Recruitment

1st External review of modelling aspects in stock assessments of tropical tuna in the eastern Pacific Ocean

6 - 10 Nov 2023 - Videoconference

Key messages on recruitment

- Steepness = 1 for estimation
- Lognormal recruitment deviates with fixed Rsd
- No autocorrelation in estimation
- Use bias correction ramp
- Use dynamic B0
- Include precautionary assumptions about steepness in reference points and management goals

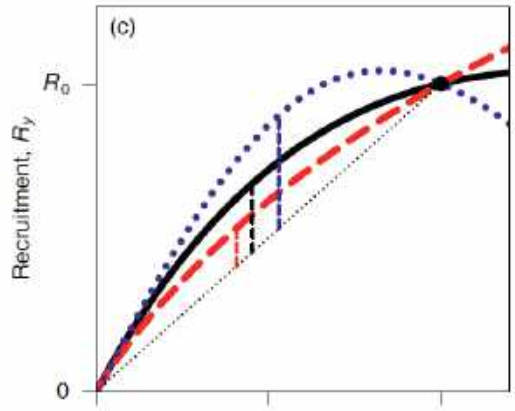
Outline

- What is currently assumed
- Good Practices
- The stock-recruitment relationship
  - Functional form
  - Steepness
  - Spawning biomass definition
- Temporal variation
  - Rsd
  - Bias correction
  - Correlation
- Use in management
  - Average R vs R_0
  - Dynamic B_0
  - Reference points

What is currently assumed

Parameter	YFT	BET	SKJ
Stock-Recruitment	Beverton-Holt fixed steepness = (0.7, 0.8, 0.9, and 1.0)	Beverton-Holt fixed steepness = (0.7, 0.8, 0.9, and 1.0)	Beverton-Holt fixed steepness = 1
Recruitment variation	Quarterly, lognormal, sd fixed at 1.0, penalized likelihood, bias adjustment ramp	Quarterly, lognormal, sd fixed at 0.6, penalized likelihood, bias adjustment ramp, (recruitment regime parameter)	Quarterly, lognormal, sd fixed at 0.6, penalized likelihood, bias adjustment ramp
Spawning biomass	Proportion of mature females, batch fecundity, fraction of females spawning per day, by age (from length)	Proportion mature at length converted into age-at-maturity	Proportion mature and batch fecundity

