Comisión Interamericana del Atún Tropical
Inter-American Tropical Tuna Commission

BIGEYE TUNA IN THE EASTERN PACIFIC OCEAN, 2019: benchmark assessment

Haikun Xu, Mark N. Maunder, Carolina Minte-Vera, Juan L. Valero, Cleridy Lennert-Cody, and Alexandre Aires-da-Silva

11TH MEETING SCIENTIFIC ADVISORY COMMITTEE San Diego, California (USA)
11-15 May 2020
Postponed until a later date to be determined

Issues with EPO tropical tuna stock assessments

- Management advice based on a "best assessment" approach
- *F* multiplier from the YFT and BET base case assessments used to determine the duration of the seasonal closure
- 2018: BET assessment model not reliable enough to determine closure (SAC-09 INF)
  - Assessment overly sensitive to new data (mainly for the indices of abundance from the longline fishery)
  - Other issues
- 2019: same conclusion extended to YFT assessment (SAC-10 INF-F)

2018-2020: Workplan to improve the stock assessments of tropical tuna

- Included external reviews of the YFT and BET assessments

- Both external reviews suggested a variety of alternative models rather than a replacement for base case

- Change from “best assessment” to a risk analysis approach which considers multiple models and explicitly deals with stock assessment uncertainty

The staff's pragmatic risk analysis approach

Described in Maunder et al. 2020 (SAC-11- INF-F):

1. **Identify alternative hypotheses** (‘*states of nature*’) about the population dynamics of the stock that address the main issues in the assessments
   - YFT: SAC-11-J; BET: SAC-11 INF-F
2. **Implement stock assessment models representing alternative hypotheses**
   - YFT: SAC-11-07; BET: SAC-11-06
3. **Assign relative weights to each hypothesis (model)**
   - YFT: SAC-11 INF-J; BET: SAC-11 INF-F
4. **Compute combined probability distributions for management quantities using model relative weights**
   - SAC-11-08

List of models *retained* in the risk analysis

Model name	Number	Description	h=0.7	h=0.8	h=0.9	h=1.0
Env-Fix	1	Environment, Fixed				
Env-Gro	2	Environment, Estimate growth				
Env-Sel	3	Environment, Dome selectivity				
Env-Mrt	4	Environment, Adult mortality				
Srt-Fix	5	Short-term, Fixed				
Srt-Gro	6	Short-term, Estimate growth				
Srt-Sel	7	Short-term, Dome selectivity				
Srt-Mrt	8	Short-term, Adult mortality				
Mov	9	Pre-adult movement				
Gro	11	Estimate growth				
Sel	11	Dome selectivity				
Mrt	12	Adult mortality				

48 model runs

Outline

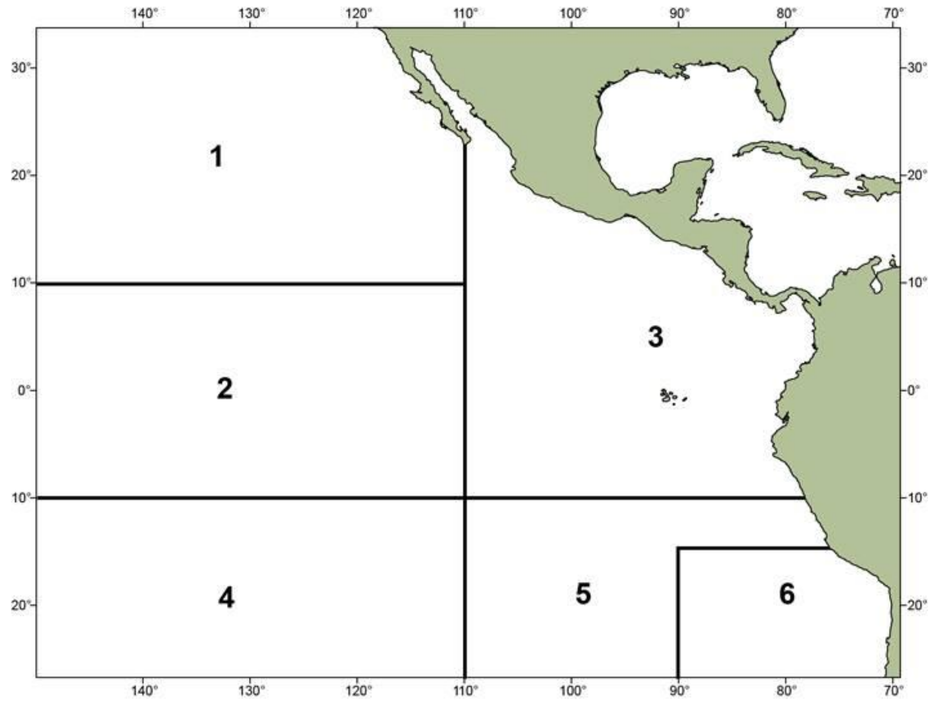
- Fleet definition - fisheries and “surveys”
- Data - catch, index of abundance, and size composition
- Model assumptions - growth, natural mortality, recruitment, and selectivity
- The differences among the twelve models
- Model results

Fisheries

Fleet	Gear	Set type	Years	Area	Catch data
FISHERIES					
1	LL	-	1979-present	1	Retained catch only (1,000)
2			1979-1993; 1994-present	2	
3				3	
4				4	
5				5	
6				6	
7	LL	-	1979-present	1	Retained catch only (tons)
8			1979-1993; 1994-present	2	
9				3	
10				4	
11				5	
12				6	
13	PS	OBJ	1979-present	2	Retained catch only (tons)
14				3	
15				4	
16				5	
17				6	
18	PS	OBJ	1979-present	2-6	Discards of small fish (tons)
19	PS	NOA+DEL	1979-present	2	Retained catch only (tons)
20				3	
21				4	
22				5	
23				6	

This assessment uses the "areas-as-fleets" approach

Area

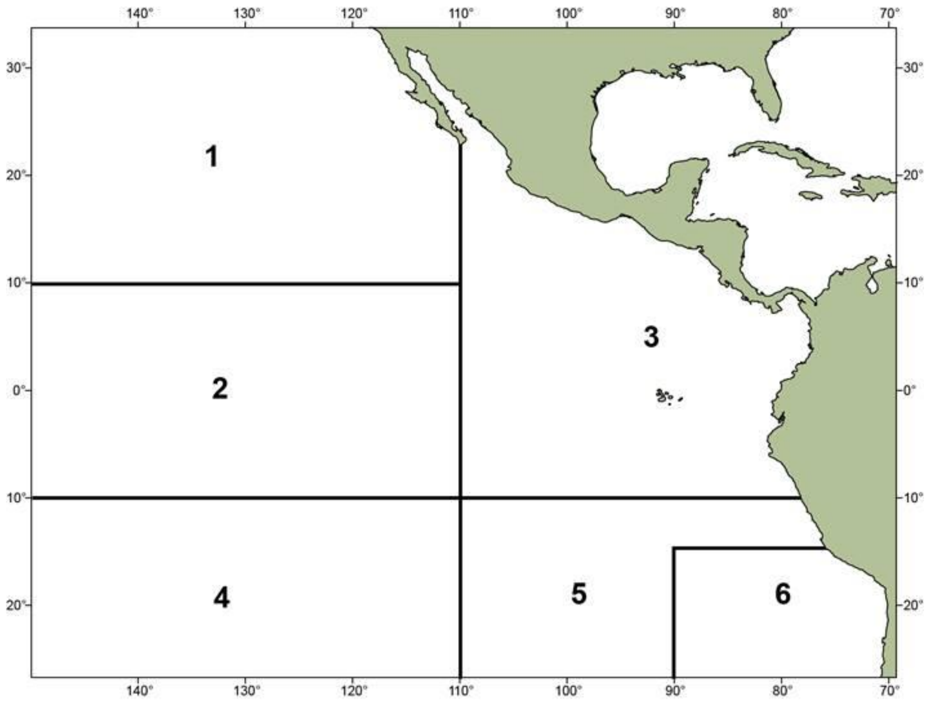


“Surveys”

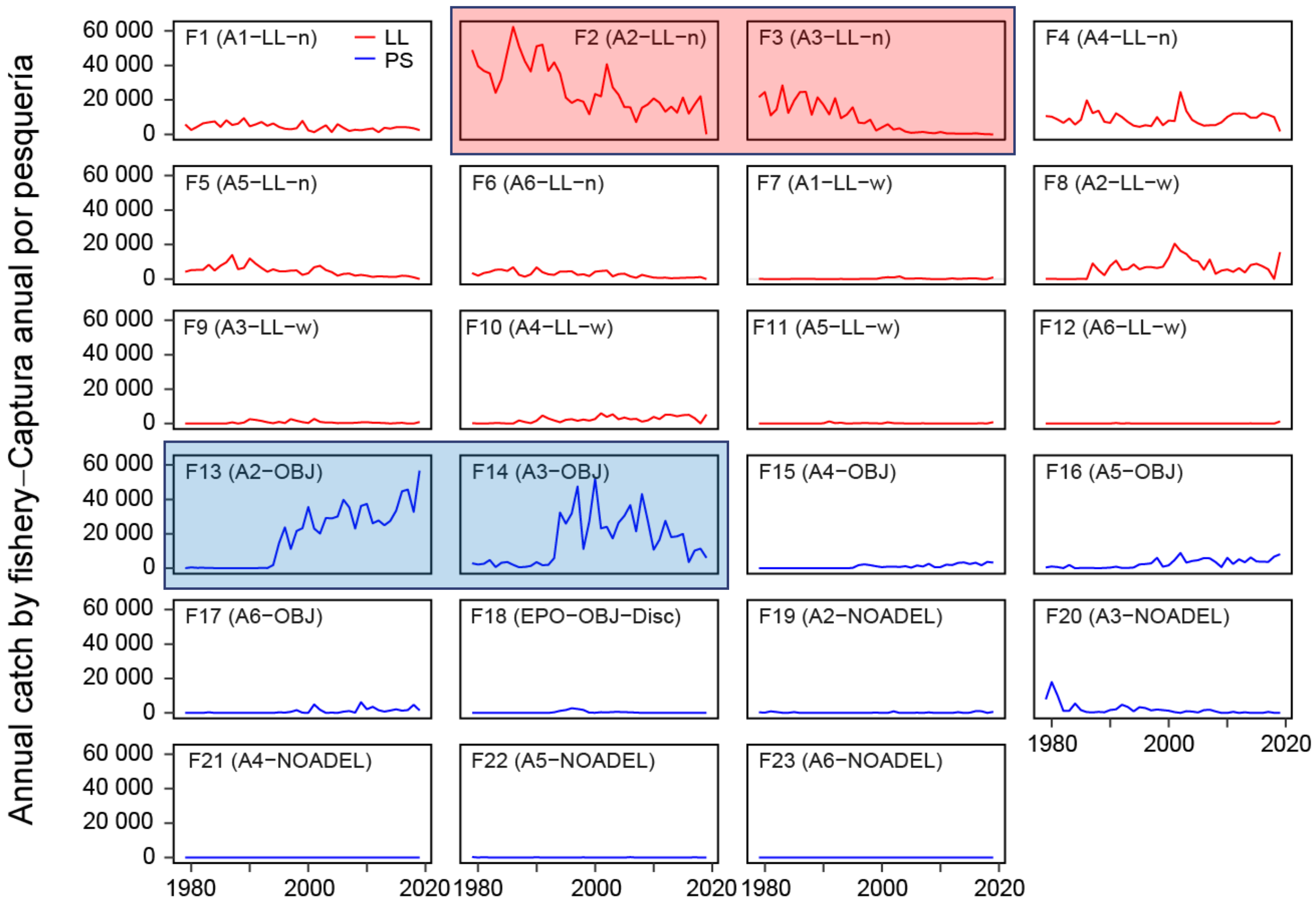
Fleet	Gear	Set type	Years	Area	Catch data
“SURVEYS”					
24	LL	-	1979-1992	2-6	No catches
25			1995-present		

