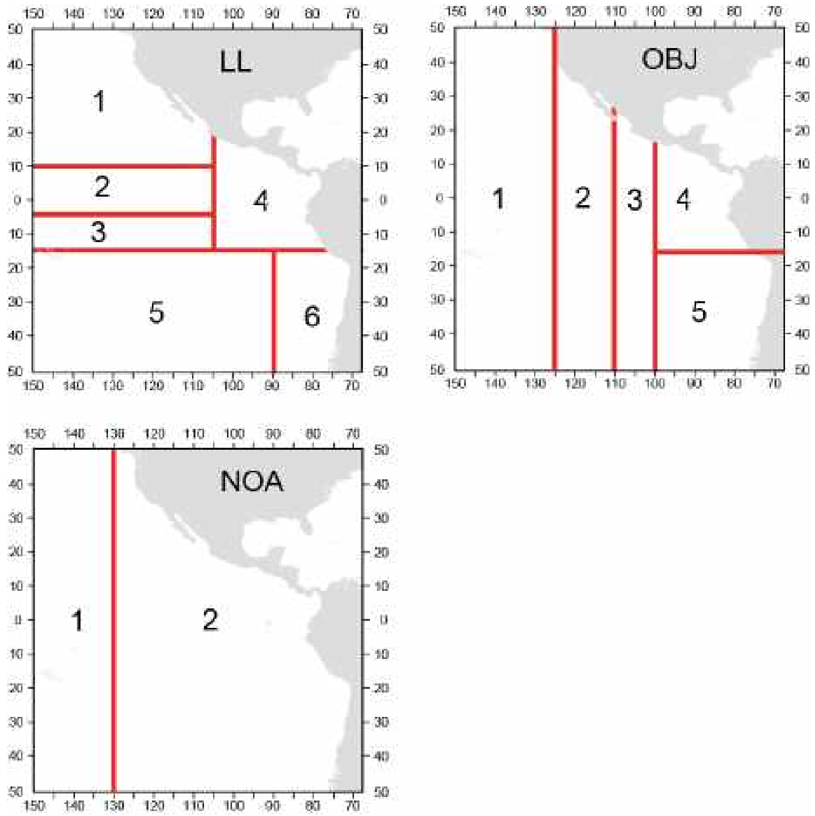
- Six improvements have been made since the last benchmark assessment (SAC11)
- These improvements can be categorized into three groups:
  - Fishery definitions (1)
  - Survey fleet characteristics
    - Definition (2)
    - Standardization methodology (3)
  - Fishery fleet characteristics
    - Source of longline composition data (4)
    - Time blocks for longline selectivity (5)
    - Standardization methodology (6)

Fishery definitions (1)

- SAC11: compromised (longline vs. purse-seine) fishery definitions based on both length compositions and CPUE

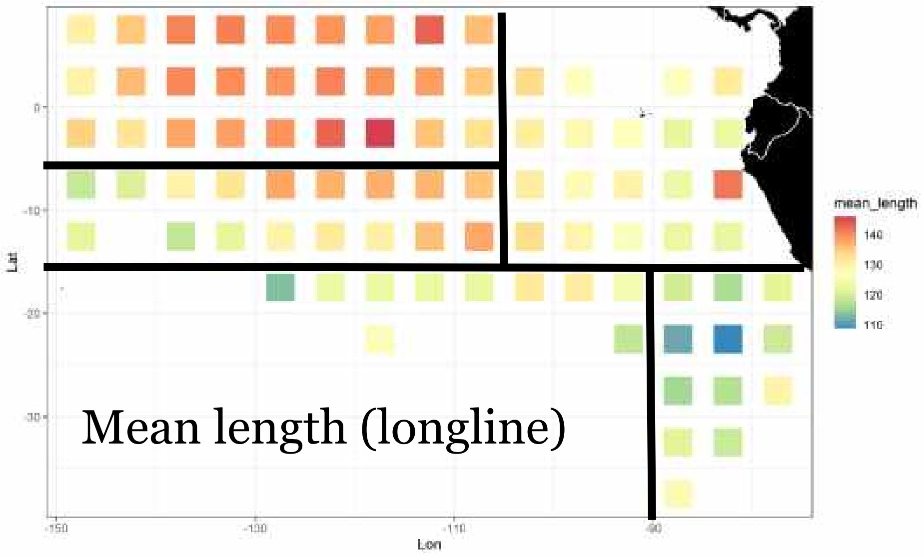


- SAC14: independent gear and set-type specific fishery definitions based solely on length compositions

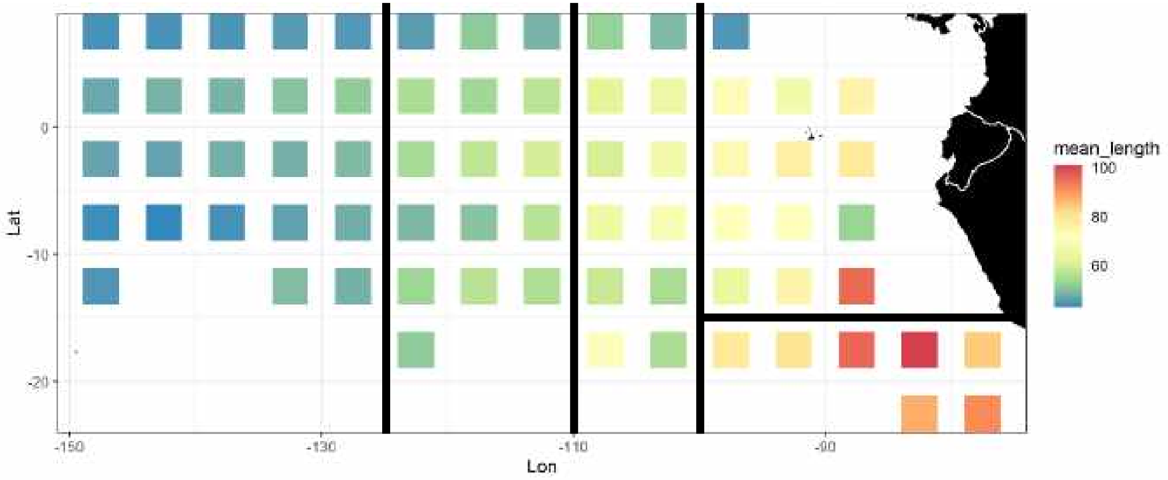


Fishery definitions (1)

- Fisheries are defined by fitting a regression tree algorithm to gear and set-type specific length composition data
- Data can be grouped by latitude, longitude, quarter and cyclic quarter
- Why using independent gear and set-type specific fishery definitions?

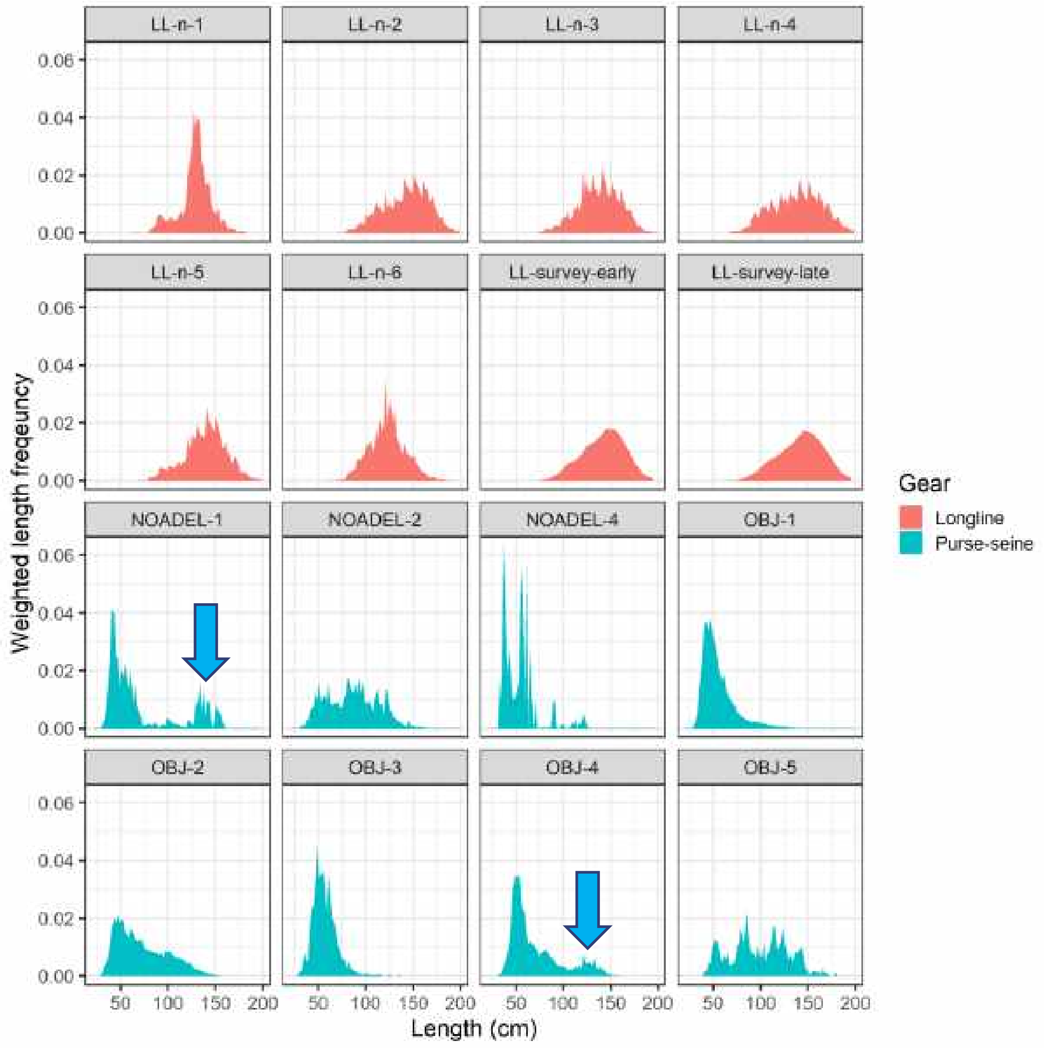


Mean length (floating-object)