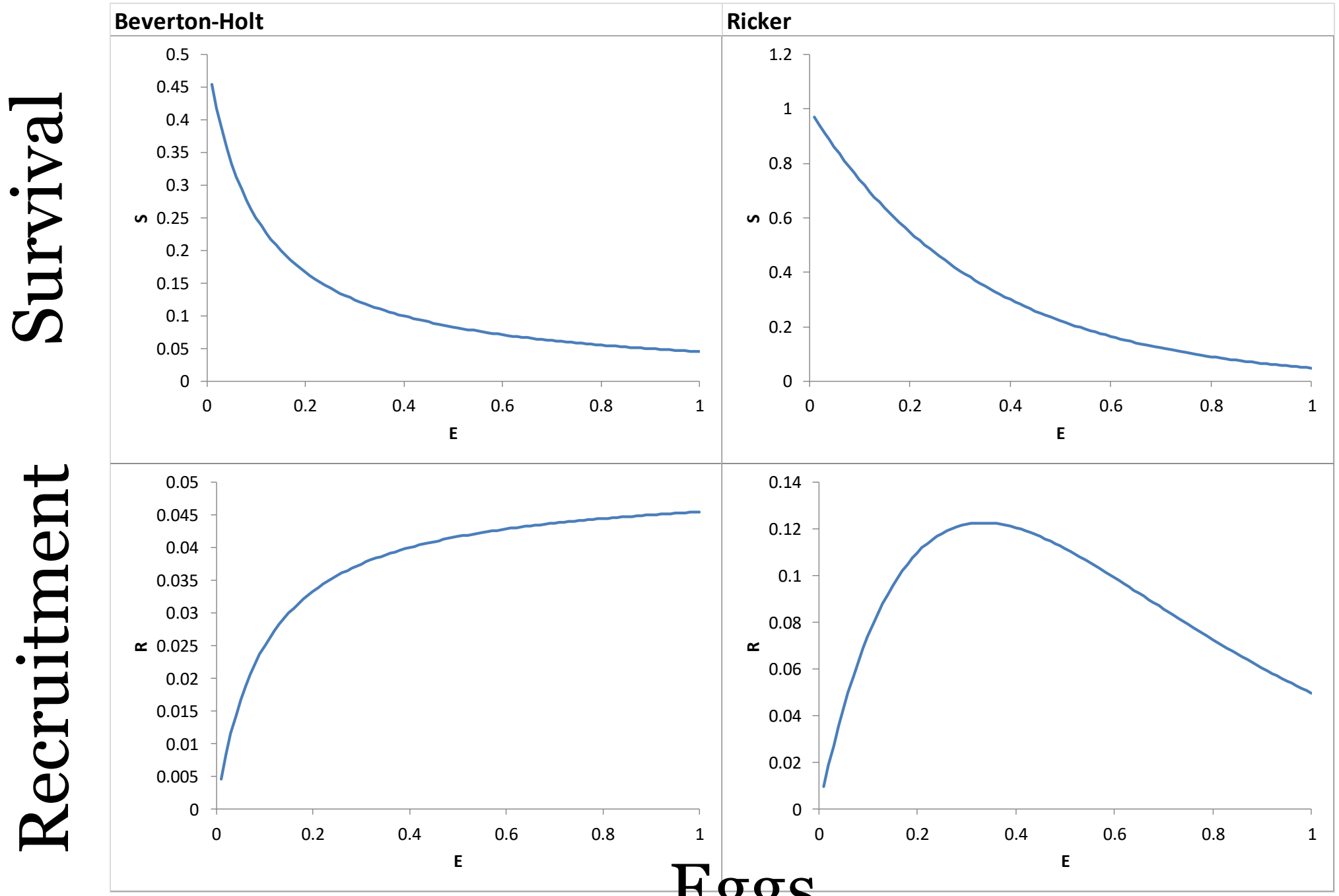
CAPAM Good Practices



- Assume that recruitment is independent of stock size (i.e., h = 1)
- Put precaution in limit reference points
- Target reference points should not solely be related to YPR (i.e., MSY when h = 1) in cases where the fisheries select juveniles
- Autocorrelation should be ignored, the standard deviation fixed at a reasonable value, the bias correction ramp defined in Stock Synthesis applied.
- MSY calculations, projections, and other management quantity calculations should be based on average recruitment over a period where recruitment is estimated relatively precisely and is considered to represent the current or desired conditions.
  - Dynamic reference points that are based on the time series of estimated recruitments do not have this issue.

The holy grail

Functional Form: Does the stock-recruitment relationship make sense?

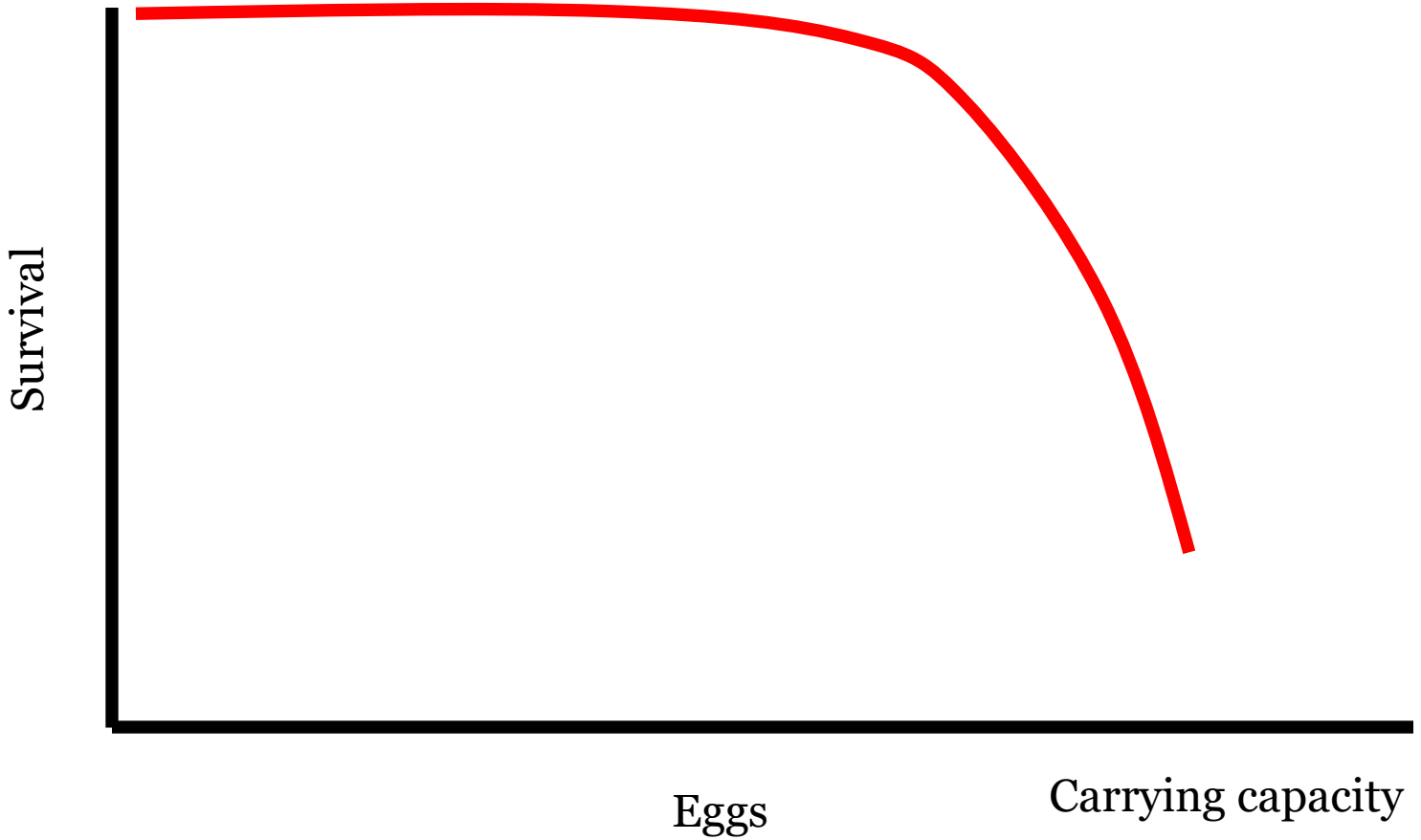

Survival
Recruitment
Eggs
Beverton-Holt
Ricker
S
R
E
0
0.2
0.4
0.6
0.8
1
0.5
0.45
0.4
0.35
0.3
0.25
0.15
0.1
0.05
1.2
0.14
0.12
0.08
0.06
0.04
0.02
0.045
0.035
0.03
0.025
0.01
0.005


It's only a model.