- In Stock Synthesis: a “survey” is modeled as a fleet that has data, such as indices of abundance and age/length compositions, but no catch.
- Not real surveys: data for the two surveys are from the JPN commercial longline fleet
- No surveys in Area 1: indices of abundance from this area are likely not representative of the “core” region of the bigeye distribution

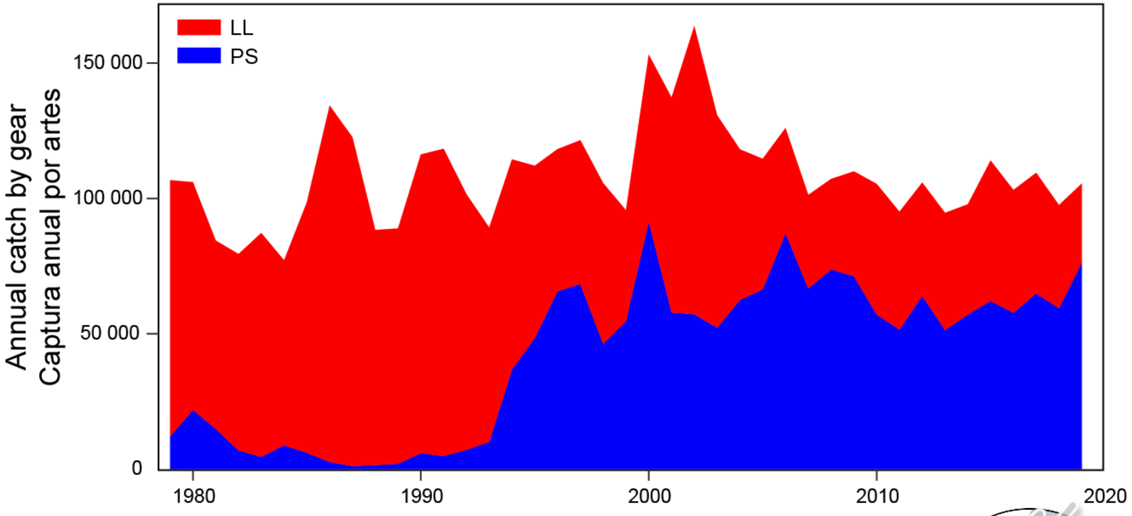
Area



Data - catch

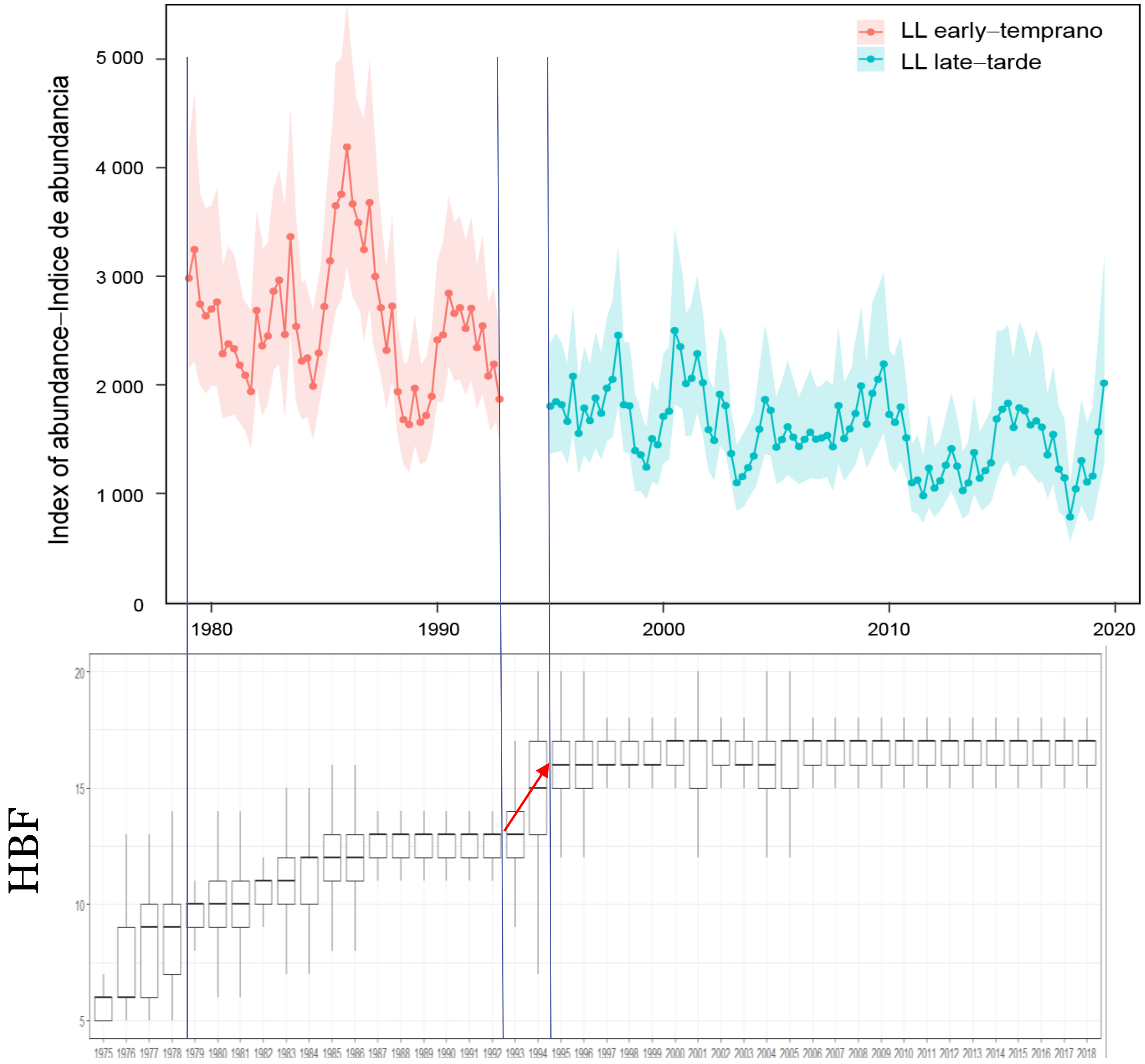


- Areas 2 and 3 are the main fishing grounds for both LL and OBJ fisheries
- Before 1993, catch (in metric tons) was primarily contributed by the LL fishery; after 1997, the OBJ fishery caught more bigeye than did the LL fishery



Note: longline catches are submitted in both number (Fisheries 1-6) and weight (Fisheries 7-12), but those submitted in number are converted to weight in this figure for comparison purpose

Data - index of abundance



New model and new data source for longline indices of abundance:

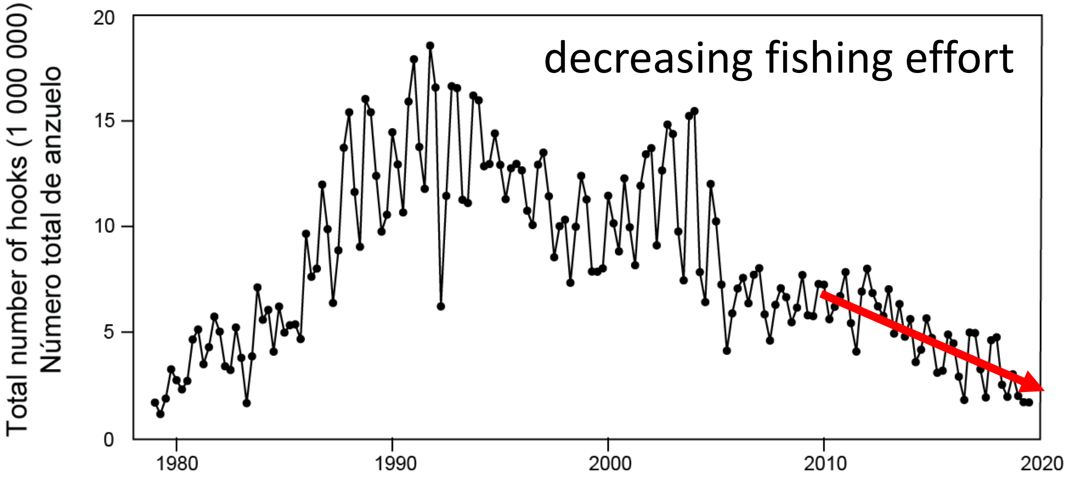
- Standardized using a **spatiotemporal model** (VAST)
- 1° cell x month **x vessel** catch and effort data from the JPN fleet

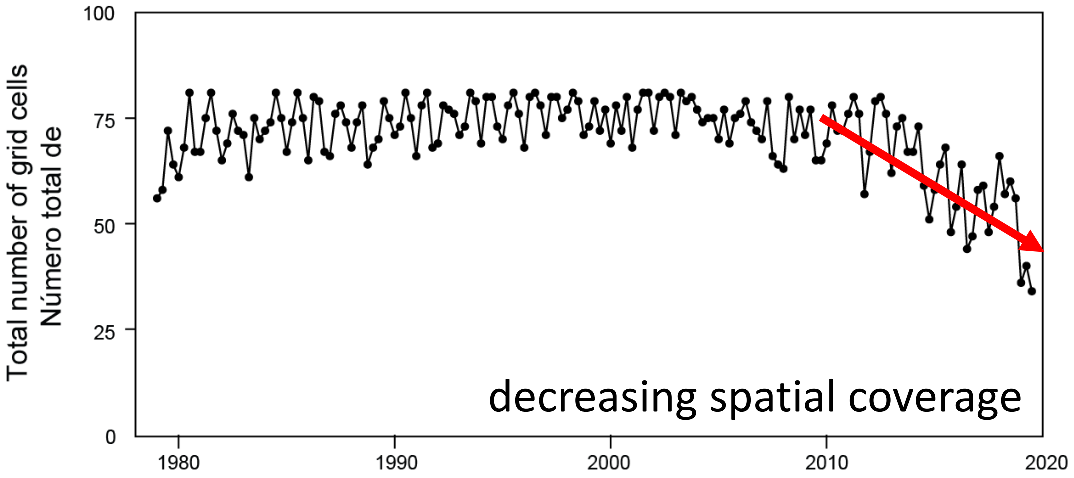
What's new in longline indices of abundance:

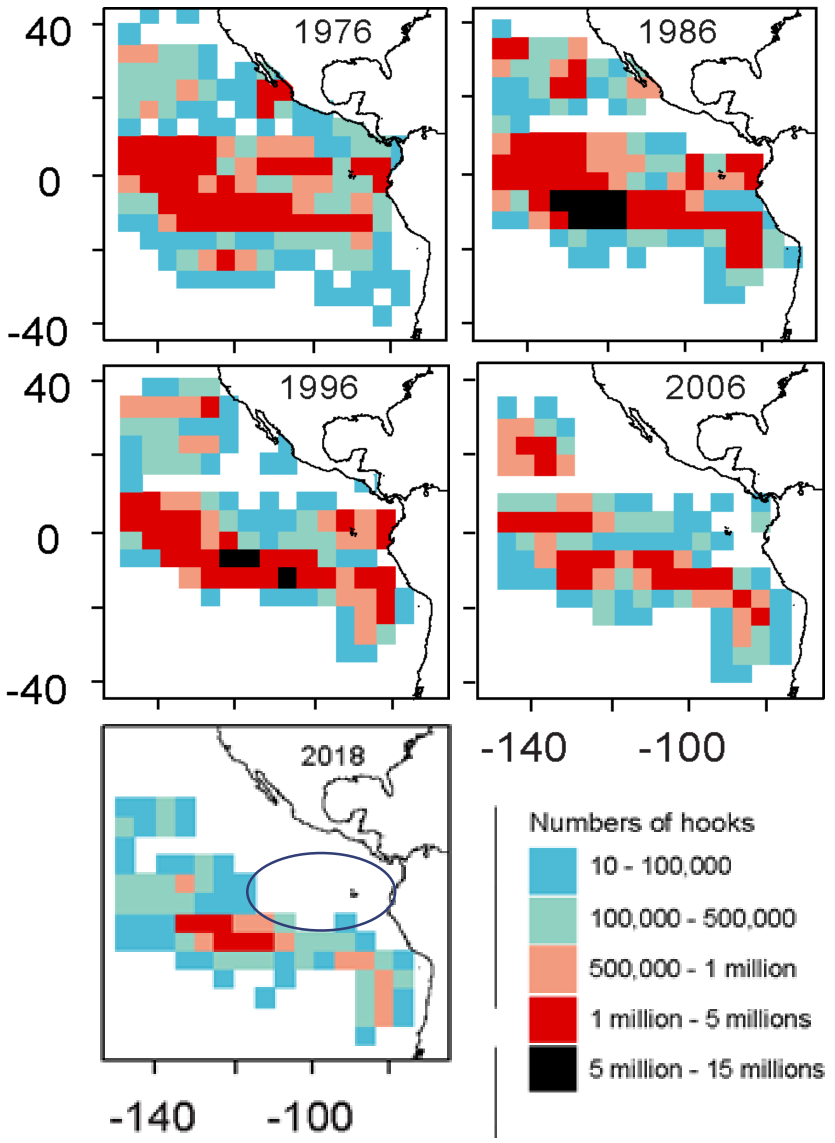
- The longline index is split into **two** indices: 1979-1992 (early) and 1995-2019 (late)
- **Different** catchabilities and selectivities for the two indices due to the change in HBF
- Use **time-varying** CV estimated by the spatiotemporal model
- **Different** average CVs for the two indices: estimated for the early index and fixed (0.15) for the late index

Data - index of abundance

Contraction of the JPN longline fishery







Data - index of abundance

Since 2010, the JPN longline fleet has decreasing fishing effort and spatial coverage in the EPO ->

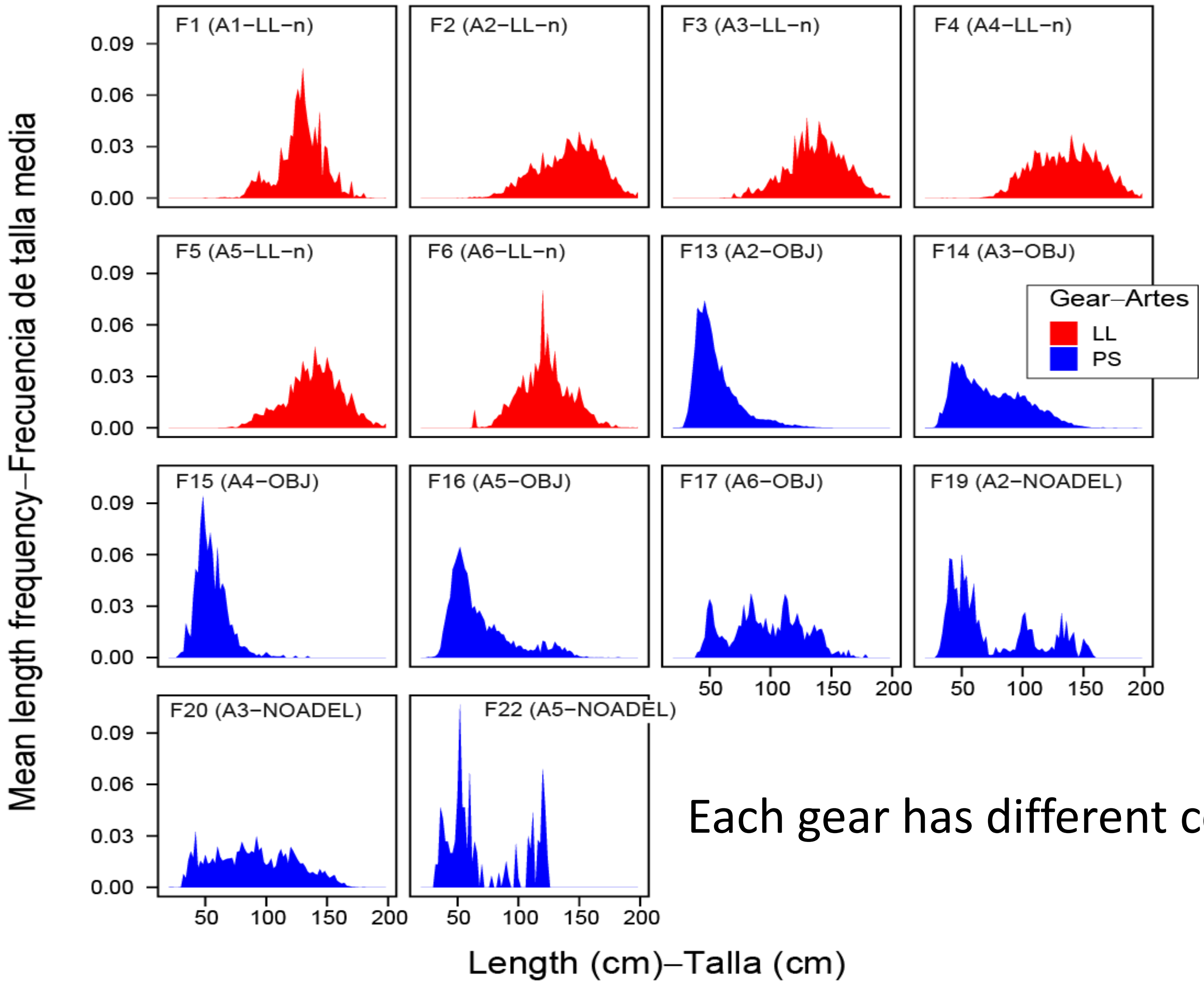
Decreasing sample size and increasing unsampled area in the EPO ->

Increasingly more uncertain longline index ->

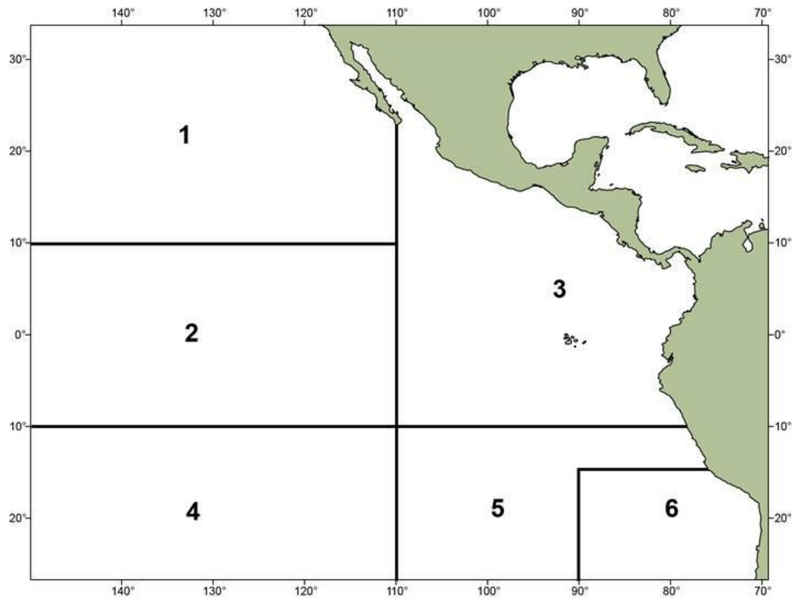
How to deal with the contraction of the JPN longline fishery?

Use time-varying index CV estimated by the spatiotemporal model -> the large CV in recent years means the index in those years is down-weighted in the stock assessment model