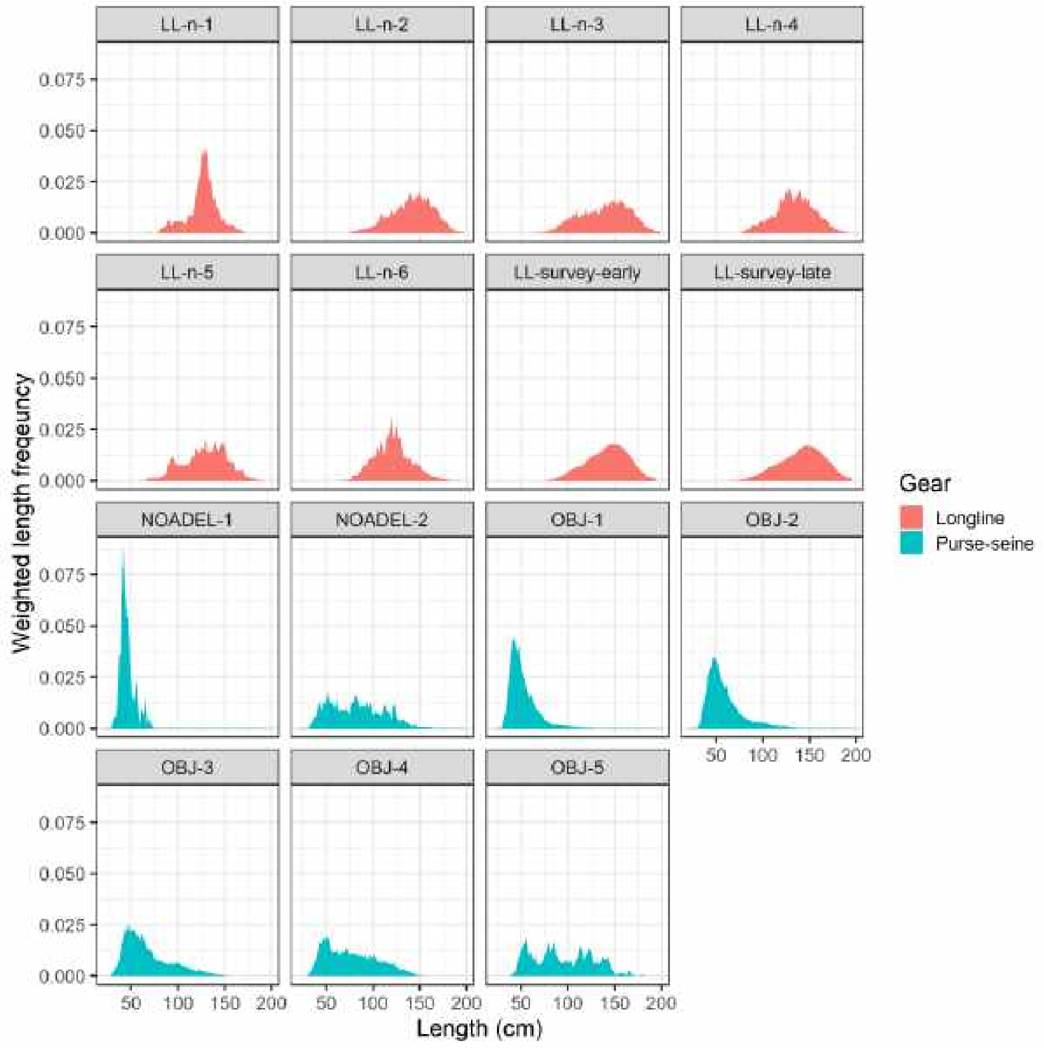


Fishery definitions (1)

SAC11



SAC14



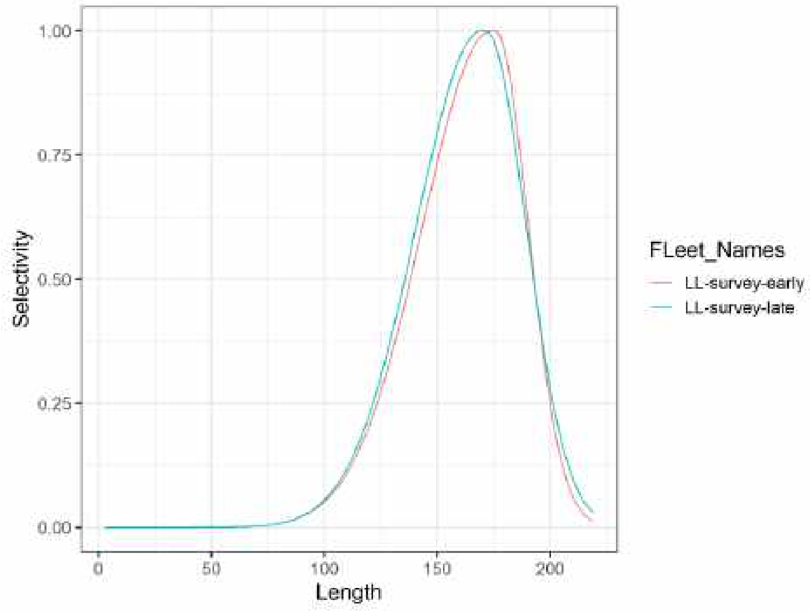
Survey fleet: definition (2)

SAC11

- Two longline survey fleets are defined based on the time of operation: ‘early’ (1979-1992) and ‘late’ (1995-2019)
- Catchability and selectivity are estimated separately for the two survey fleets
- Why splitting the index into two time periods? Gear configurations (hooks-between-floats and mainline material) of Japanese longline vessels changed rapidly in 1993 and 1994.

SAC11 “base” model

- The catchability is slightly higher for the early period (1.58) than for the late period (1.34)
- Similar selectivity curves for the two periods



Survey fleet: definition (2)

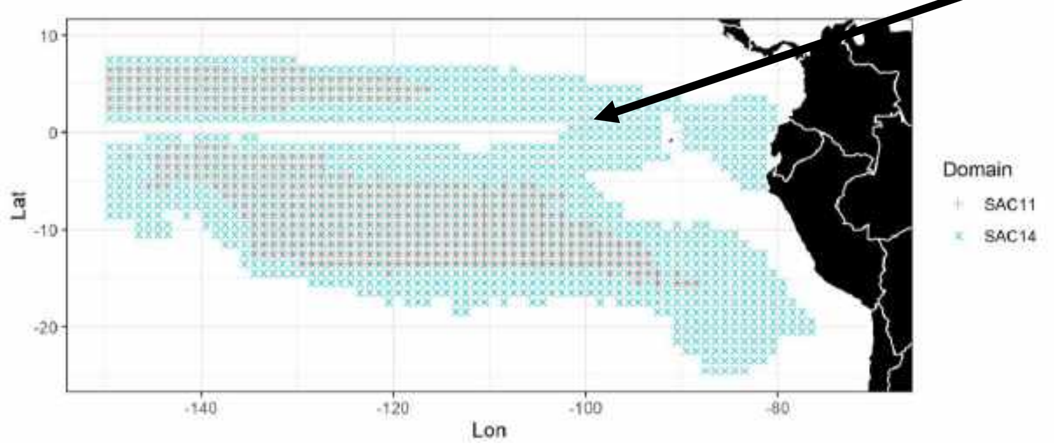
The SAC14 model does not split the survey fleet into two time periods:

- Theoretical reasons
  - Splitting the abundance index by time wastes important information in the CPUE data (e.g., the continuous trend of population abundance over a long period)
  - If the assessment model is misspecified, splitting the abundance index can introduce bias as the model may not be able to scale the split abundance indices reliably
- Practical reasons
  - The assessment model estimates a higher catchability for the early period, which is not likely given that the catchability for the target species tends to increase over time (effort creep)
  - Similar selectivity curves are estimated for the survey fleets in the early and late periods

Survey fleet: standardization methodology (3)

1. Spatial domain

- SAC11 spatial domain: cells with at least 80 quarters of JPN CPUE data between 1979-2019
- The SAC11 spatial domain does not cover the eastern EPO where bigeye depletes faster, so the abundance index is likely hyper-stable
- SAC14 spatial domain: cells with at least 20 quarters of JPN CPUE data between 1979-2019



The expanded new spatial domain results in an increased influence of imputed fish density (for unfished locations) on the index of abundance, so the imputation method in the spatiotemporal model needs to be properly specified

Survey fleet: standardization methodology (3)

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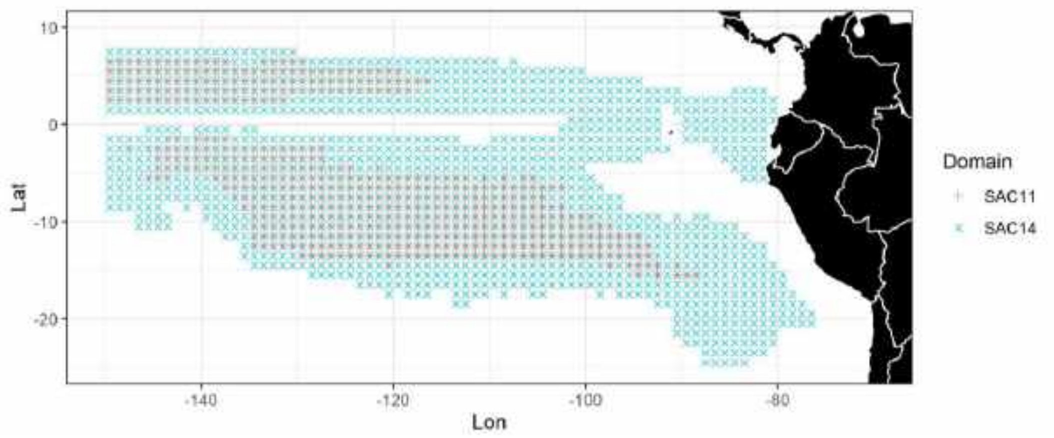


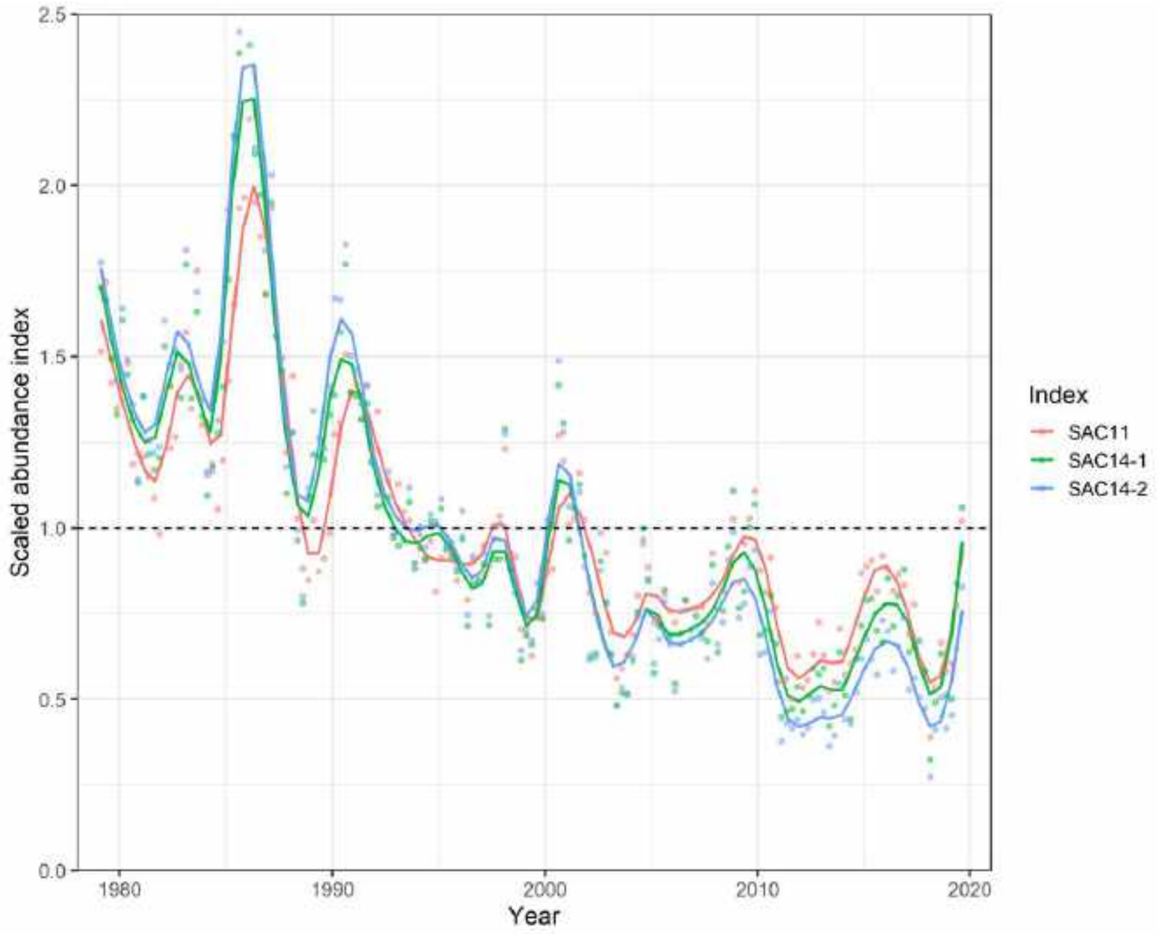
2. Spatiotemporal (ST) model

- The ST model has five terms: year-quarter, spatial, ST, catchability (HBF), and vessel effects terms, of which the spatial heterogeneity of depletion rate is described by the ST term
- ST model (SAC11) assumes that the ST term is correlated only in space: the ST term for the unfished eastern EPO is over-imputed because the imputation ignore preferential sampling
- ST model (SAC14) assumes that the ST term is correlated in both space and time: the imputation for the unfished eastern EPO is heavily influenced by CPUE data from the same area in adjacent years