Problems with Beverton-Holt and Ricker stock-recruitment models

- Density dependence is unlikely to be linear
- Density dependence is not continuous at a constant rate
- Density dependence probably occurs at a critical stage/period
- Changes in survival due to density dependence should be strongest close to the carrying capacity
- Despite the above, the general shapes of the Beverton-Holt and Ricker make intuitive sense

Expected survival



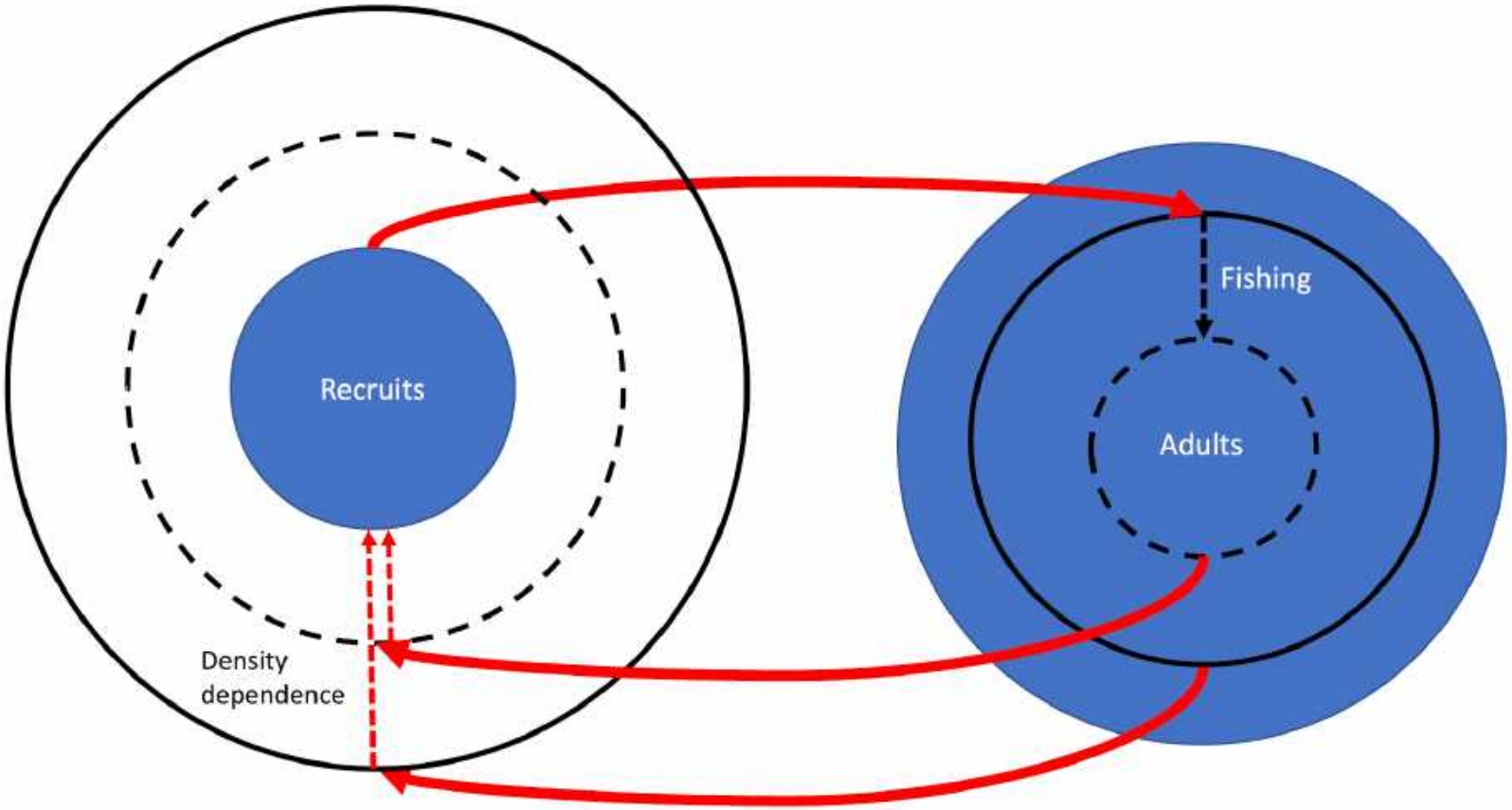
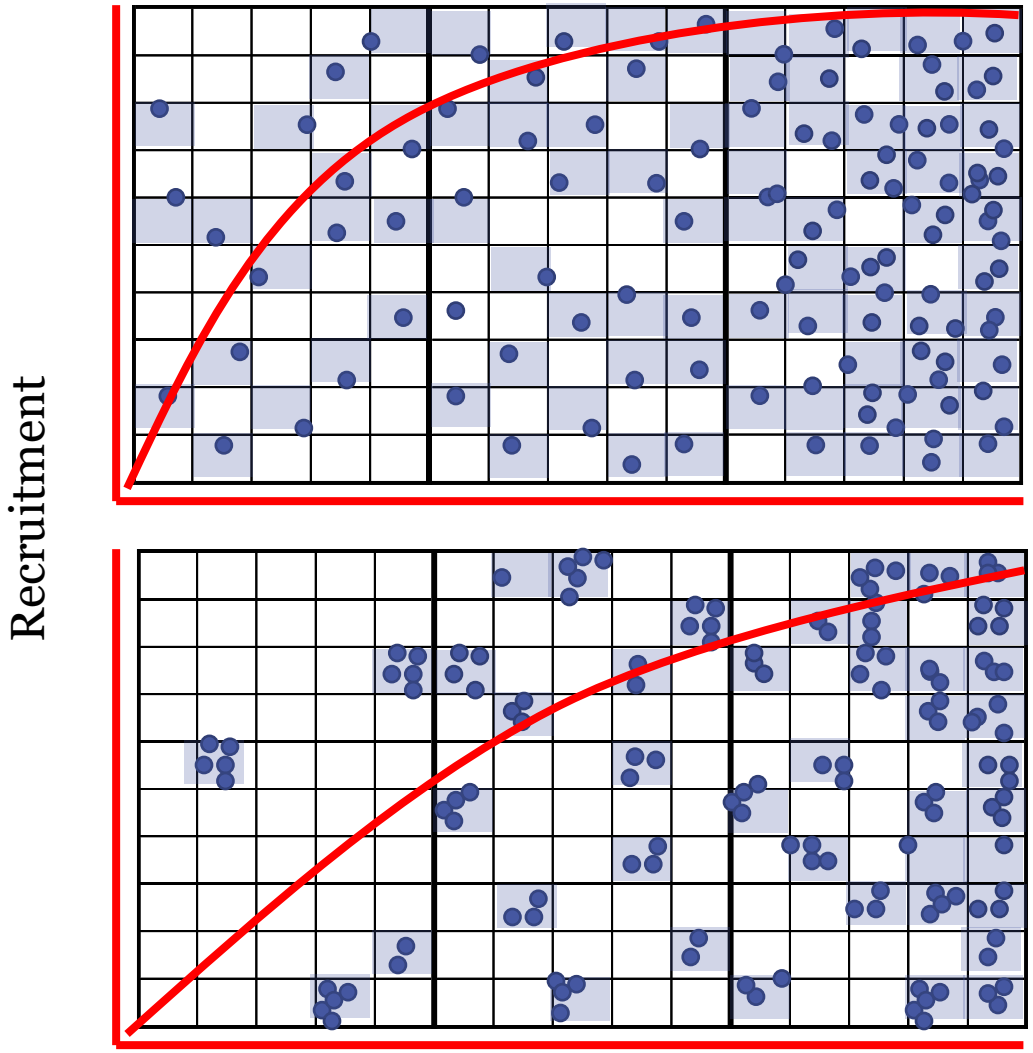