Data – size composition



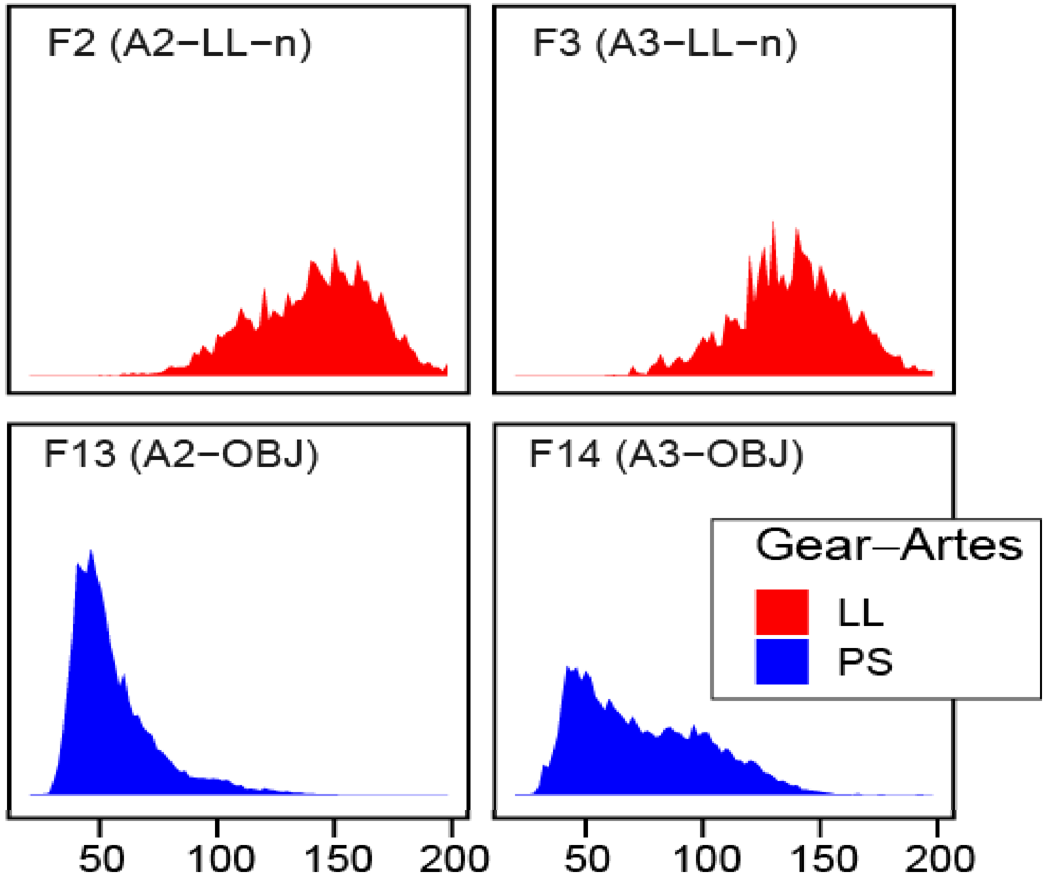
Area

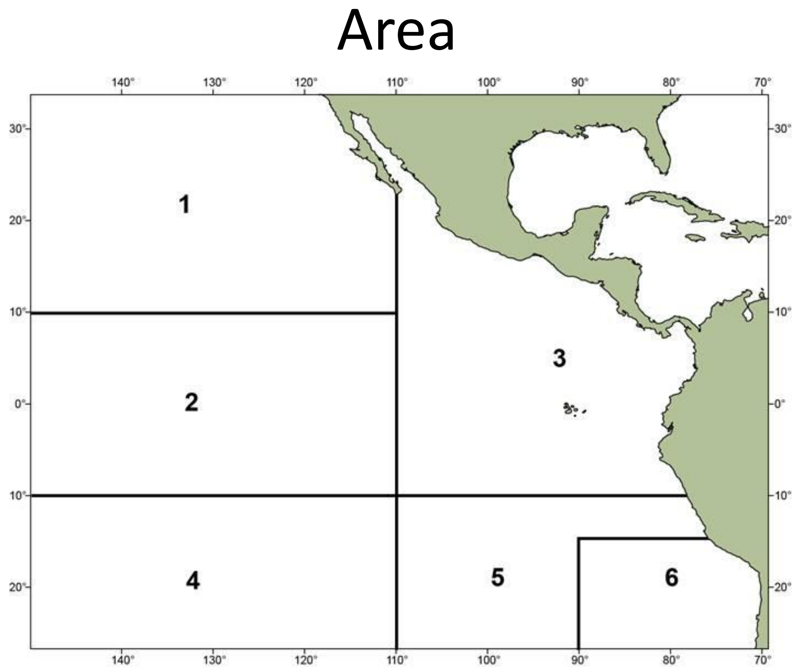


Each gear has different compositions among the 6 areas

Data – size composition

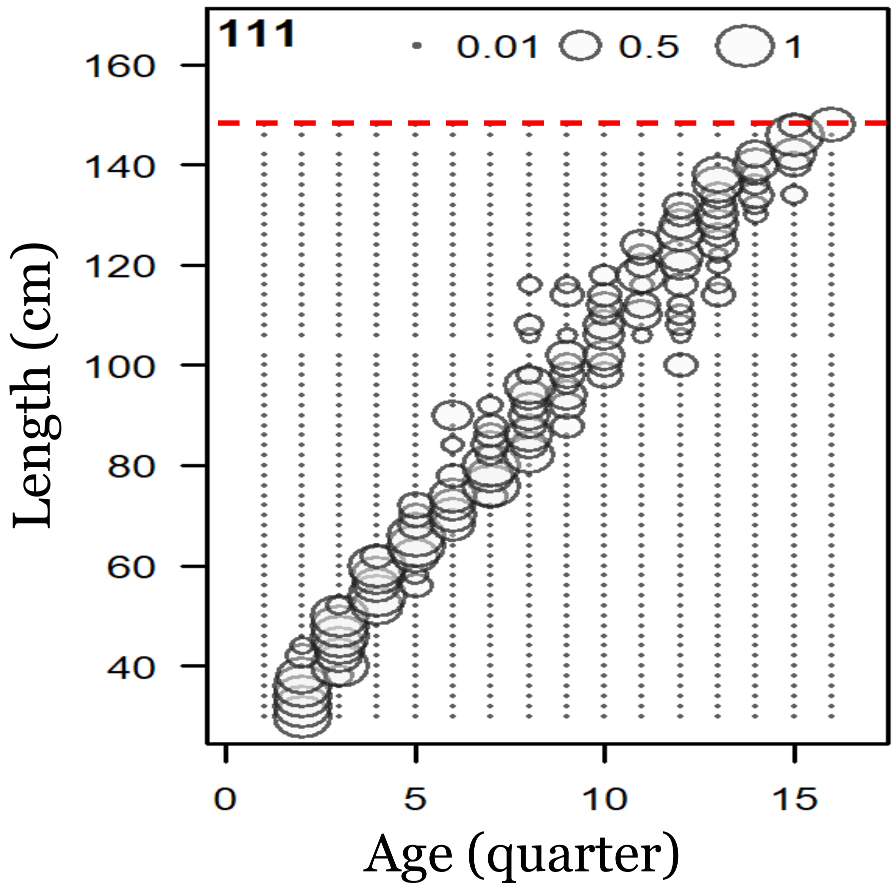
In the same area, LL fisheries catch larger bigeye than OBJ fisheries





Data – conditional age at length

Age at length data is available for the OBJ fishery (in Area 3) in the third quarter of 2002

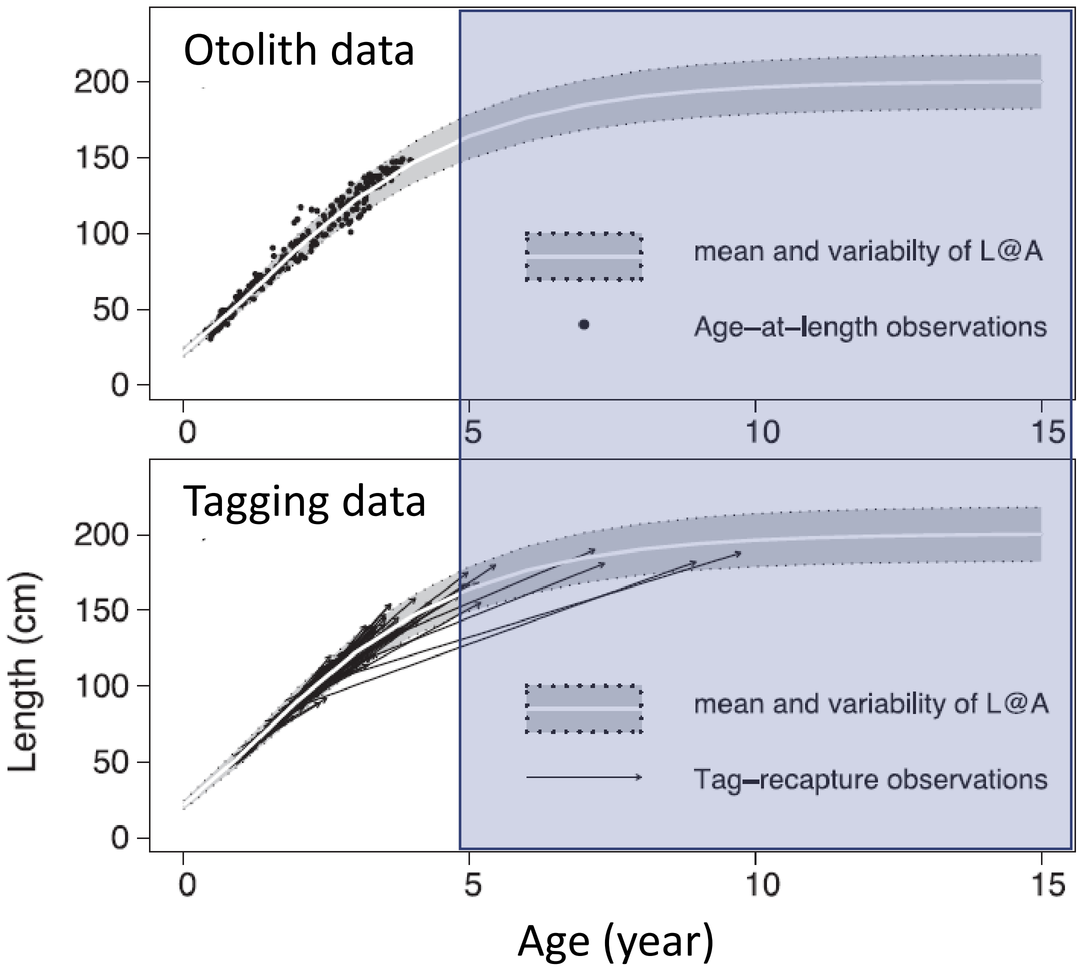


- The age at length data is included in the three reference models that estimate the growth curve
- The data does not cover bigeye larger than 150 cm and older than 4 years

Model (Env-Fix) assumptions - general

- Based on Stock Synthesis (v3.30.15), an integrated age-structured assessment model
- One stock of bigeye in the EPO
- Two sexes are included in the model – only natural mortality is sex-specific
- Model 1979-2019 with a quarterly time step
- The maximum population age bin is 40 quarters
- The Francis method is used to weight composition data

Model (Env-Fix) assumptions - growth



Silva et al. (2015)

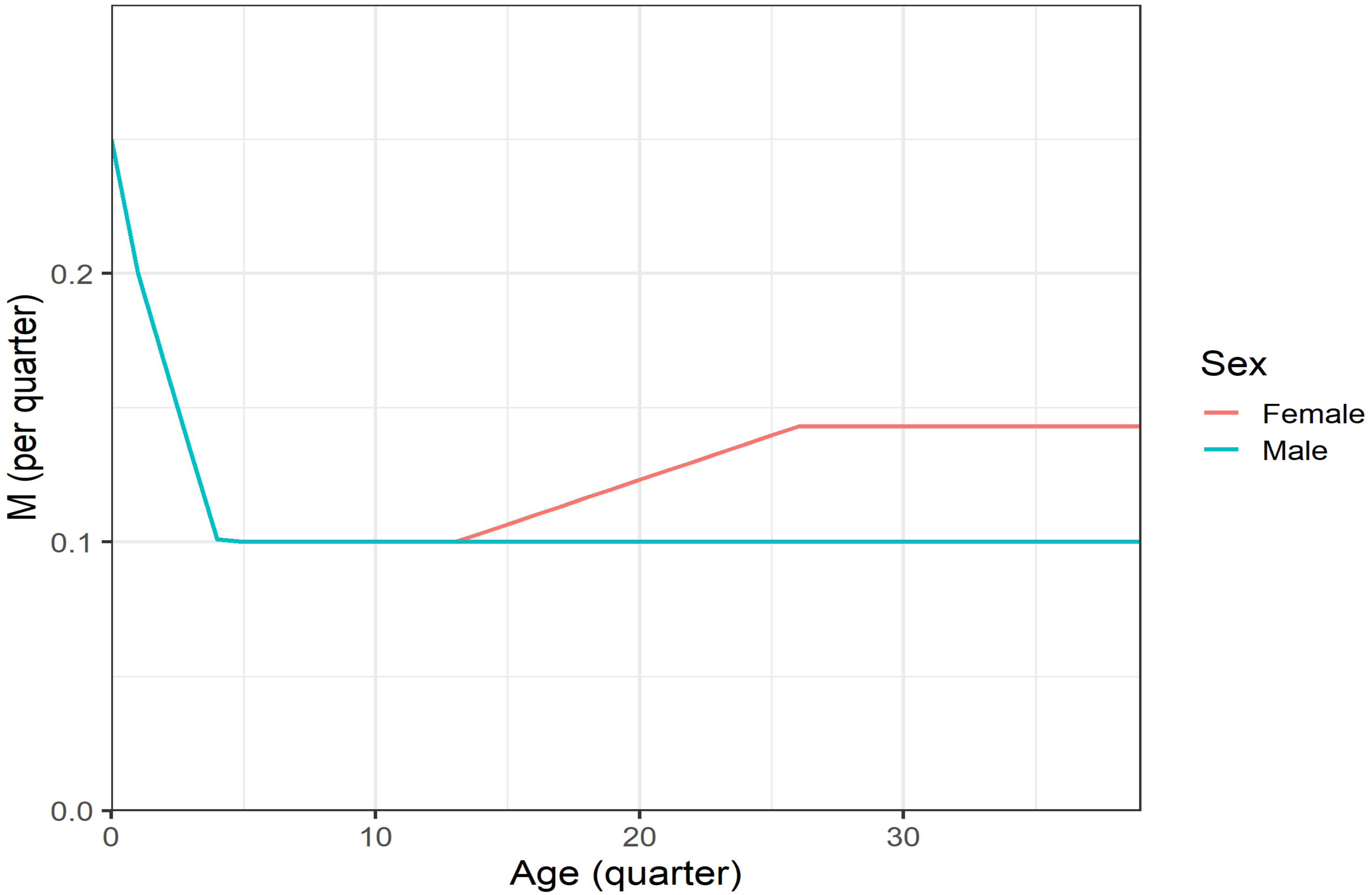
Estimated using an integrated approach that includes both age-at-length otolith data and length increment tagging data (Silva et al. 2015)