Survey fleet: standardization methodology (3)

Comparing three standardized longline indices of abundance for bigeye tuna in the EPO:

- The index from the SAC11 ST model
- The index from the SAC11 ST model with the SAC14 spatial domain (SAC14-1)
- The index from the SAC14 ST model with the SAC14 spatial domain (SAC14-2)



As expected, the index used in SAC14 shows a faster decreasing rate of population abundance than the index used in SAC11

Survey fleet: standardization methodology (3)

The methodology for standardizing survey length compositions is also improved:

- The spatial domain is expanded to be consistent with the abundance index
- The standardization model for survey length composition is modified:
  - The ST model (SAC11) is fit to length-specific CPUE data, which is obtained by matching CPUE data with length frequency data
  - On average less than 15% of CPUE data have associated length frequency data: the data matching results in more than 85% of CPUE data being wasted
  - The ST model (SAC14) is fit only to length frequency data: the standardized length frequencies are then raised to standardized fish abundance from the CPUE standardization model
  - The new approach to computing standardized survey length frequencies is based on all rather than <15% of CPUE data

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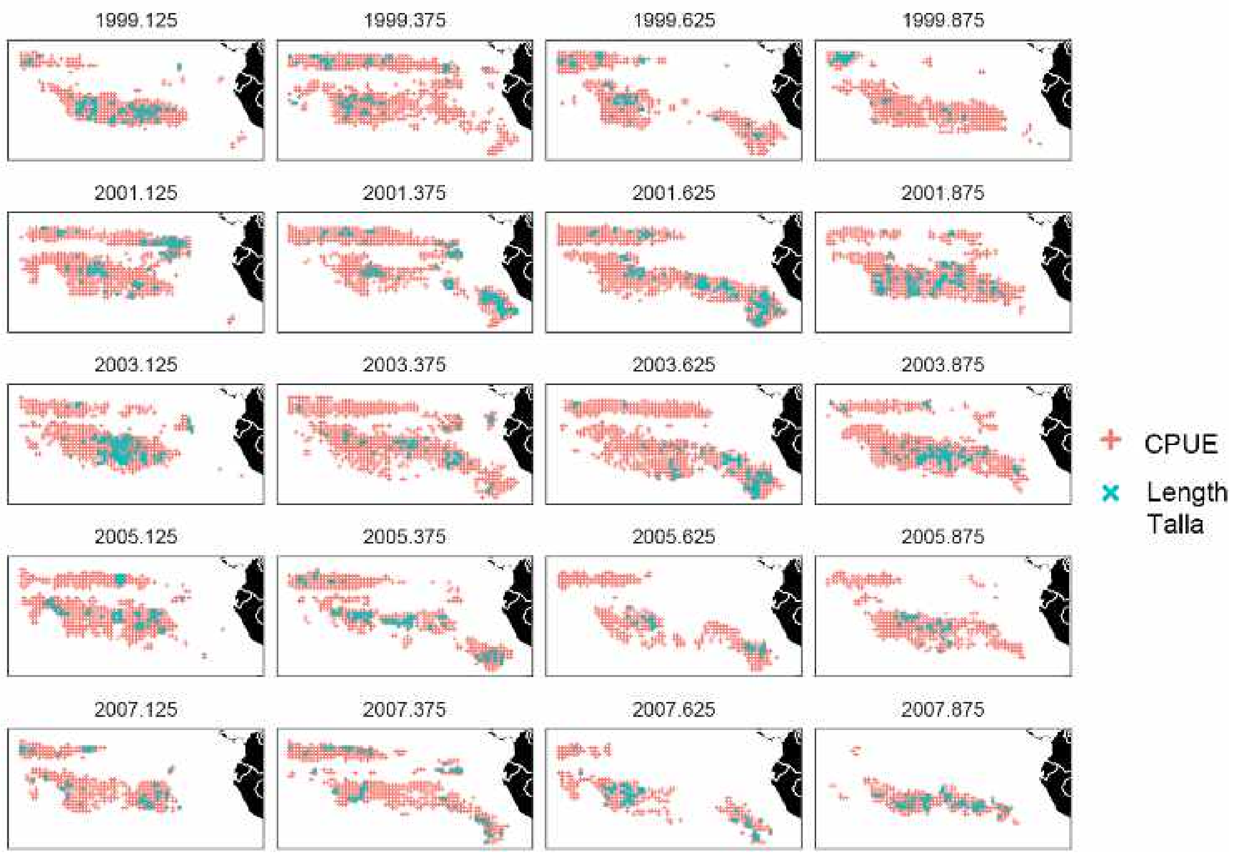
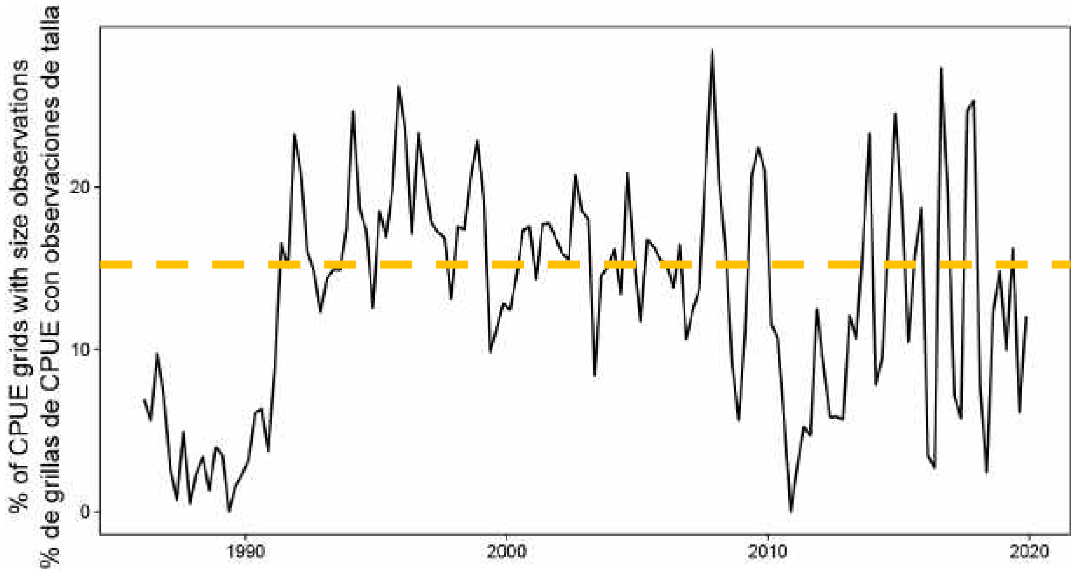
Survey fleet: standardization methodology (3)

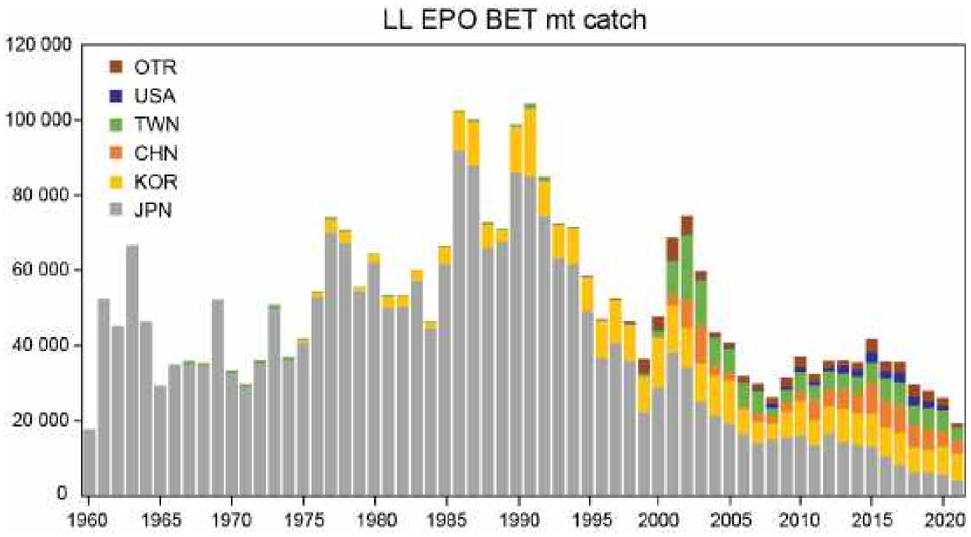
Longline length composition data can be very sparse