Fig. 6. Illustration of a stock limited by the carrying capacity (i.e., habitat) of recruits. The filled circles represent the carrying capacity, the solid line circles represent the production of adults or recruits, and the dashed line circles represent the production of adults or recruits after fishing. When the dashed circle is larger than the solid circle, more individuals are produced than can be supported by the carrying capacity and variability in the carrying capacity controls the number of individuals for that stage. When the dashed circle is smaller than the solid circle, the carrying capacity does not control the number of individuals and the variability is controlled by the number of individuals entering that stage, which could be controlled by variability in the carrying capacity of the prior stage or by the density-independent mortality or fishing. In cases where the dashed circle could be larger or smaller than the solid circle, the variability could be determined by all sources.

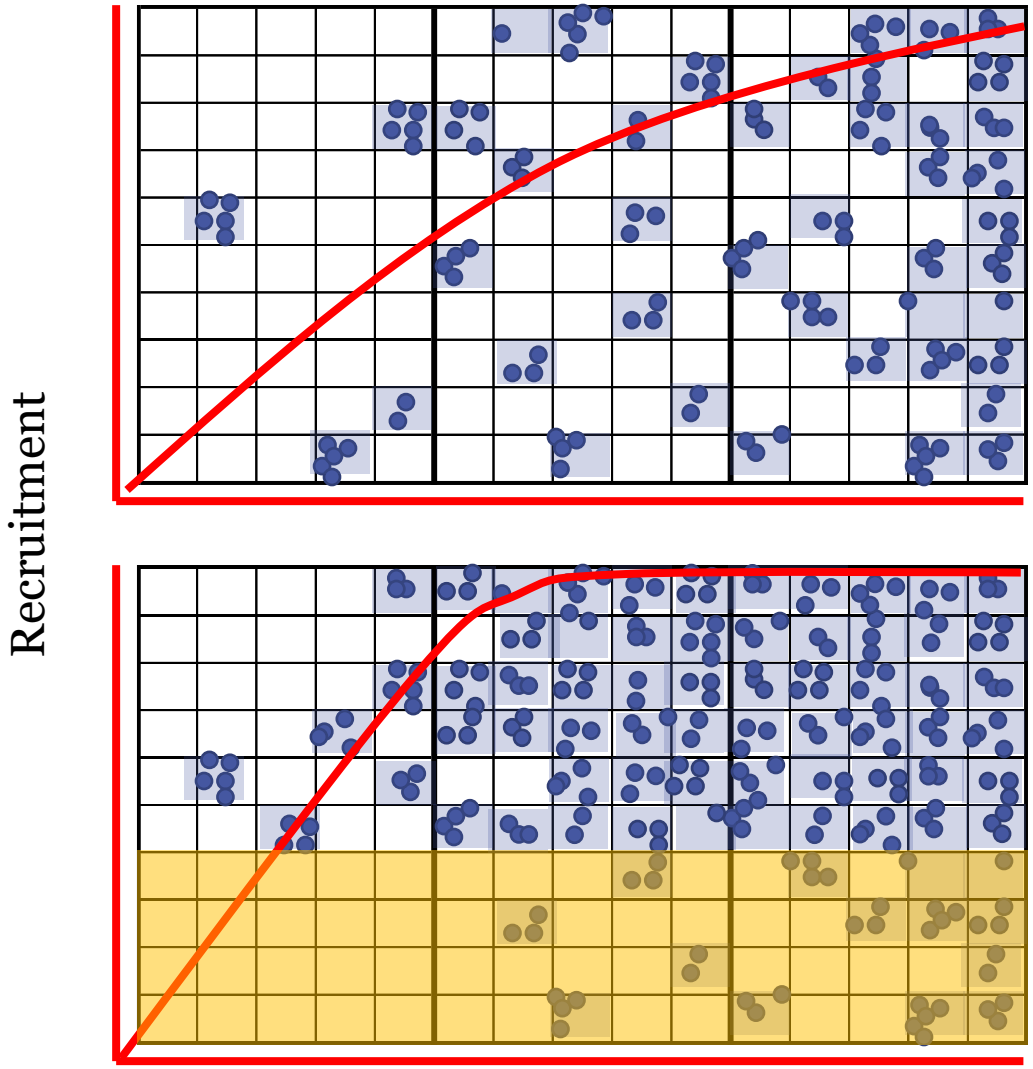
Maunder, M.N. 2022. Stock-recruitment models from the viewpoint of density-dependent survival and the onset of strong density-dependence when a carrying capacity limit is reached. Fis. Res. 249, 106249