Issues with the estimation of growth curve:

- **Very limited** tagging data and **no** otolith data for large (old) bigeye: the estimated mean length at old ages are more uncertain
- Tagging data **may not be representative** of the EPO stock: limit in both space (tagged at 95°W) and time (tagged in 2000-2004)

Model (Env-Fix) assumptions - Natural mortality (M)

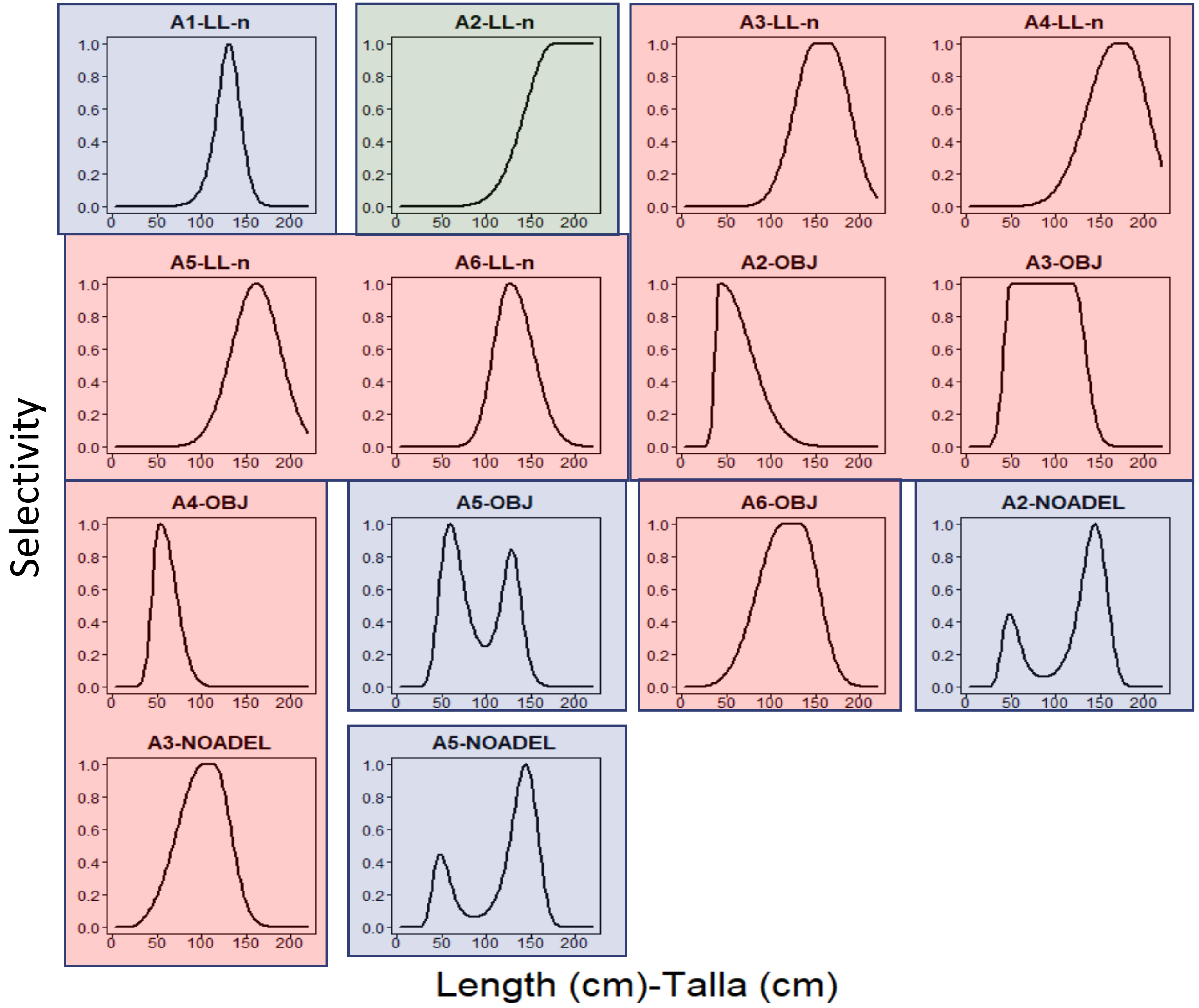
age-specific vectors of natural mortality are assumed for bigeye



Model (Env-Fix) assumptions - recruitment

- Beverton-Holt stock-recruit relationship
- Recruitment is quarterly: use the quarter-as-year approach
- Four steepness (h) are assumed: 1.0, 0.9, 0.8, 0.7
- No autocorrelation in recruit deviates
- Recruitment variability (σ_R) = 0.6 (quarterly)
- Bias adjustment follows Methot and Taylor (2011)

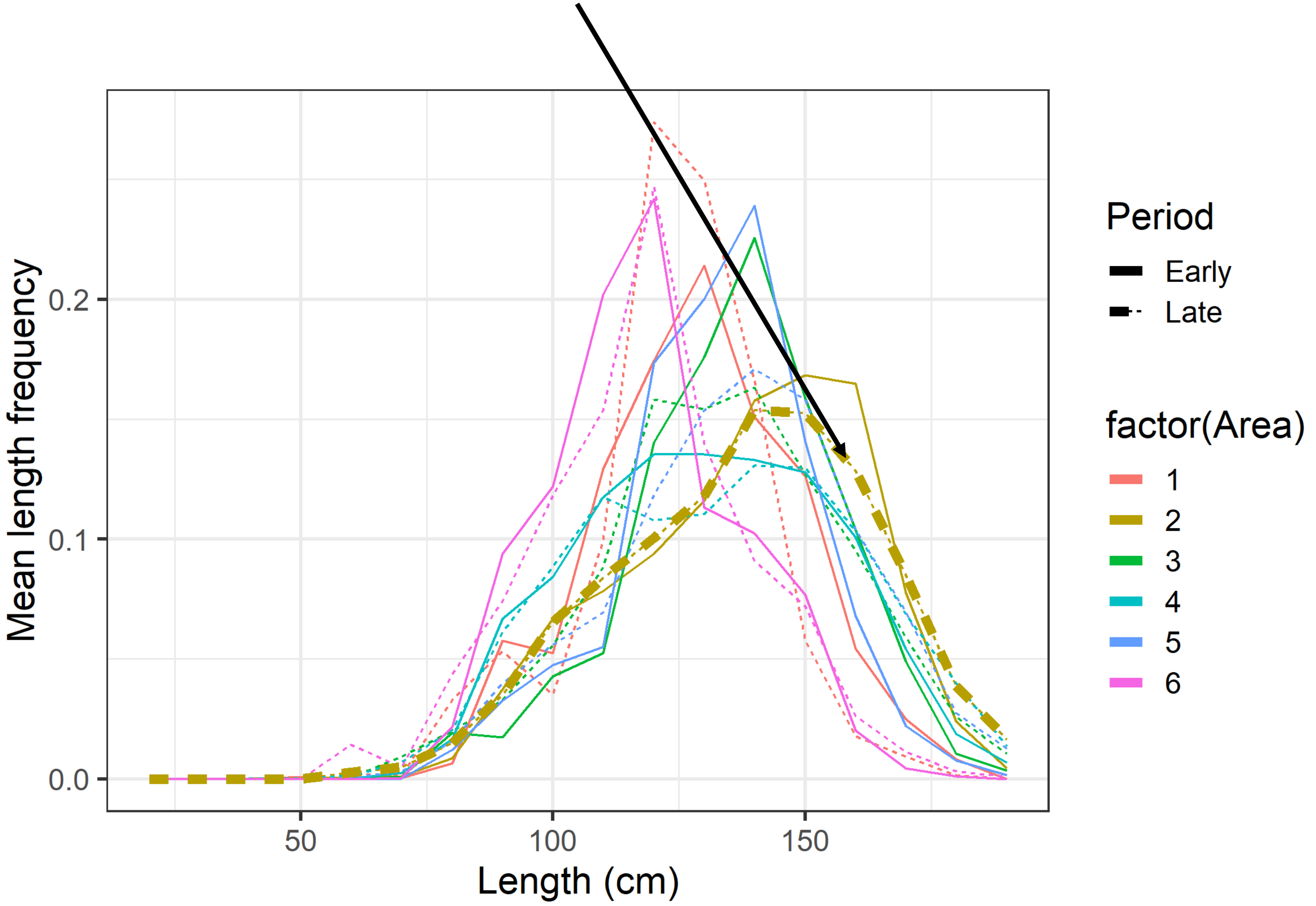
Model (Env-Fix) assumptions - selectivity



- Most fisheries have dome-shaped selectivity
- A few fisheries have spline selectivity because there are more than one peaks in the aggregated length frequency
- One longline fishery has asymptotic selectivity

Model (Env-Fix) assumptions - selectivity

Why choosing the longline fishery in Area 2 to have asymptotic selectivity?