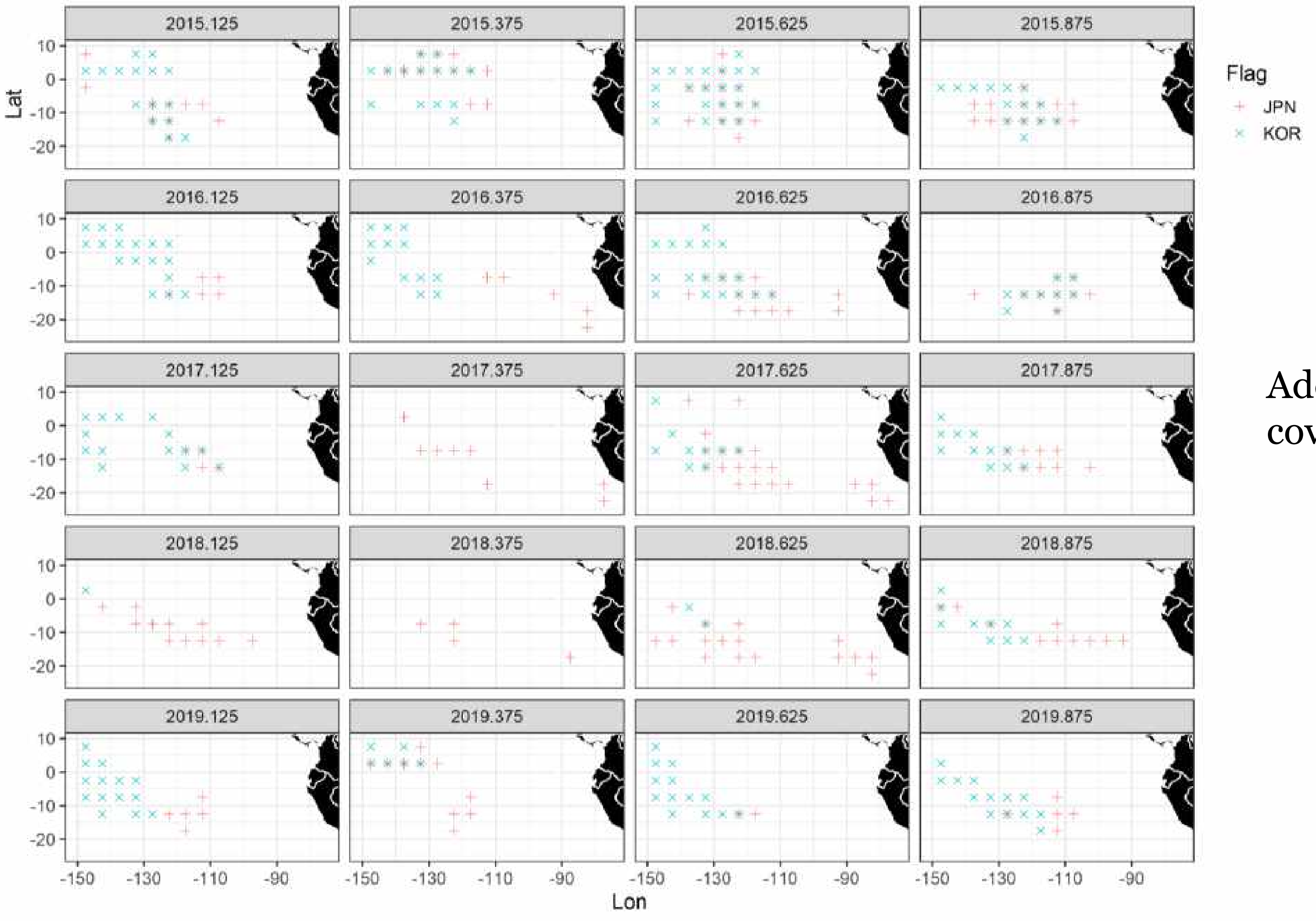


Fishery fleet: source of longline composition data (4)

- SAC11: longline composition data are solely from Japan
- Concerns have been raised about the representativeness of Japanese data in the 2010s
    - The ratio of Japanese catch to total longline catch has decreased from around 100% before 1985 to less than 25% since 2017
    - The spatial coverage and sample size of Japanese longline composition data have decreased notably in the 2010s
- SAC14: longline composition data are from Japan and Korea

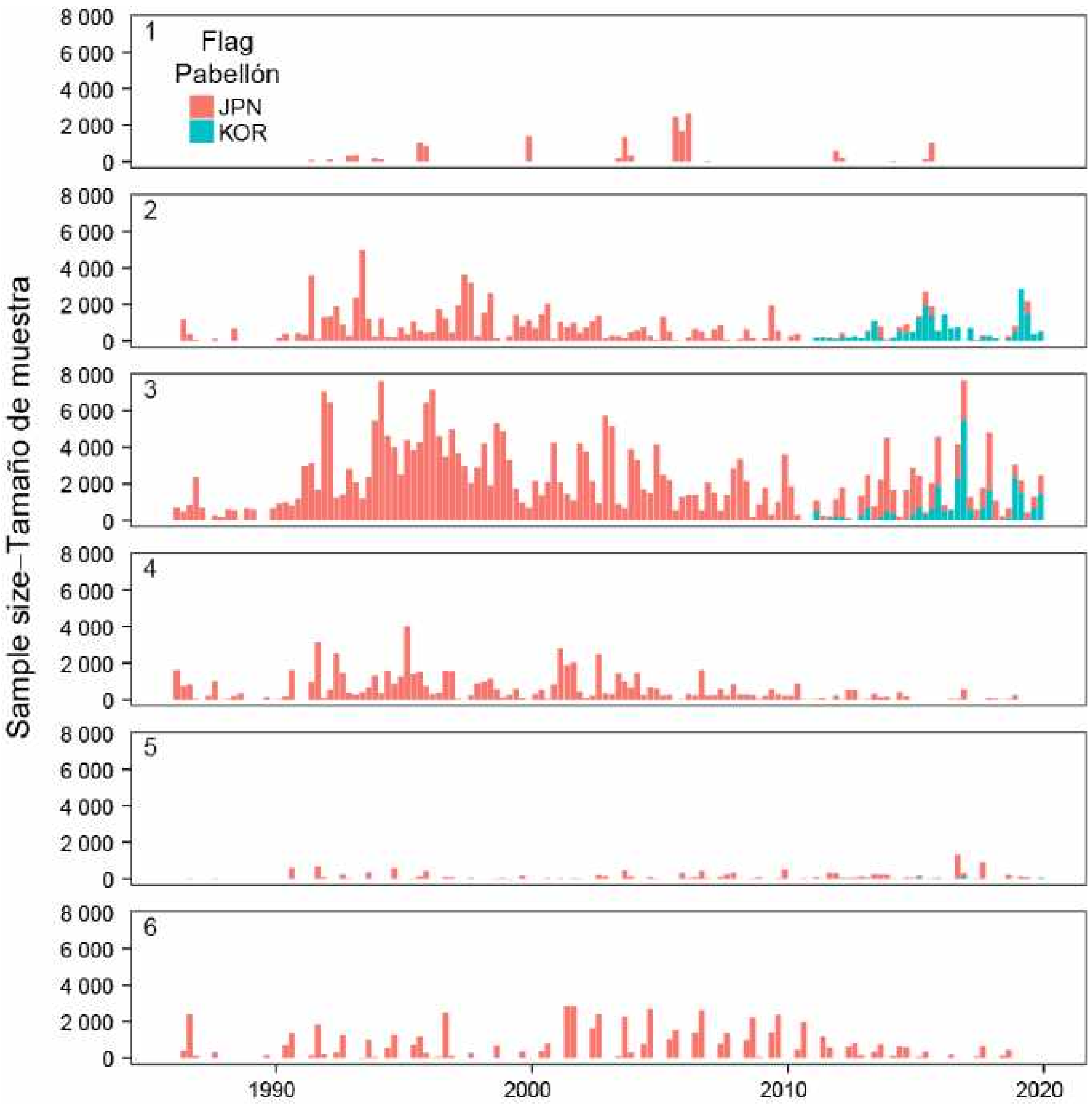


Fishery fleet: source of longline composition data (4)



Adding Korean data expands the spatial coverage of longline composition data

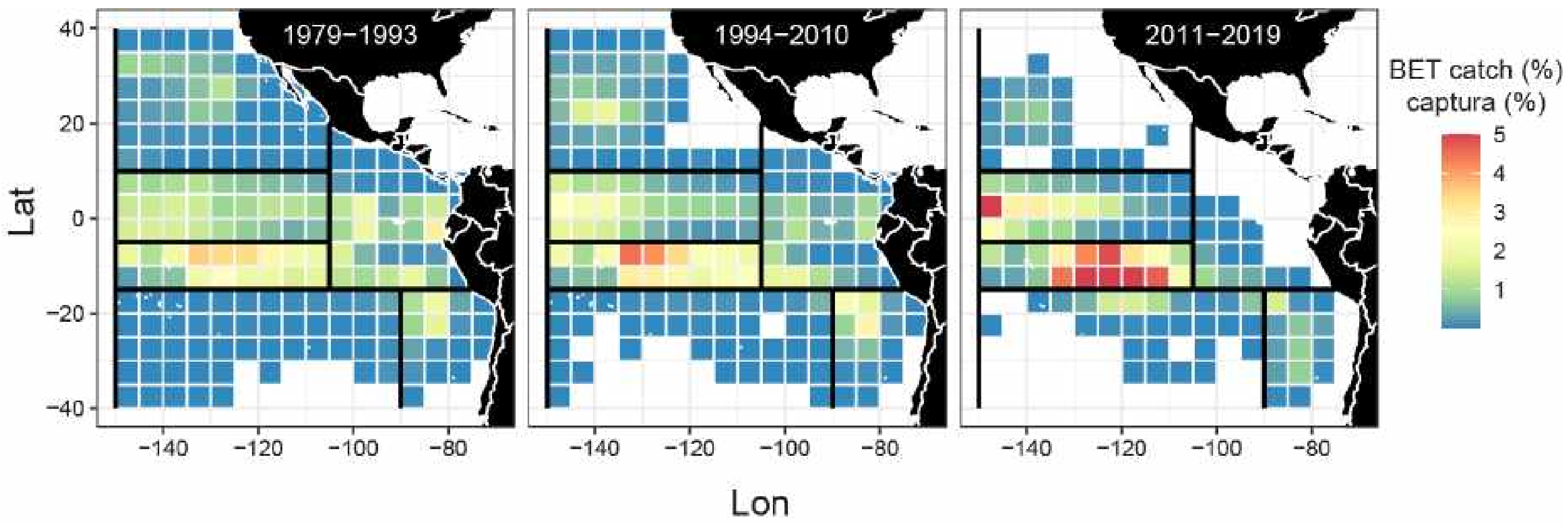
Fishery fleet: source of longline composition data (4)