A stock–recruitment model for highly fecund species based on temporal and spatial extent of spawning



Maunder, M.N. and Deriso, B.R. (2013) A stock–recruitment model for highly fecund species based on temporal and spatial extent of spawning. Fisheries Research

Expansion into unfavorable spawning habitat



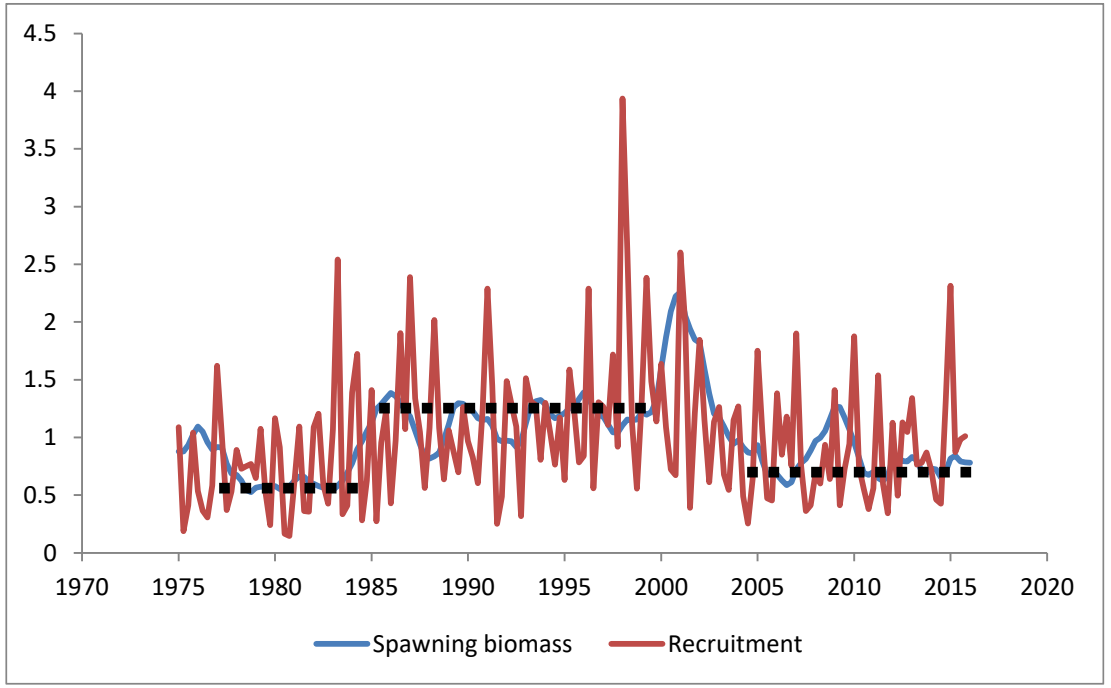
Unproductive habitat

Strong density dependence (h = 1)

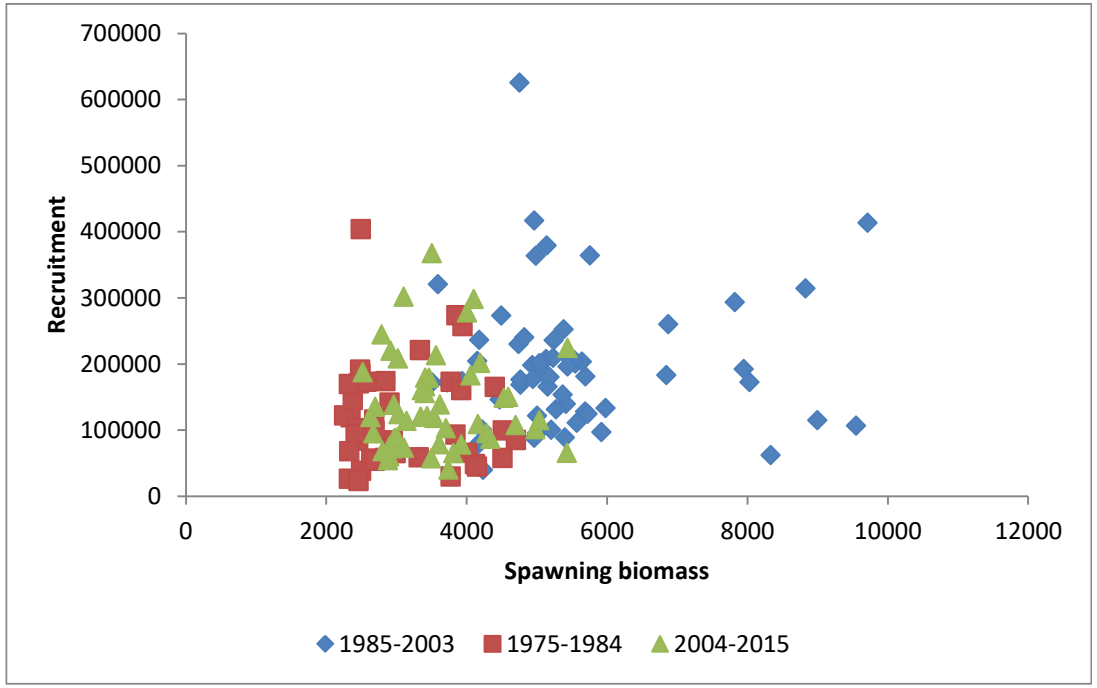
Strong density dependence?