Reference models - Differences from model Env-Fix

Differences are highlighted in red

Model	Years	R regime	Growth	Natural mortality	F2 Selectivity	Auxiliary data
Env-Fix	1979-2019	Yes	std (L_1)	Fix	Asymptotic	
Env-Gro		Yes	all six	Fix	Asymptotic	age-at-length
Env-Mrt		Yes	std (L_1)	Est (quarter 26)	Asymptotic	
Env-Sel		Yes	std (L_1)	Fix	Dome-shape	
Gro		No	all six	Fix	Asymptotic	age-at-length
Mov		No	std (L_1)	Est (quarter 13)	Asymptotic	
Mrt		No	std (L_1)	Est (quarter 26)	Asymptotic	
Sel		No	std (L_1)	Fix	Dome-shape	
Srt-Fix	2000-2019	No	std (L_1)	Fix	Asymptotic	
Srt-Gro		No	all six	Fix	Asymptotic	age-at-length
Srt-Mrt		No	std (L_1)	Est (quarter 26)	Asymptotic	
Srt-Sel		No	std (L_1)	Fix	Dome-shape	

Years: which years are modelled

R regime: whether a recruitment regime parameter is estimated for 1979-1993

Growth: which growth parameters are estimated

Natural mortality: fixed or estimated for some ages

F2 Selectivity: the selectivity of Fishery 2 is asymptotic or dome-shape

Reference models - Differences from model Env-Fix

Estimate growth (6 parameters):

The Richards growth curve

$$L(a) = L_1 + (L_2 - L_1)\left(\frac{1 - \exp(-K(a - a_1))}{1 - \exp(-K(a_2 - a_1))}\right)^{1/b}$$

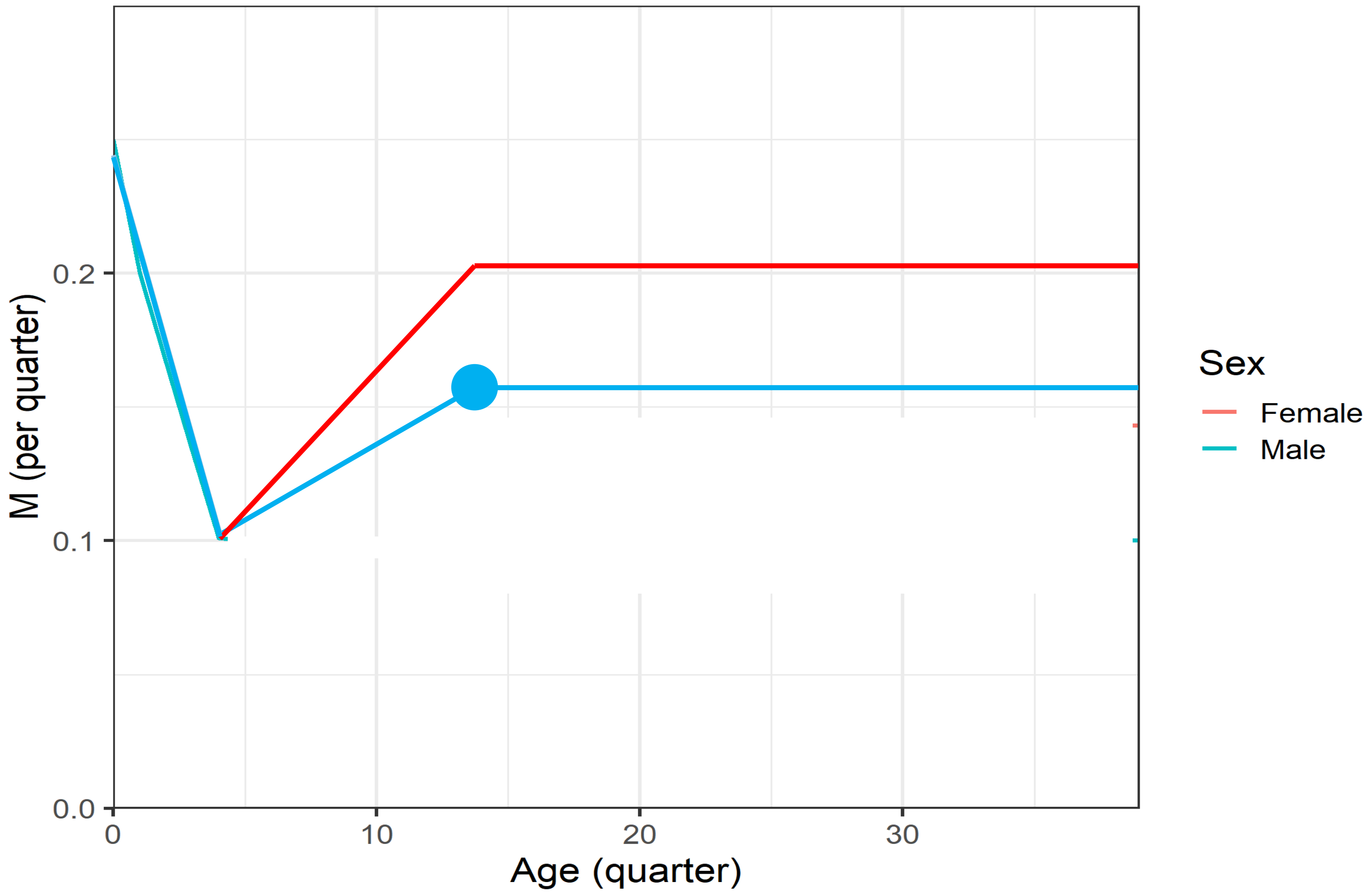
L_1: mean length at age 0
L_2: mean length at age 40 quarters
K: growth rate
b: shape parameter

standard deviation(L_1)
standard deviation(L_2)

Reference models - Differences from model Env-Fix

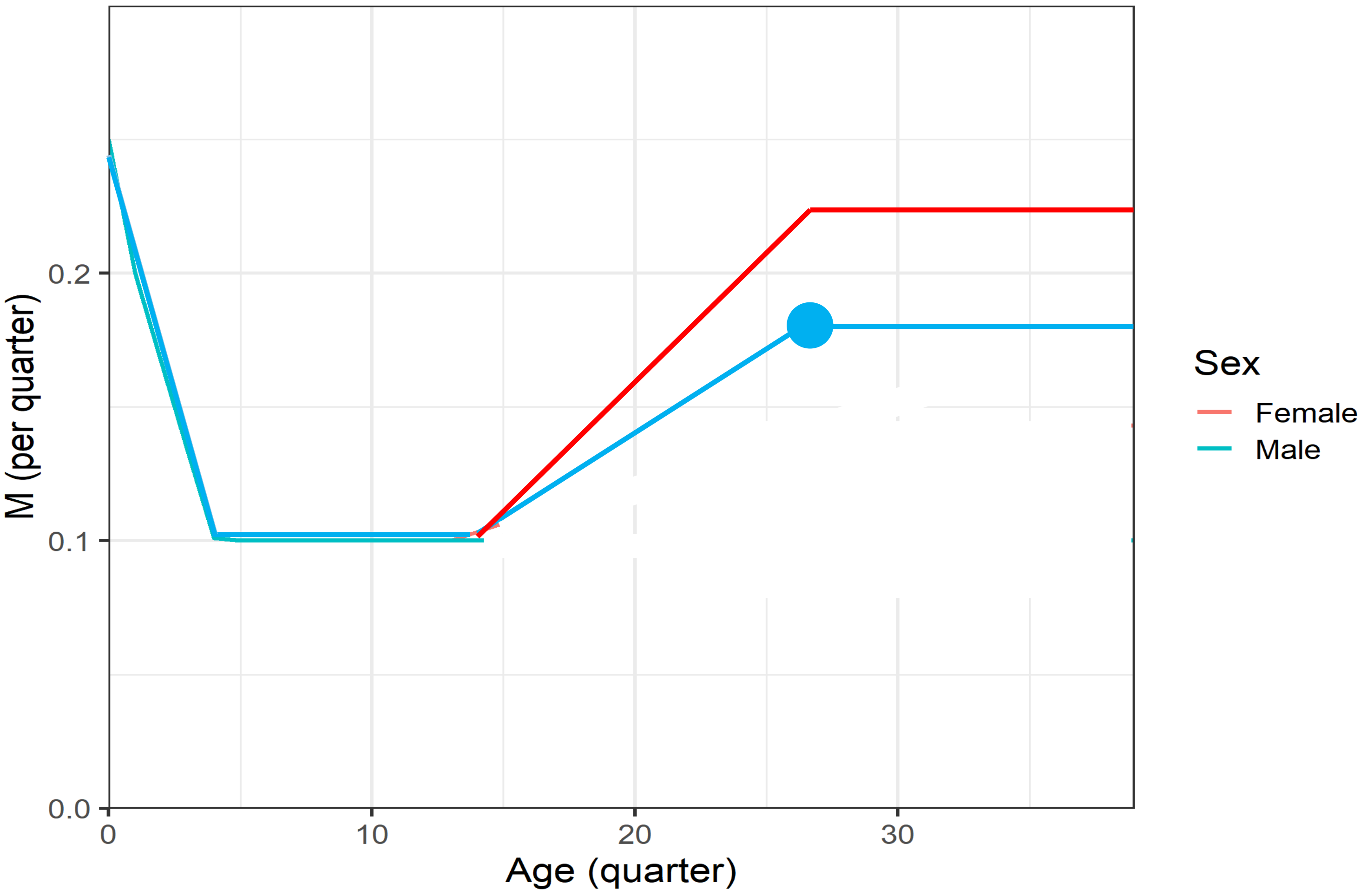
Estimate pre-adult movement (1 parameter)

The difference between male and female M is fixed

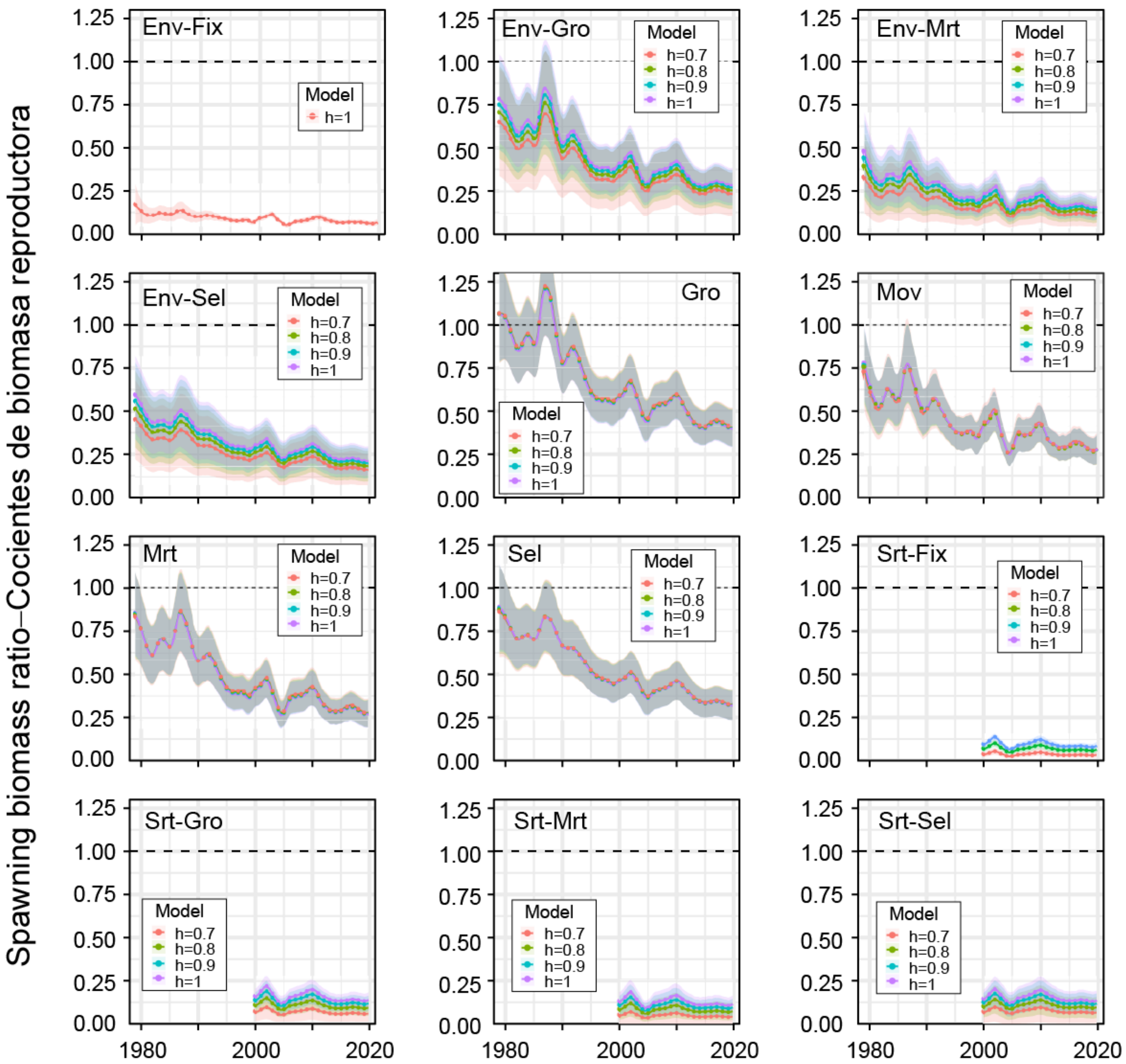


Reference models - Differences from model Env-Fix

Estimate adult natural mortality (1 parameter)
The difference between male and female M is fixed