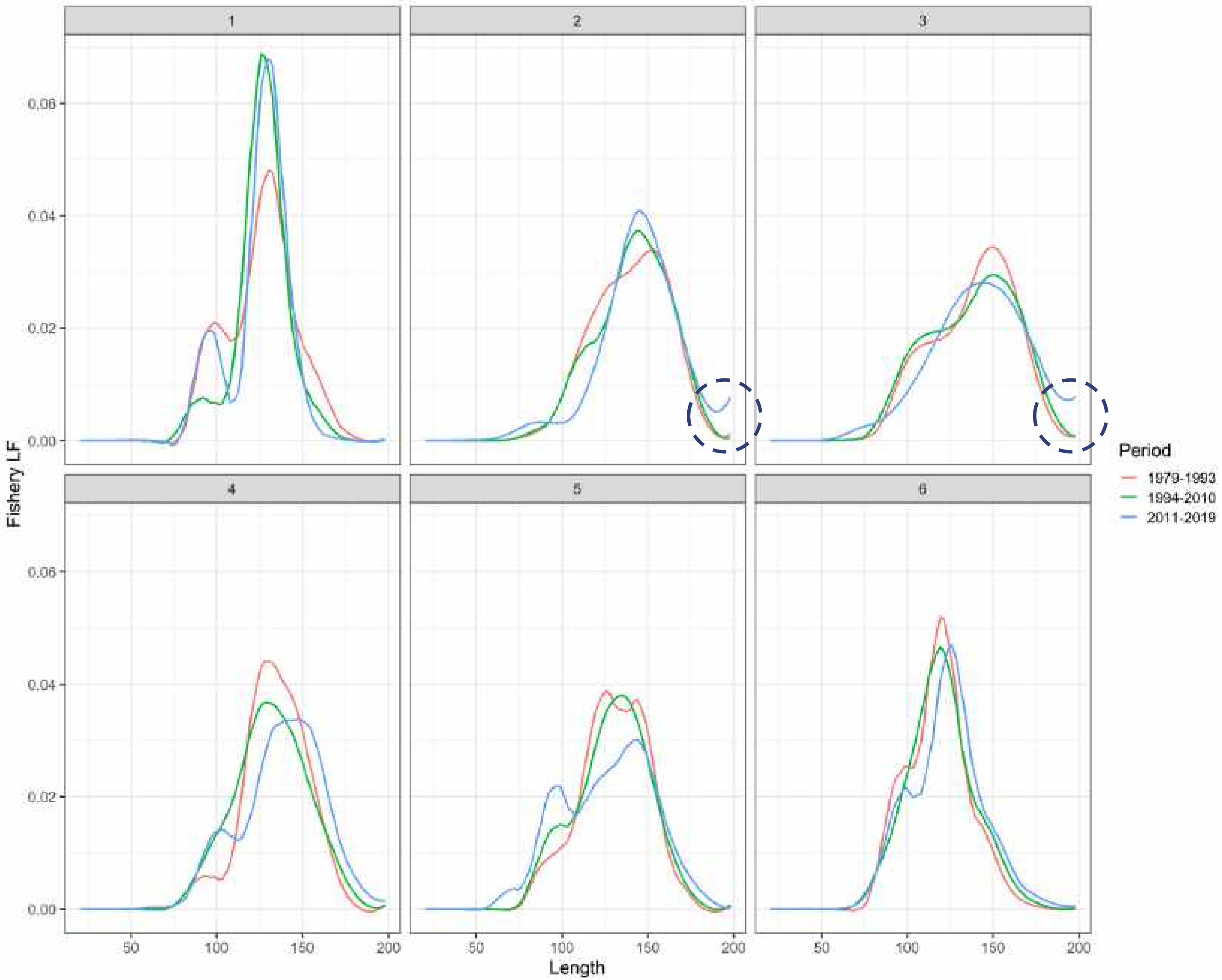
Adding Korean data also increases the sample size of length compositions for the two most important longline fleets (2 and 3)

Fishery fleet: selectivity time-blocks for LL fisheries (5)

- SAC11: two blocks (1979-1993 and 1994-2019; gear configurations of Japanese longline vessels changed rapidly in 1993 and 1994)
- SAC14: three blocks (1979-1993, 1994-2010, and 2011-2019)
  - Korean longline length composition data is available since 2011
  - The contribution of longline catch by CPC has changed notably since 2011 (% contribution of Japanese and Korean longline catch have decreased and increased, respectively)
  - The spatial distribution of longline catch has shifted sharply since 2011



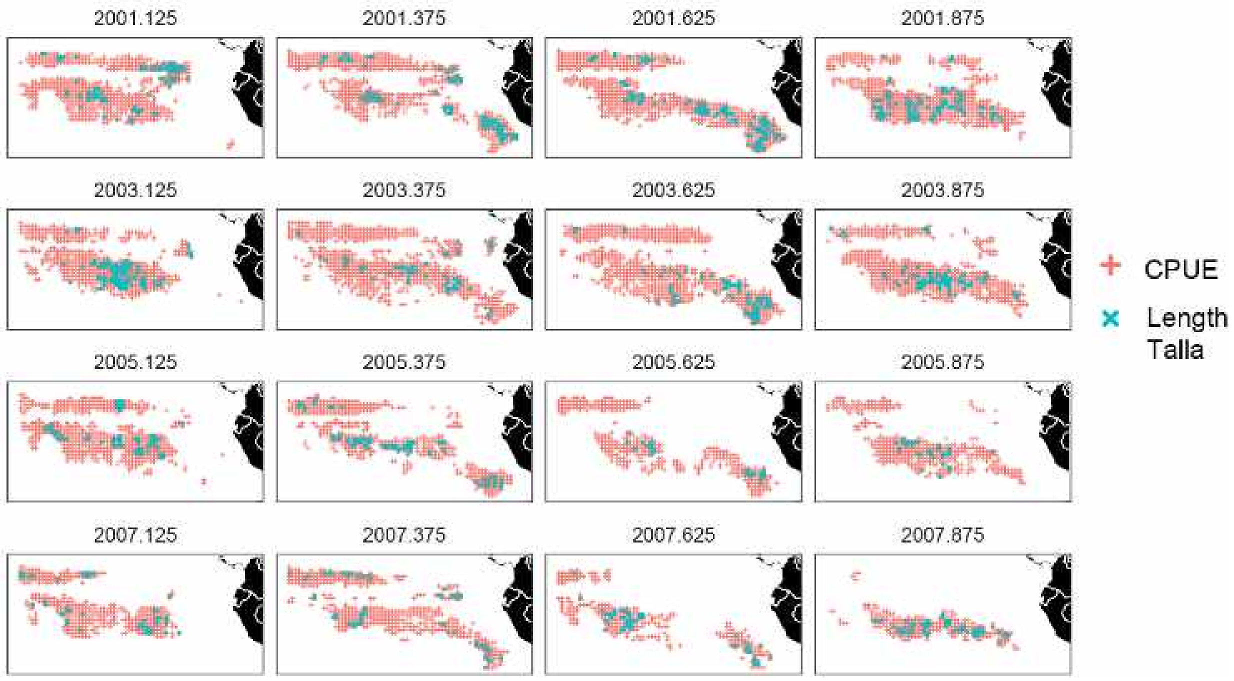
Fishery fleet: selectivity time-blocks for LL fisheries (5)



The aggregated fishery length frequencies since 2011 are pronouncedly different from those before 2011 for the two most important longline fisheries (2 and 3), further supporting the addition of another split in 2011.

Fishery fleet: methodology of computing LL length frequencies (6)

- SAC11: length composition data for longline fishery fleets are computed by spatially raising raw length compositions to catch amount
- Limitation of this methodology: length compositions may not adequately represent fishery removal as less than (on average) 15% of the grids with positive Japanese catch have associated length compositions



Fishery fleet: methodology of computing LL length frequencies (6)

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- Limitation of this methodology: length compositions may not adequately represent fishery removal as less than (on average) 15% of the grids with positive Japanese catch have associated length compositions
- SAC14: develop a ST model to impute length frequencies for the strata with positive catch but no length frequencies
- In this way, length frequencies for longline fishery fleets can be raised to total catch and are therefore more representative

2. Improvements made to the assessment model

- Six improvements have been made since the last benchmark assessment (SAC11)
- These improvements can be categorized into three groups:
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3. Impact of the improvements on the new "base" model

- The "base" reference model (Env-Fix) from SAC11 is the platform to illustrate the impacts of the six improvements on model results
- Impact of each improvement can be evaluated separately: the six improvements are made progressively in a stepwise manner
- A total of seven models, including the chosen SAC11 reference model (M0) and six stepwise models (M1-M6), are compared in this section

Model	Component	Description
M0		SAC11 model (Env-Fix)
M1	Fishery definition	New fishery definitions and remove poorly-sampled LF
M2	Survey fleet	Remove the time block in the abundance index and associated length composition data
M3		New abundance index and the associated LF
M4	Fishery fleets	Add Korean LL LF (since 2011) to LL fisheries' LF
M5		Add a time block in 2010 to LL selectivity
M6		Standardized longline LF

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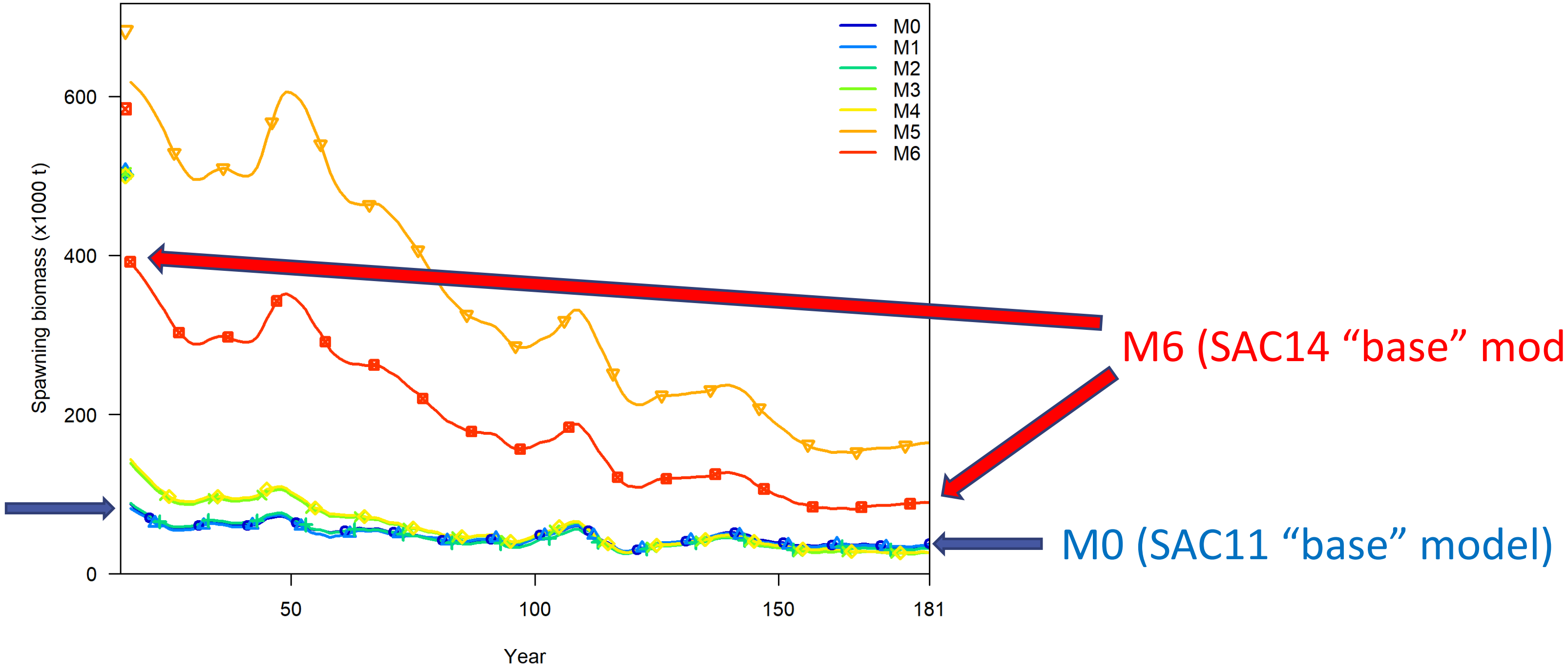
3. Impact of the improvements on the new "base" model



Model	Component	Description
M0		SAC11 model (Env-Fix)
M1	Fishery definition	New fishery definitions and remove poorly-sampled LF
M2	Survey fleet	Remove the time block in the abundance index and associated length composition data
M3		**New abundance index and the associated LF**
M4	Fishery fleets	Add Korean LL LF (since 2011) to LL fisheries' LF
M5		**Add a time block in 2010 to LL selectivity**
M6		**Standardized LL Fisheries' LF**

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4. Model diagnostics for the new "base" model

- Empirical selectivity
- R_0 likelihood profile
- Retrospective analysis
- Age-structured production model