Steepness: Is there a stock-recruitment relationship?

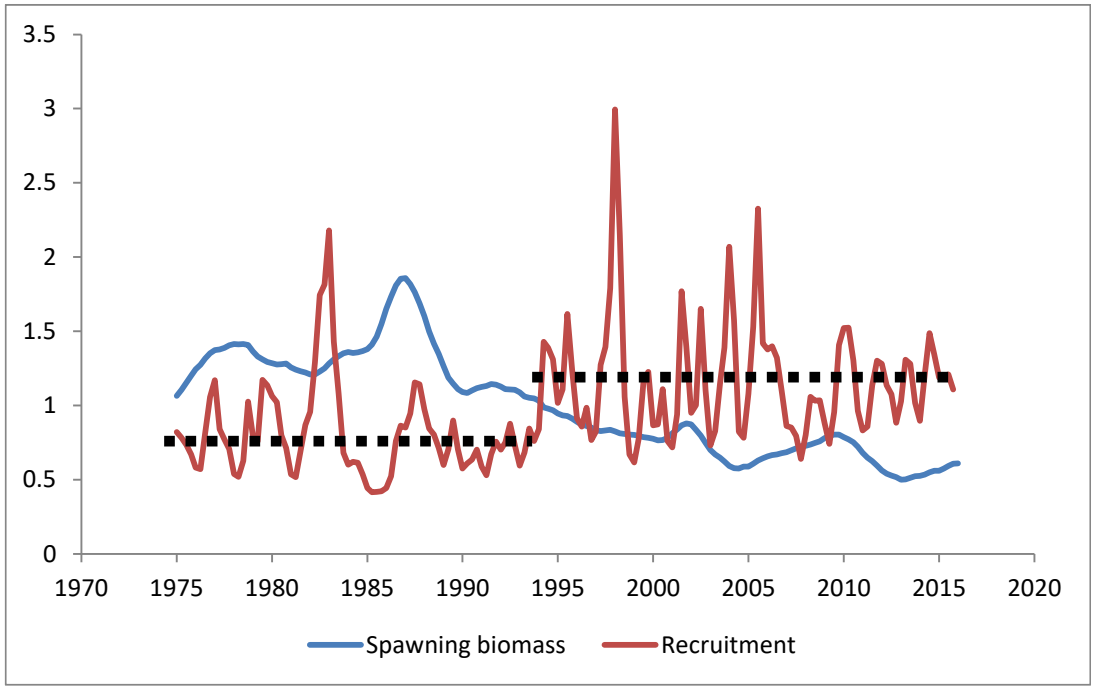
Yellowfin tuna in the EPO



Yellowfin tuna in the EPO



Bigeye tuna in the EPO



Vert-pre et al. 2013. Frequency and intensity of productivity regime shifts in marine fish stocks. PNAS 110: 1779–1784

to year. We found that the abundance hypothesis best explains 18.3% of stocks, the regimes hypothesis 38.6%, the mixed hypothesis 30.5%, and the random hypothesis 12.6%. Fisheries management

- Based on surplus production not just stock-recruitment

Sellinger et al. 2023. The robustness of our assumptions about recruitment: A re-examination of marine recruitment dynamics with additional data and novel methods. Fish. Res. 106862.

the recruitment time series for regime shifts for 432 stocks. Our results indicated that 57% of stocks did not have a significant correlation between spawning biomass and recruitment over the observed biomasses. Environmental conditions played a larger role in recruitment variation than spawning biomass. The presence, location,

Steepness: Can we estimate the stock-recruitment relationship?