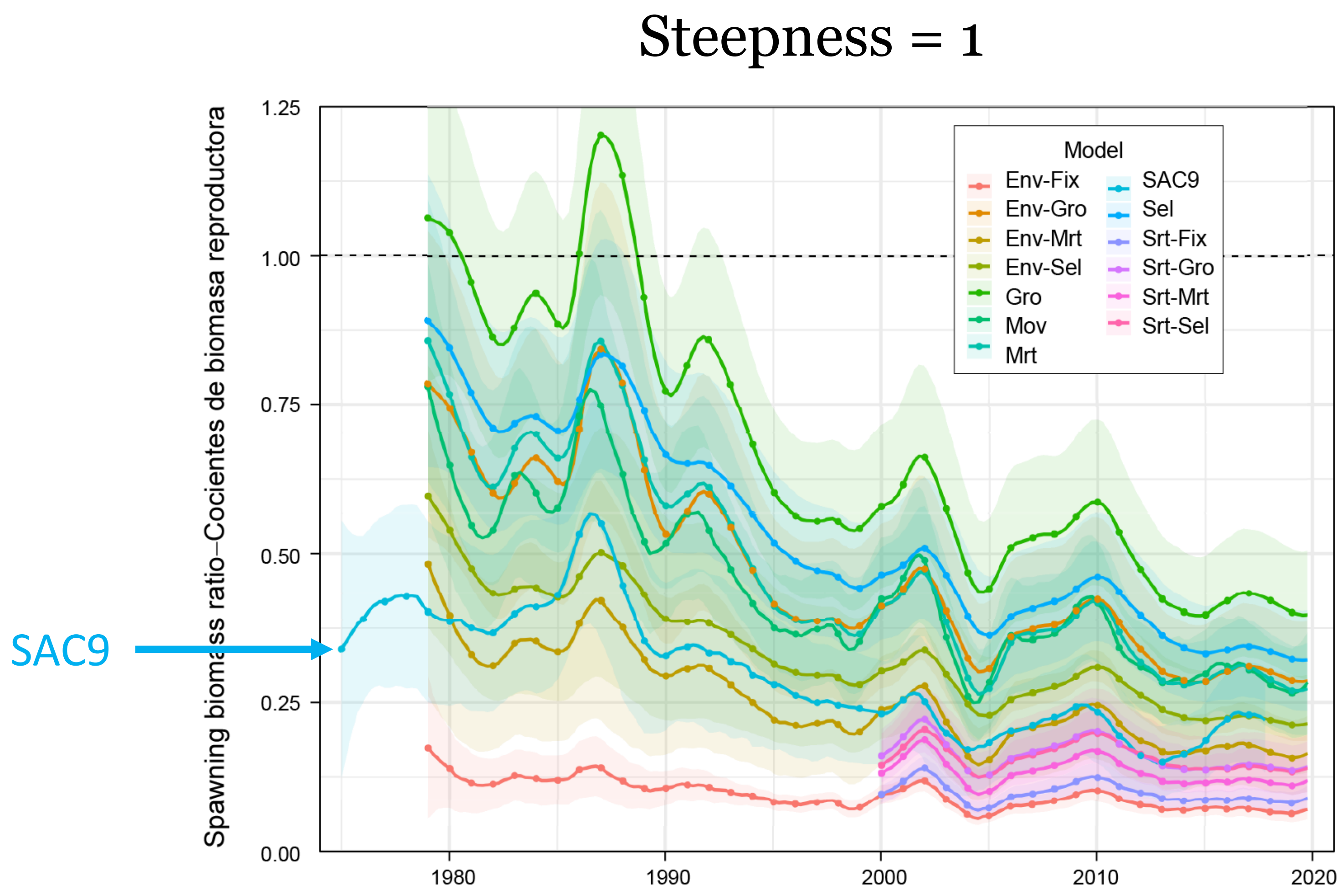


Model results - spawning biomass ratio



Spawning biomass ratio is sensitive to steepness in some, but not all, reference models

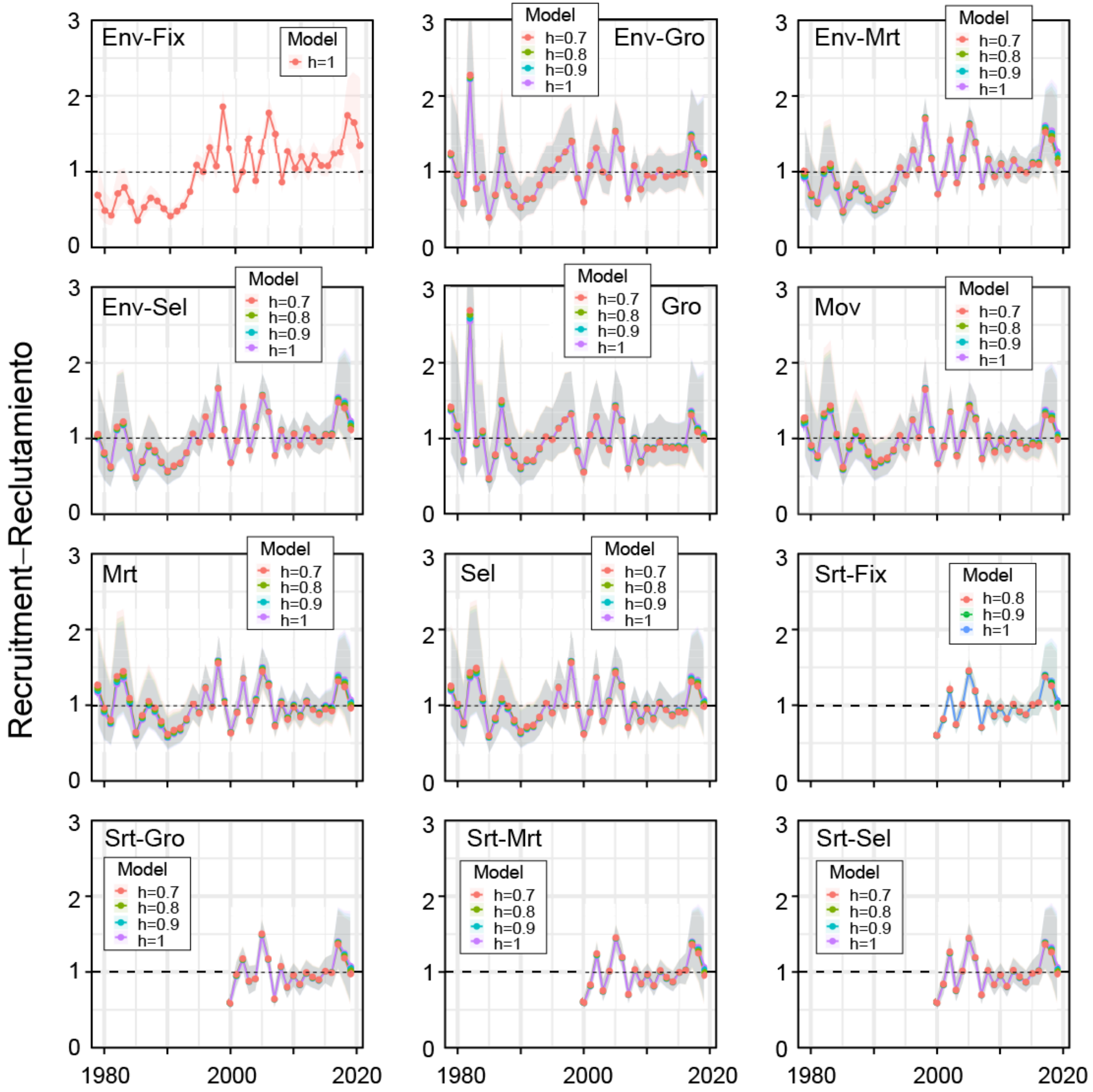
Model results - spawning biomass ratio



The twelve reference models estimate a large range of spawning biomass ratio for 2019, from 0.1-0.4

The previous assessment model (SAC9) lies in the middle of the twelve reference models: six reference models are more optimistic and the other six are more pessimistic than the previous assessment model