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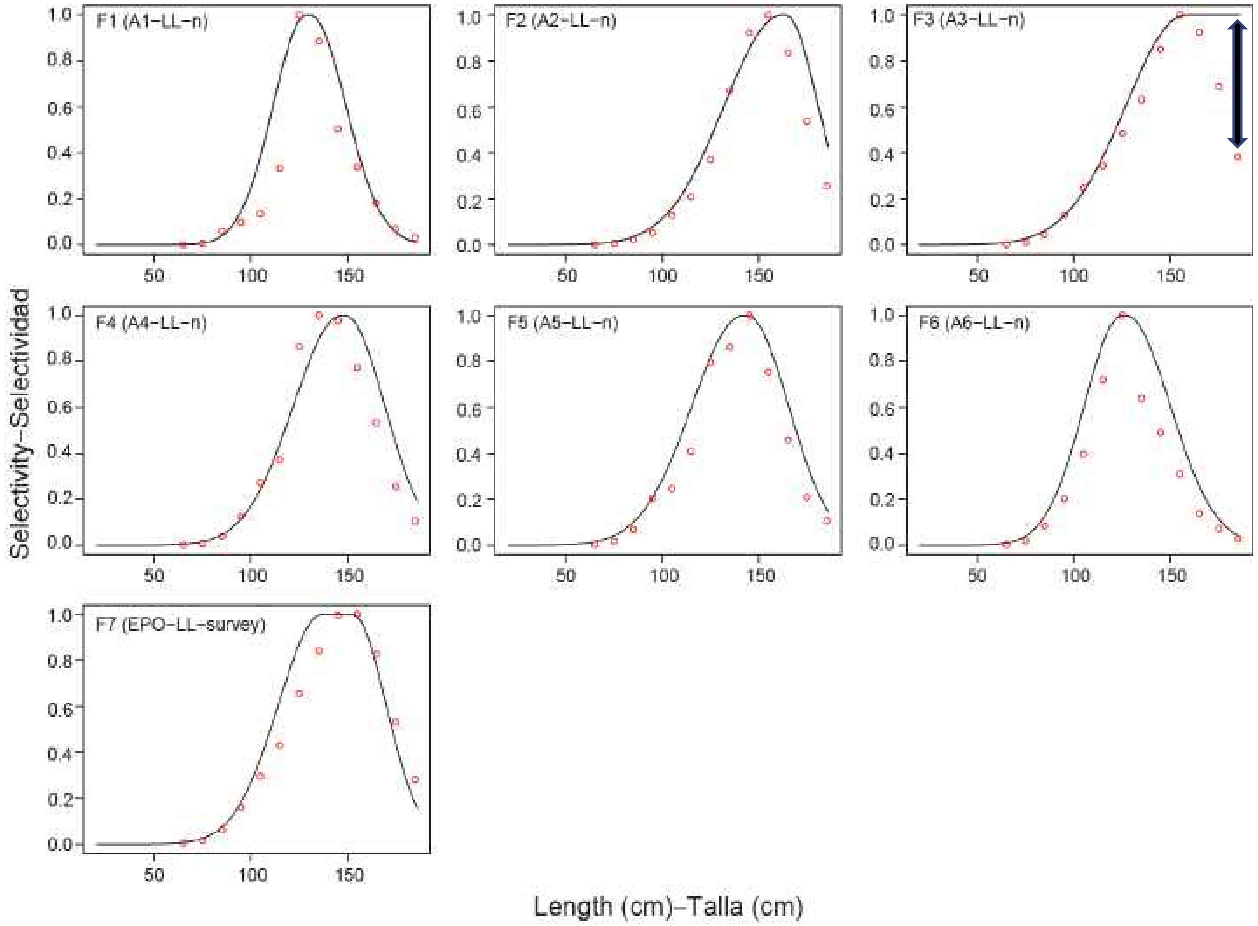
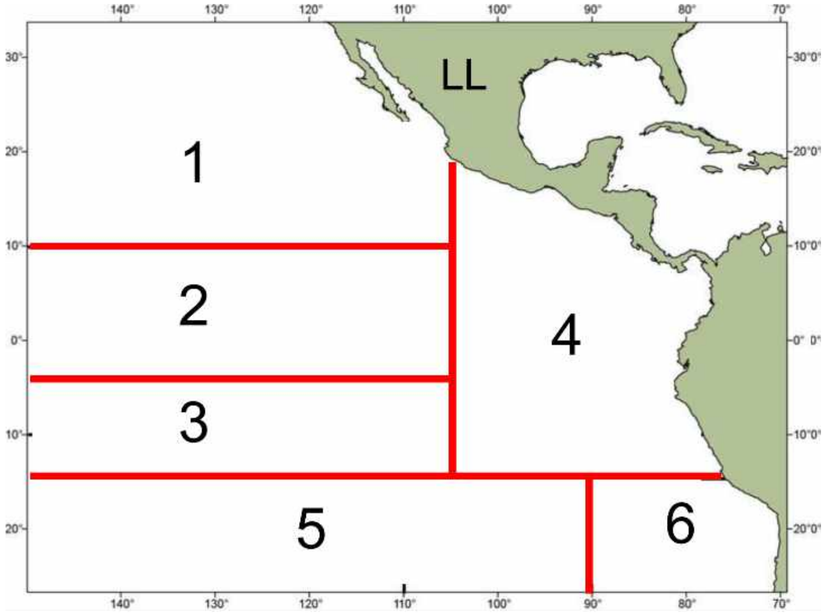
Empirical selectivity

Longline selectivity for 2011-2019



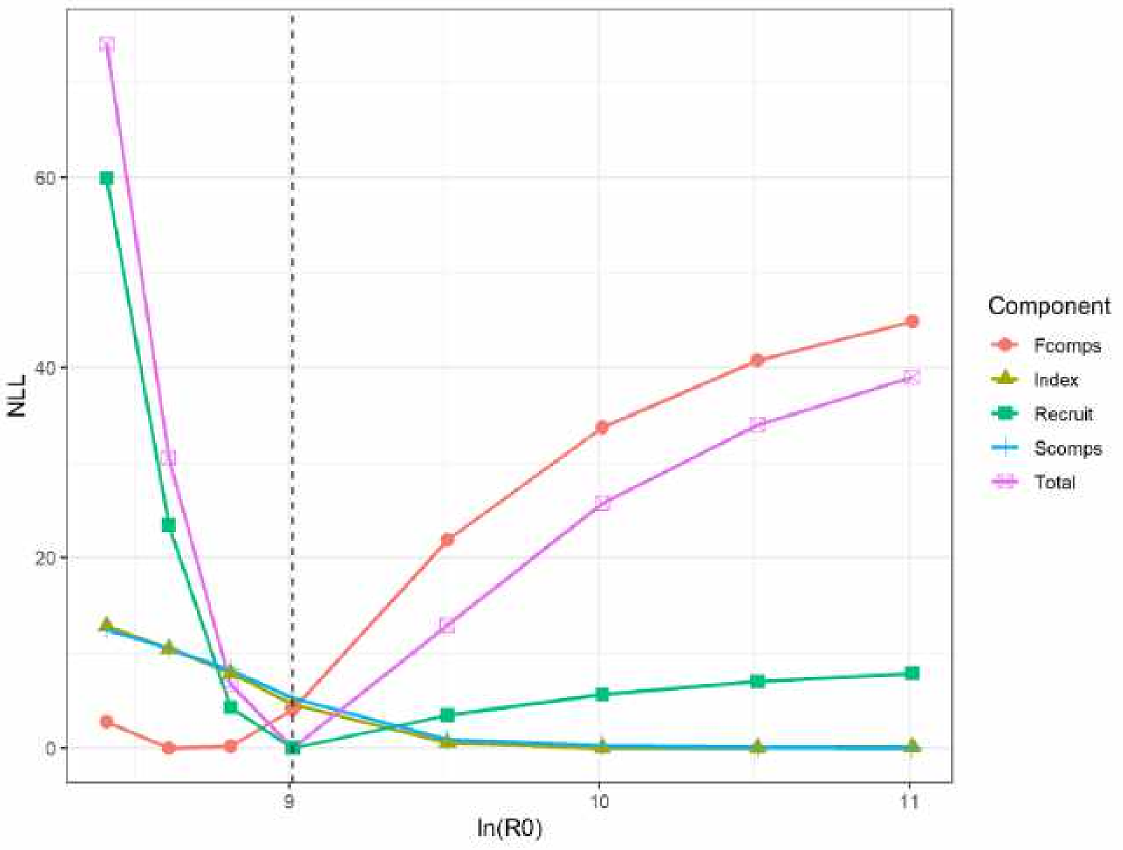


R_0 likelihood profile

Conflicting information from fishery and survey fleet about the scale of population abundance:

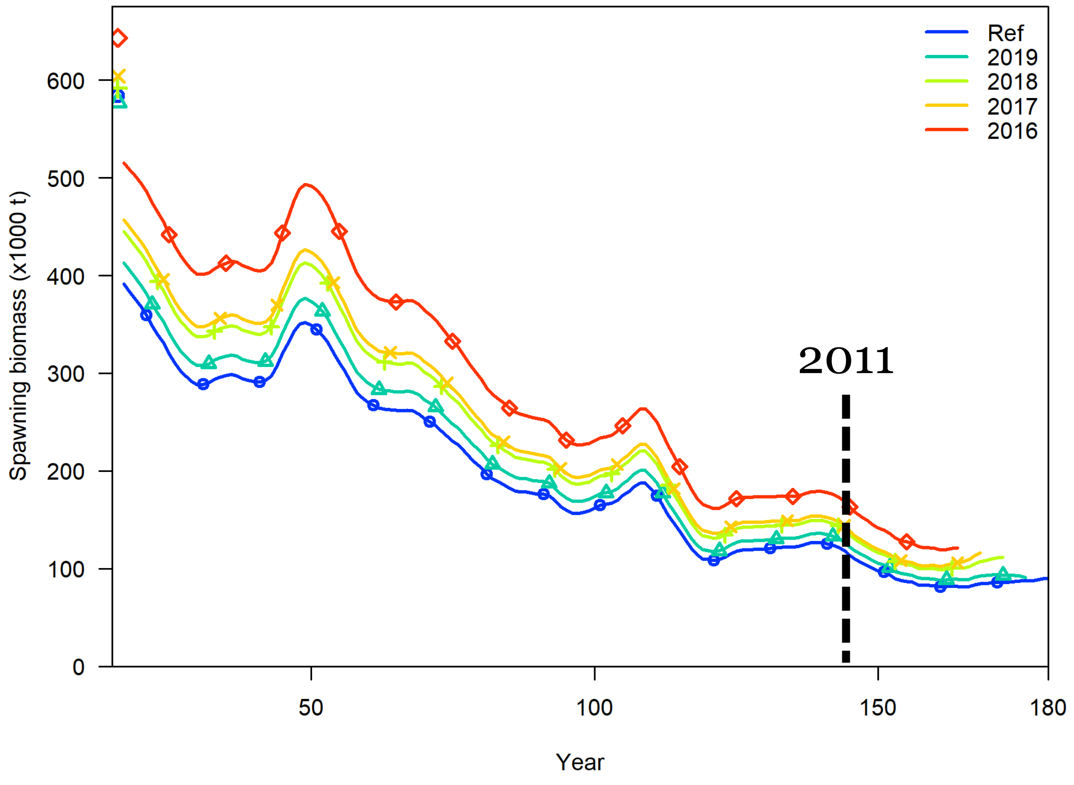
- Survey abundance index and length compositions indicate a higher absolute abundance than the MLE, but they don't include information regarding how high the absolute abundance should be
- Fishery length compositions indicate a slightly lower absolute abundance than the MLE
- The recruitment penalty strongly penalizes an estimate of absolute abundance lower than the MLE.