Bias in estimating steepness

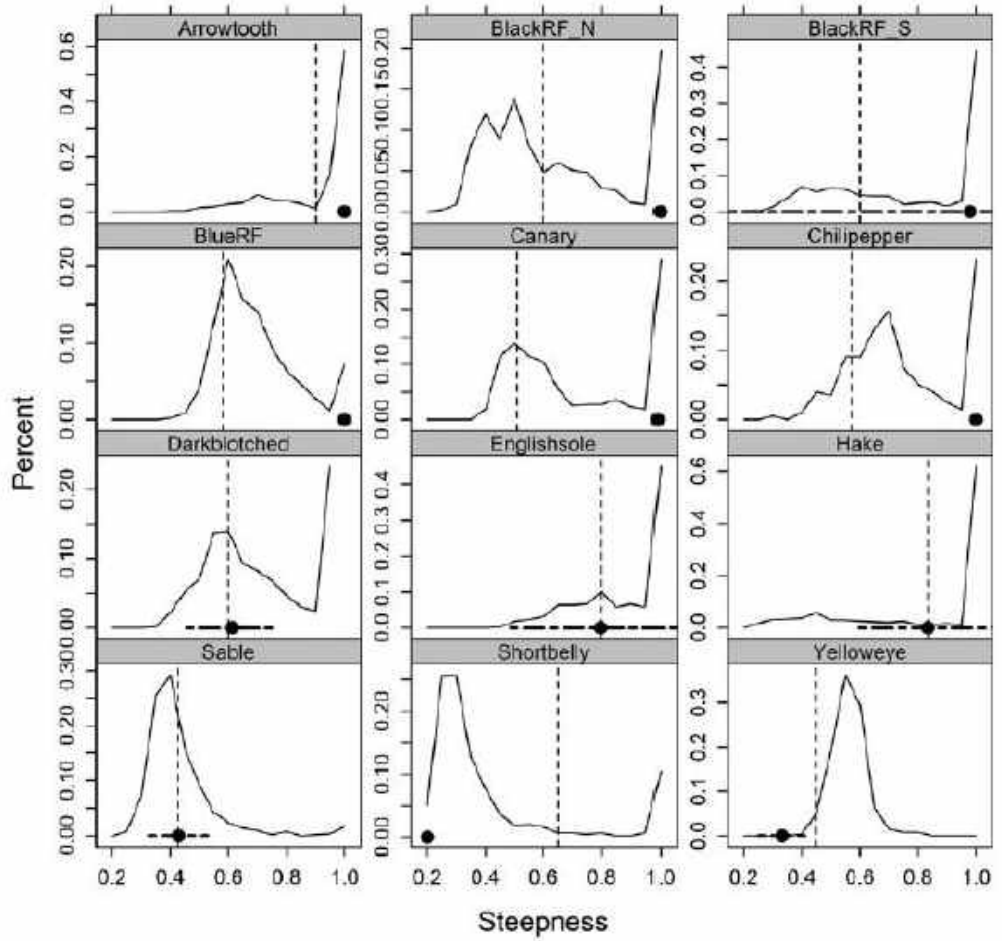


Fig. 4. Distribution of steepness estimated from the simulated data where converged simulations were selected based on the positive definite Hessian matrix. Dashed lines represent true or assumed values of steepness from original assessments. Dots represent estimated values of steepness from original data sets and bold dash lines represent confidence intervals around estimates.

Lee et al. (2012) Can steepness of the stock-recruitment relationship be estimated in fishery stock assessment models? Fisheries Research 125-126: 254-261.

Temporal variation

Temporal variation

- Lognormal

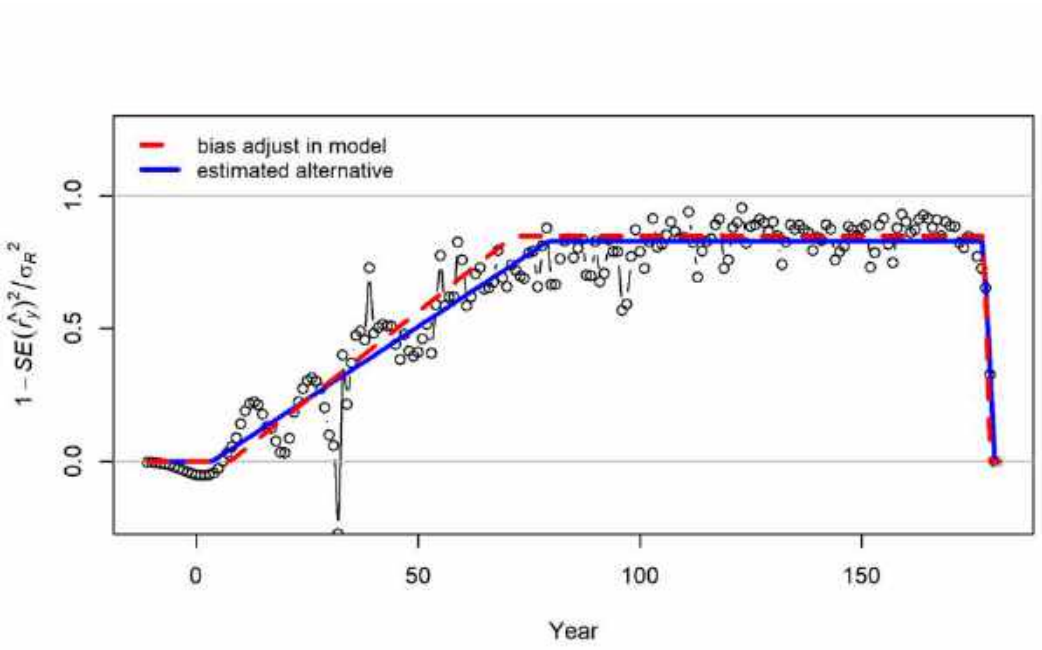
$$R_t = f(B_t, \ldots) e^{\varepsilon_t - 0.5\sigma^2}$$

Temporal variation

- Estimates of Rsd require integration
- Penalized likelihood requires adjustment to the bias correction when there is not “full” data

$$R_t = f(B_t, \ldots)e^{\varepsilon_t - 0.5\sigma^2}$$

$$- 0.5b_t\sigma^2$$



Temporal variation

- Estimates of Rsd require integration
- Penalized likelihood requires adjustment to the bias correction when there is not “full” data
- Does Rsd make a difference in the estimates or just in management advice?
- Correlation is difficult to estimate and probably requires integration

Use in management

- Average R vs R0
  - Getting the bias correction wrong can lead to bias in management quantities that are related to the stock-recruitment relationship parameters (e.g., those that are a function of virgin recruitment such as current depletion)
  - Use average recruitment over the appropriate period for calculating management quantities
- Dynamic B0