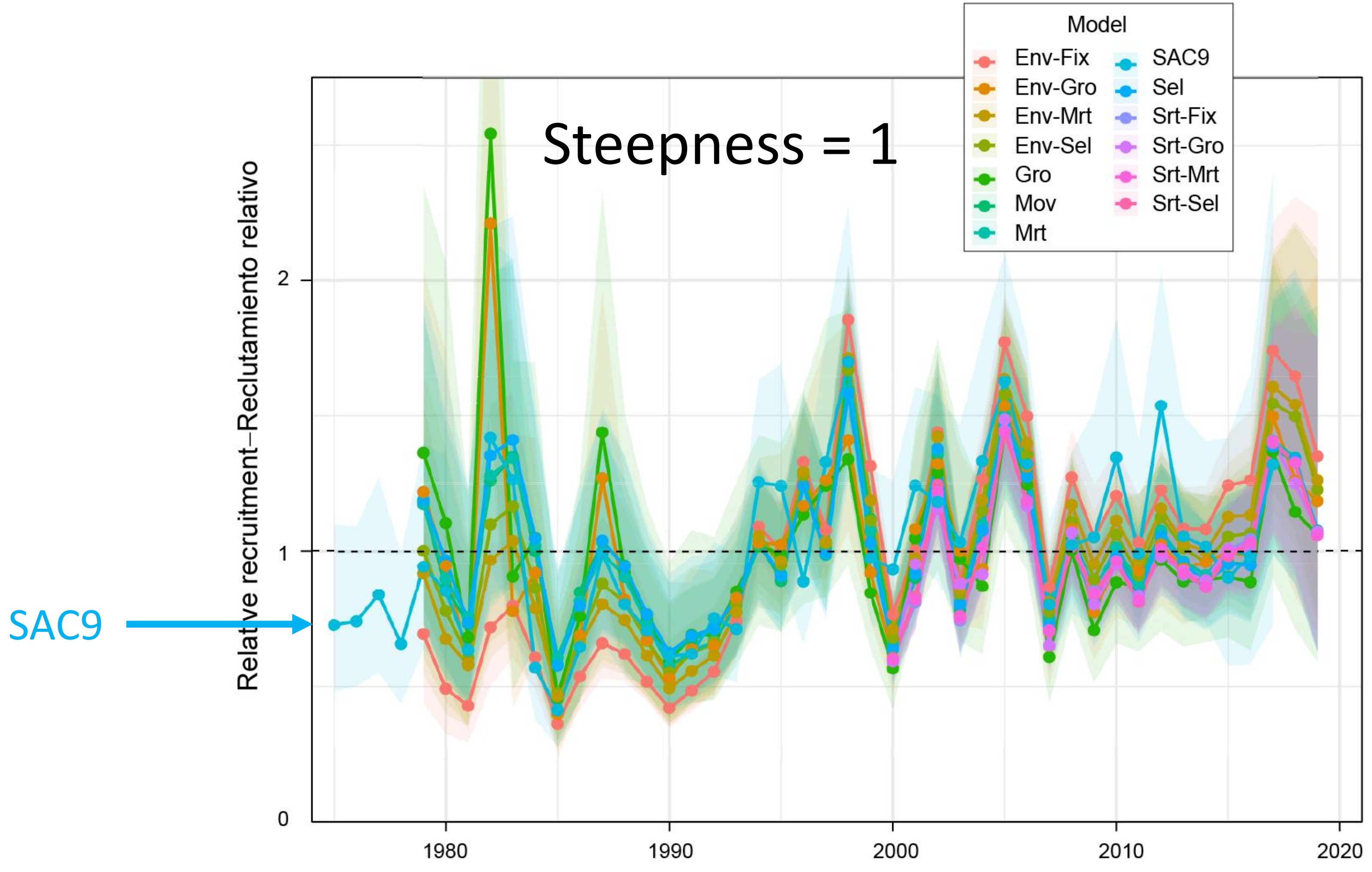
Model results - relative recruitment



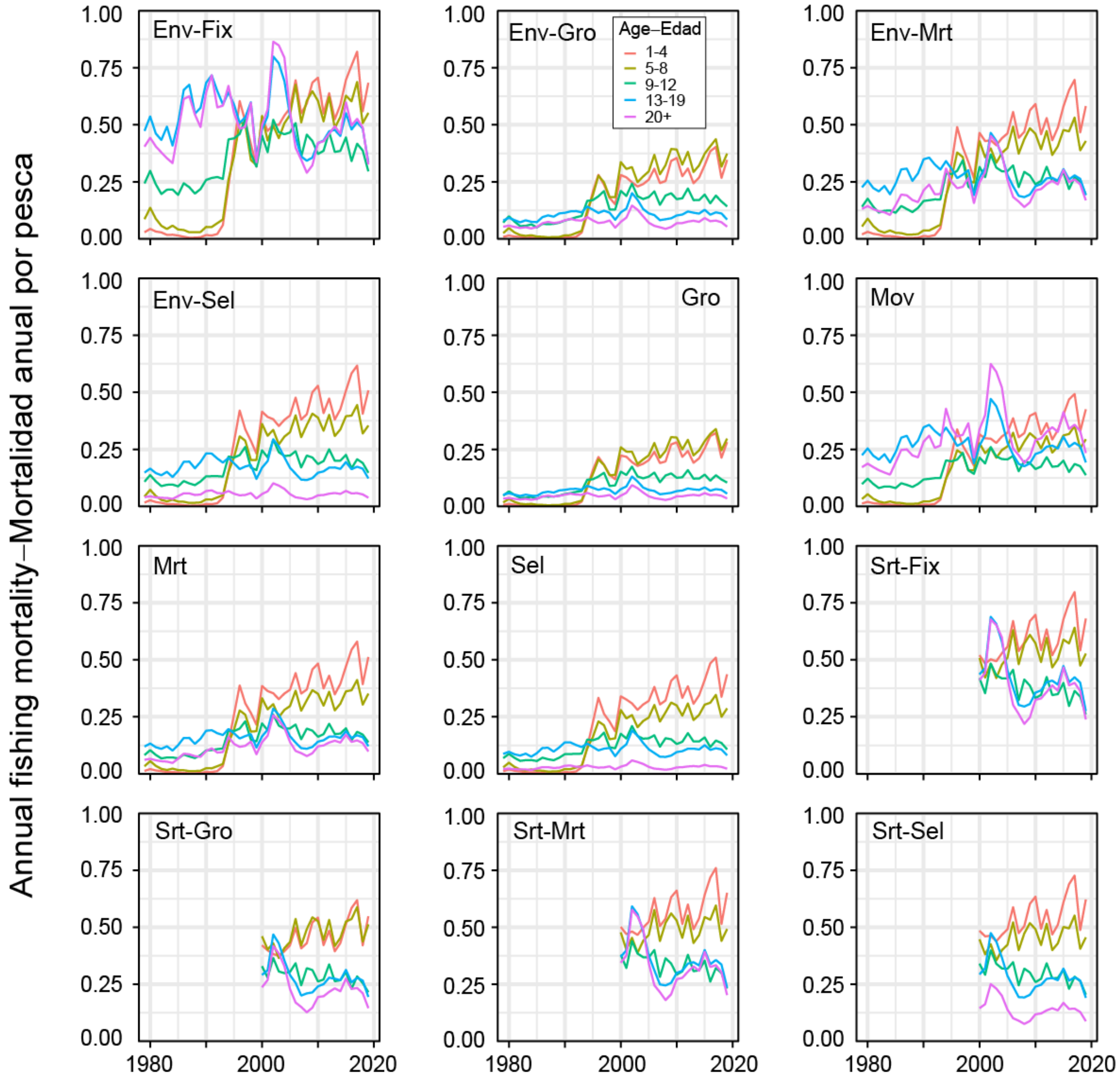
Recruitment is not sensitive to steepness in all reference models

Model results - relative recruitment

Regime shift is apparent in some, but not all, reference models

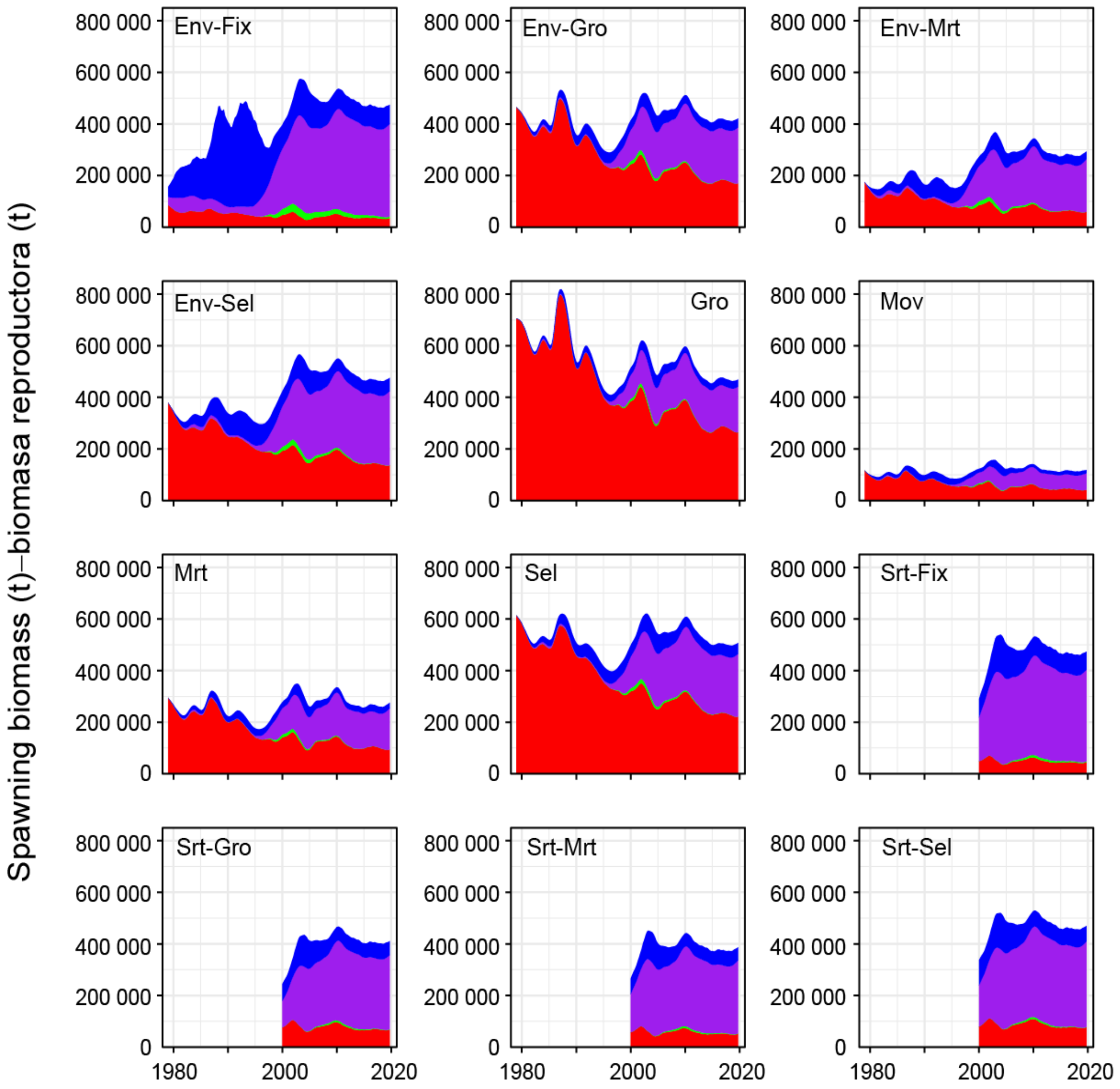


Model results - annual fishing mortality



- Before 1993, the fishing mortality on adult bigeye was larger than that on juvenile bigeye
- Due to the expansion of the OBJ fishery, all models but Model Mov suggest that the fishing mortality on adult bigeye was smaller than that on juvenile bigeye since 2000
- All models suggest the fishing mortality on adult bigeye has been relatively stable since 2010 and that on juvenile bigeye continues to increase

Model results – fishery impact plot



Blue: longline
Purple: purse-seine
Green: OBJ discard

Different models suggest different degrees of impact of the longline and purse-seine fishery, but in general:

- Discard had a small but noticeable impact
- The population before 1993 was primarily impacted by longline fisheries
- The population since 2000 was primarily impacted by purse-seine (i.e., OBJ) fisheries

Summary

Previous benchmark assessment:

- One base-case model with an assumed steepness of 1.0
- Management advice does not include probabilistic statements

This benchmark assessment:

- Explicitly considers model uncertainty
- Developed based on hierarchical hypotheses
- 4 assumed steepness (0.7, 0.8, 0.9, 1.0) X 12 models = 48 model runs

Next step in the risk analysis approach

Described in Maunder et al. 2020 (SAC-11- INF-F):

1. **Identify alternative hypotheses** (‘*states of nature*’) about the population dynamics of the stock that address the main issues in the assessments
   - YFT: SAC-11-J; BET: SAC-11 INF-F
2. **Implement stock assessment models representing alternative hypotheses**
   - YFT: SAC-11-07; BET: SAC-11-06
3. **Assign relative weights to each hypothesis (model)**
   - YFT: SAC-11 INF-J; BET: SAC-11 INF-F
4. **Compute combined probability distributions for management quantities using model relative weights**
   - SAC-11-08

CIAT

IATTC

Thank you