MLE (maximum likelihood estimate)



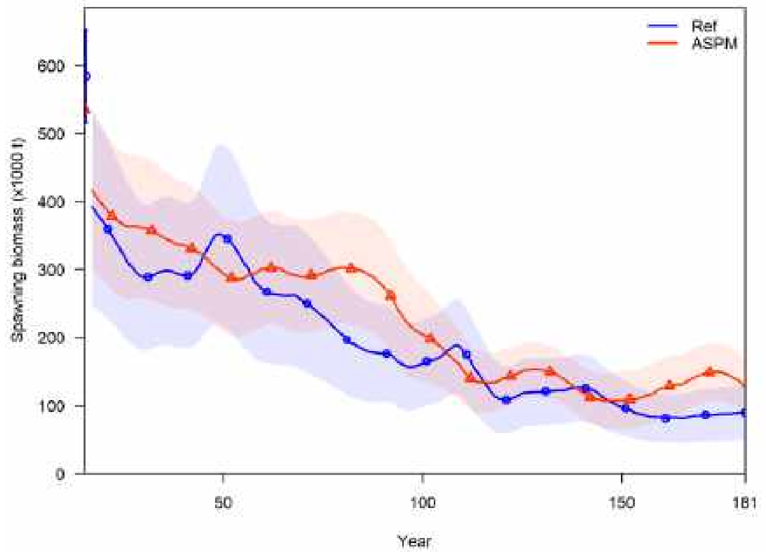
Retrospective analysis

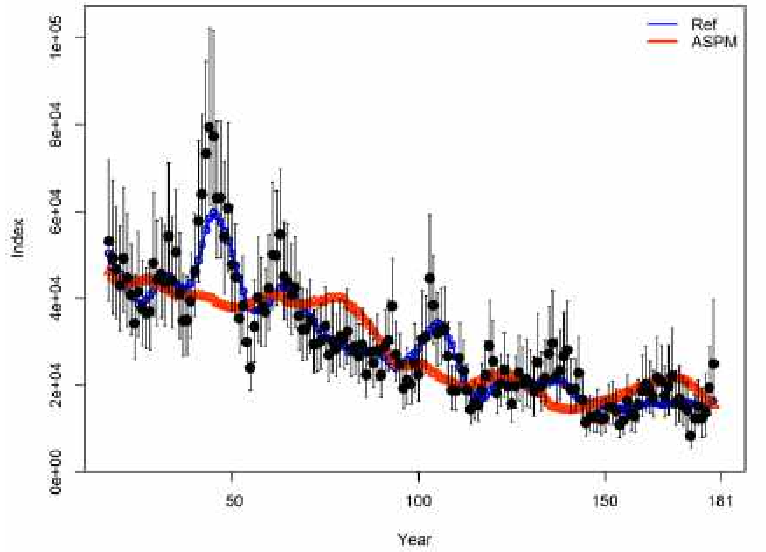
- The notable retrospective pattern suggests the new “base” model is likely mis-specified.
- The main reason is likely the discrepancy between the assumed (asymptotic) and empirical (dome-shaped) selectivity for the third longline fishery since 2011.
- The assessment model interprets this discrepancy as the stock being more depleted (the composition data for that fishery since 2011 tends to lower the scale of estimated spawning biomass)
- The number of years with an assumed asymptotic selectivity is small, leading to the estimates of spawning biomass being sensitive to the inclusion of new data.



Age-structured production model

- The new “base” model and the ASPM without recruitment deviates have similar estimates of spawning biomass
- The index of abundance predicted by the ASPM follows closely with the observed index
- The new “base” model can adequately simulate the decreasing trend in population abundance in response to increased fishing mortality.
- This diagnostics suggests that the new “base” model has a production function and can reliably estimate the scale of population abundance.





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5. Effect of the improvements on assessment results

1. Effects on model-specific results: the six improvements are applied to the twelve reference models (h=1) included in the last benchmark assessment
   - Recruitment shift
   - Spawning biomass ratio (depletion)

2. Effects on model-combined results: whether the six improvements can reduce the bimodality in model-combined joint distribution of model estimates?

Model-specific effects

The recruitment shift statistic for the new reference models to which the statistic is applicable

	Recruitment shift is real				Recruitment shift is not real			
	Env-Fix	Env-Gro	Env-Mrt	Env-Sel	Gro	Mov	Mrt	Sel
SAC11	2.4	1.5	1.8	1.6	1.2	1.3	1.4	1.3

SAC11 reference models

Model name	Description
Env-Fix	Environment, Fixed
Env-Gro	Environment, Estimate growth
Env-Sel	Environment, Dome selectivity
Env-Mrt	Environment, Adult mortality
Srt-Fix	Short-term, Fixed
Srt-Gro	Short-term, Estimate growth
Srt-Sel	Short-term, Dome selectivity
Srt-Mrt	Short-term, Adult mortality
Mov	Pre-adult movement
Gro	Estimate growth
Sel	Dome selectivity
Mrt	Adult mortality

Model-specific effects

The recruitment shift statistic for the new reference models to which the statistic is applicable

	Recruitment shift is real				Recruitment shift is not real			
	Env-Fix	Env-Gro	Env-Mrt	Env-Sel	Gro	Mov	Mrt	Sel
SAC11	2.4	1.5	1.8	1.6	1.2	1.3	1.4	1.3
SAC14	1.5	1.0	1.1	1.1	1.0	1.2	1.1	1.1

- Three of the four reference models in which the recruitment shift is assumed to be real estimate a recruitment shift of less than 10%.
- This result contradicts the assumption of a recruitment shift, so they are removed from the list of reference models for SAC14

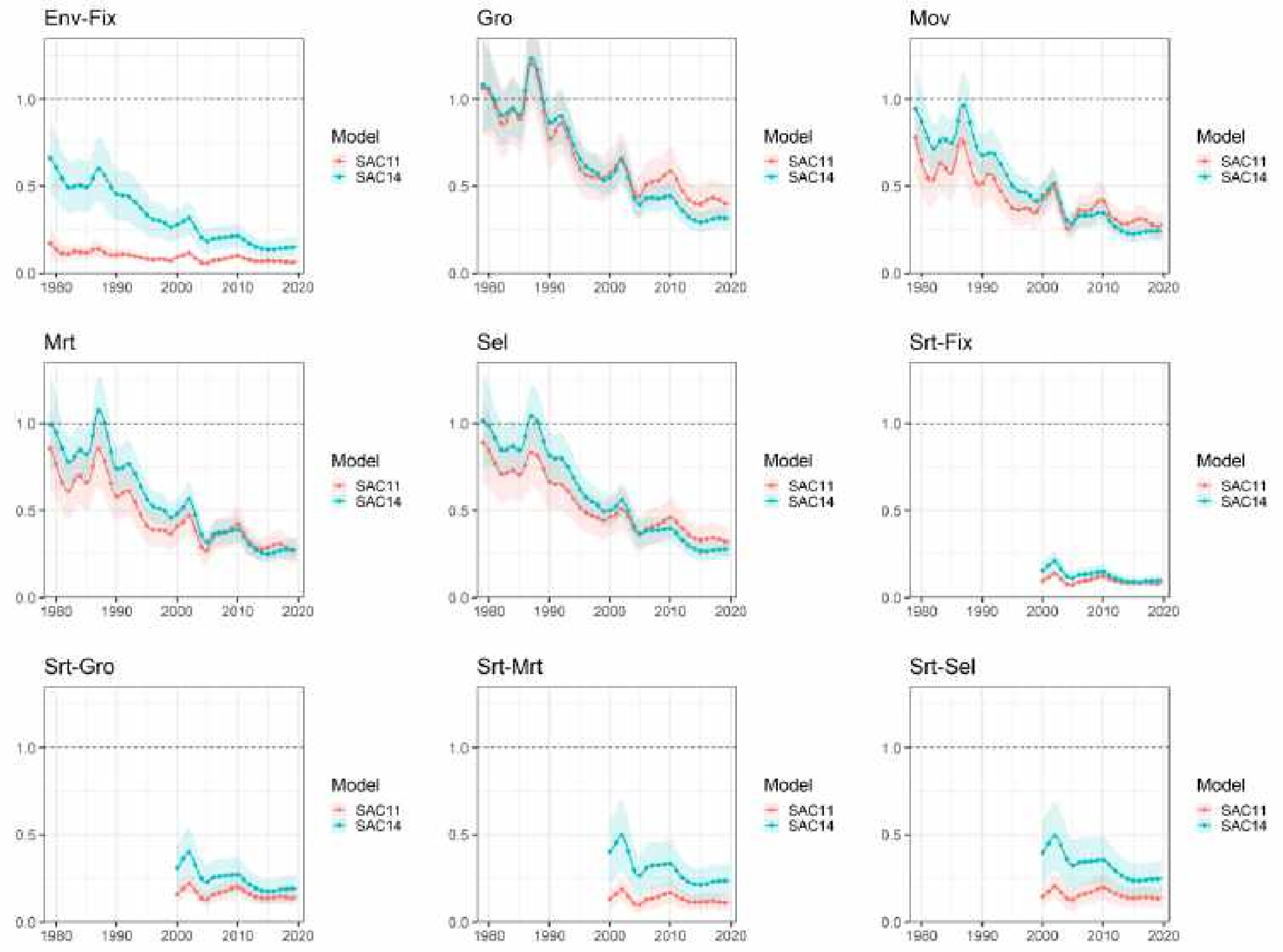
SAC14 reference models

Model name	Description
Env-Fix	Environment, Fixed
~~Env-Gro~~	~~Environment, Estimate growth~~
~~Env-Sel~~	~~Environment, Dome selectivity~~
~~Env-Mrt~~	~~Environment, Adult mortality~~
Srt-Fix	Short-term, Fixed
Srt-Gro	Short-term, Estimate growth
Srt-Sel	Short-term, Dome selectivity
Srt-Mrt	Short-term, Adult mortality
Mov	Pre-adult movement
Gro	Estimate growth
Sel	Dome selectivity
Mrt	Adult mortality

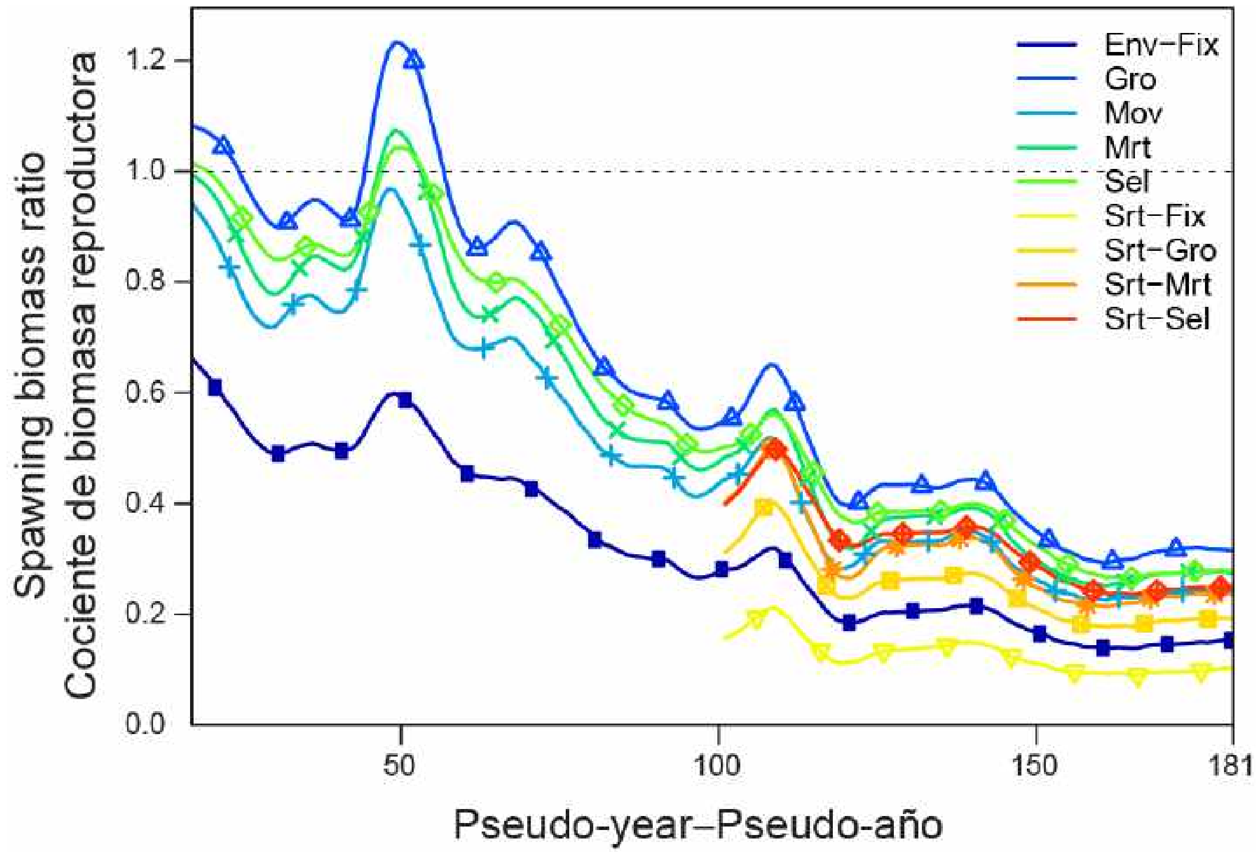
Model-specific effects

The improvements lead to

- A higher terminal spawning biomass ratio for the five pessimistic reference models (Env-Fix, Srt-Fix, Srt-Gro, Srt-Mrt, and Srt-Sel)
- A lower terminal spawning biomass ratio for the four optimistic reference models (Gro, Mov, Mrt, and Sel)
- A reduced discrepancy between the optimistic and pessimistic reference models



Model-combined effects



SAC14 reference models

Model name	Description
Env-Fix	Environment, Fixed
Srt-Fix	Short-term, Fixed
Srt-Gro	Short-term, Estimate growth
Srt-Sel	Short-term, Dome selectivity
Srt-Mrt	Short-term, Adult mortality
Mov	Pre-adult movement
Gro	Estimate growth
Sel	Dome selectivity
Mrt	Adult mortality

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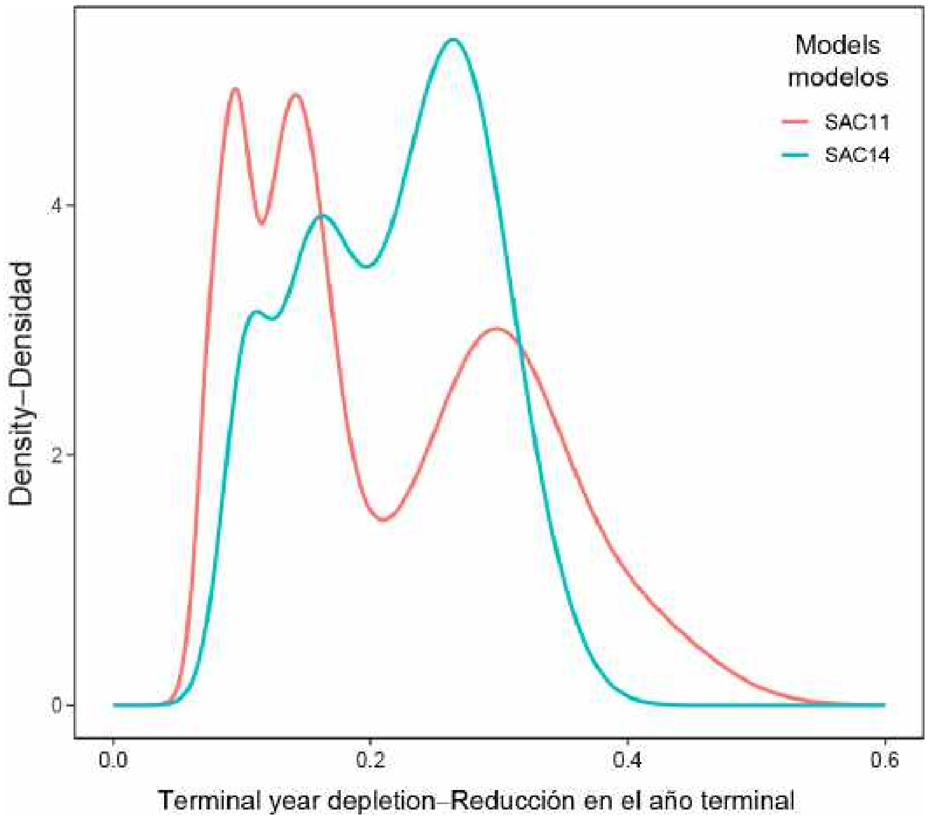
Model-combined effects

- We compute the joint distribution of terminal year depletion to investigate whether the bimodal pattern has been reduced
- For the joint distribution, the reference models are equally weighted under each overarching recruitment hypothesis
- The joint distribution for SAC11 shows two distinct and distant modes, but that for SAC14 is unimodal-like.
- **This joint distribution should not be used to provide any management advice: it is not derived from a formal risk analysis that weights model estimates based on hypotheses and model diagnostics**



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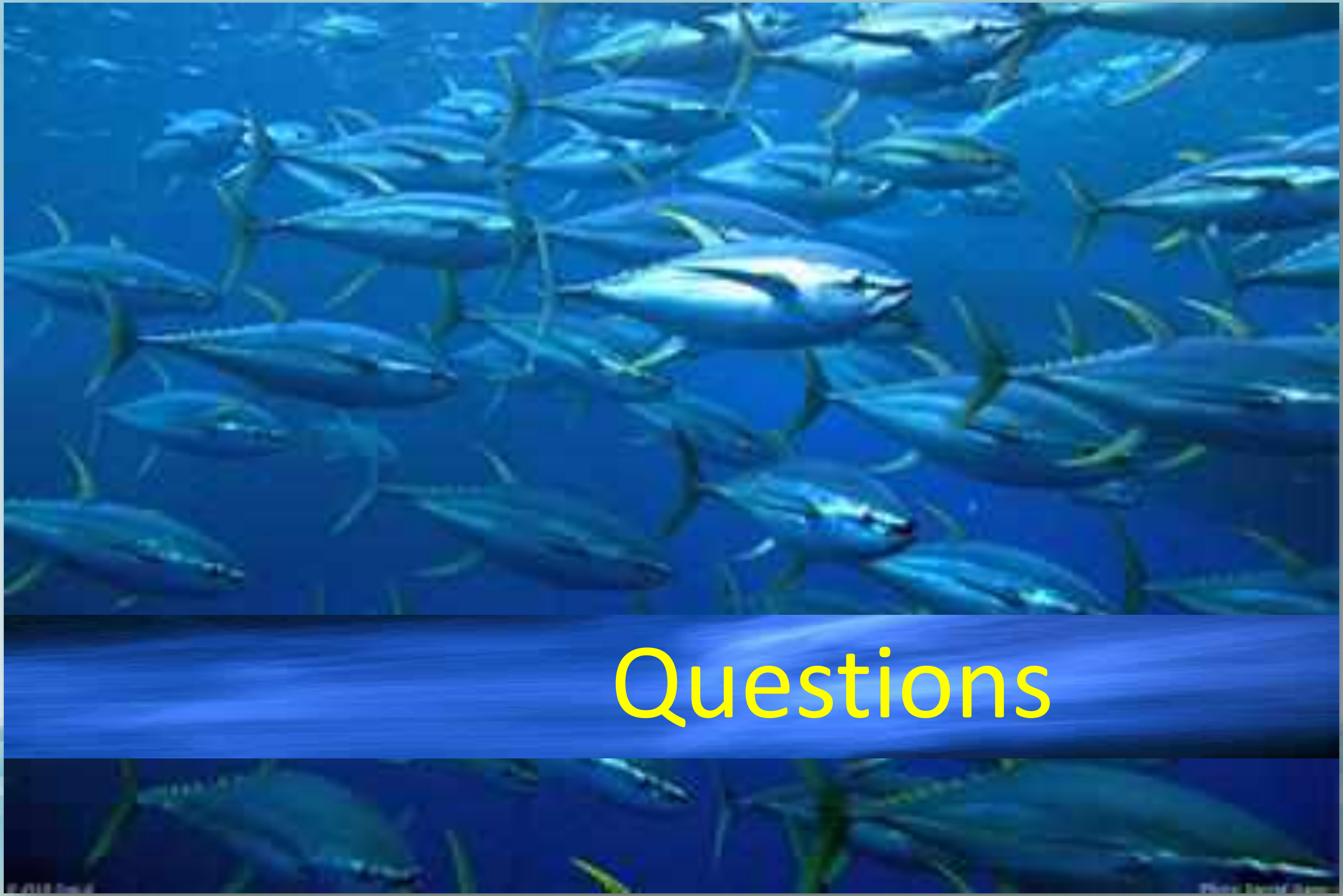
Several desirable research projects have been identified to further improve the assessment model for the 2024 benchmark assessment, including:

- Increasing the number of longline fishery fleets (assessment results are very sensitive to longline composition data)
- Exploring alternative ways of dealing with longline composition data from Japan and Korea (a joint longline fleet or two separate longline fleets)
- Improving the longline index of abundance by using finer CPUE data (Japanese scientist will kindly bring operational data to the staff after this SAC)
- Explore another natural mortality option (a new parametric curve for tunas is available)
- Considering other changes recommended by the results of the CAPAM workshop on tuna stock assessment good practices (Wellington, March 2023)

Summary

- Six major modifications are proposed by the staff to improve the stock assessment
- The new “base” reference assessment model is considered superior to the “base” reference assessment model from the last benchmark assessment:
  1. Improved fit to length composition data
  2. Included an additional source (Korean) of data in the calculation of longline length compositions
  3. More representative index of abundance
  4. More realistic initial conditions
  5. Reduced conflict between the information from the index of abundance and from length compositions about the scale of population abundance
  6. Reduced magnitude of the regime shift in recruitment (from 2.4 to 1.5)
  7. Showed very similar scales and trends of absolute abundance estimated by the new “base” model and its age-structured production model
- The proposed improvements in this exploratory analysis show potential in significantly reducing or even resolving the bimodal pattern in management quantities



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