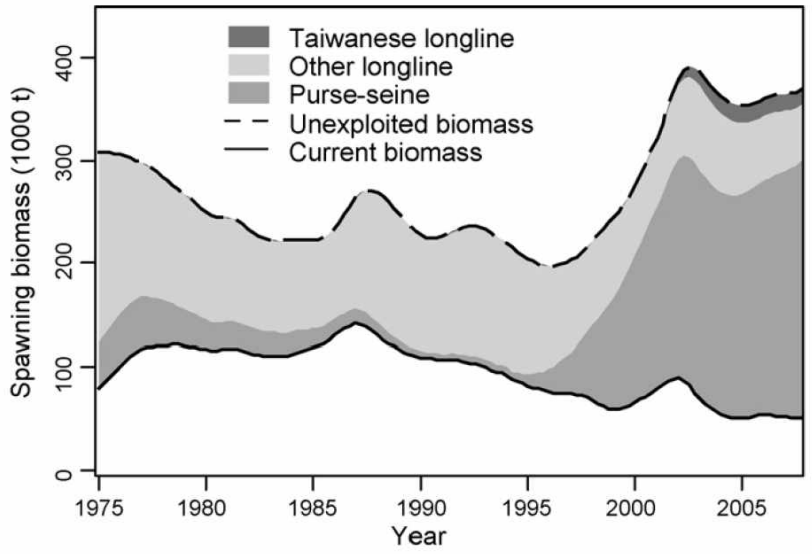
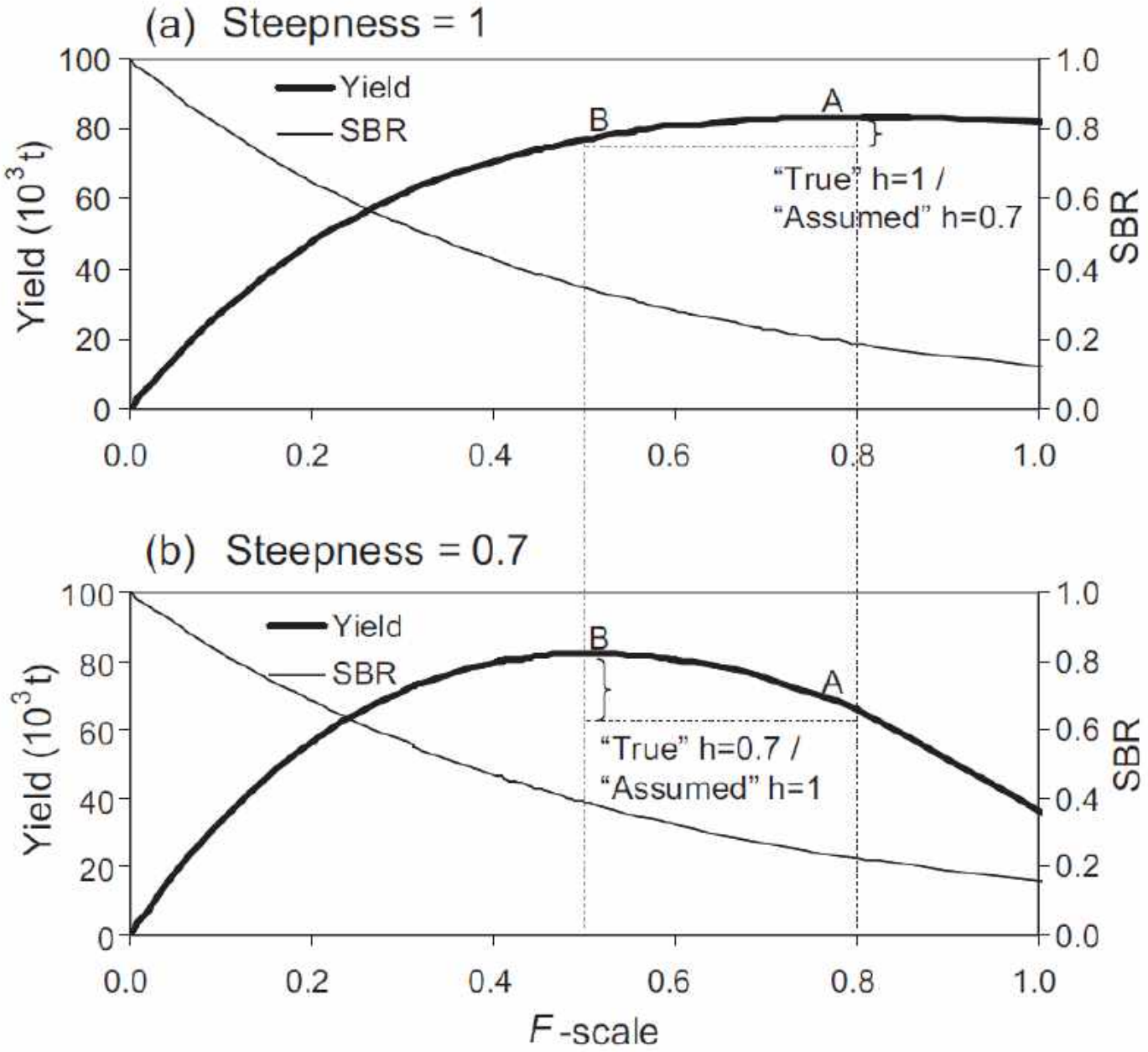


Fig. 2. Trajectory of the spawning biomass of a simulated population of bigeye tuna that was unexploited (dashed line) and that predicted by the stock assessment model (solid line). The shaded areas between the two lines show the portions of the impact attributed to each fishing method.

Management

- Stock-recruitment Important for
  - MSY based reference points
  - Depletion level



Zhu et al. 2012. Implications of uncertainty in the spawner-recruitment relationship for fisheries management: an illustration using bigeye tuna (Thunnus obesus) in the eastern Pacific Ocean. Fisheries Research, 119–120: 89–93.

Management

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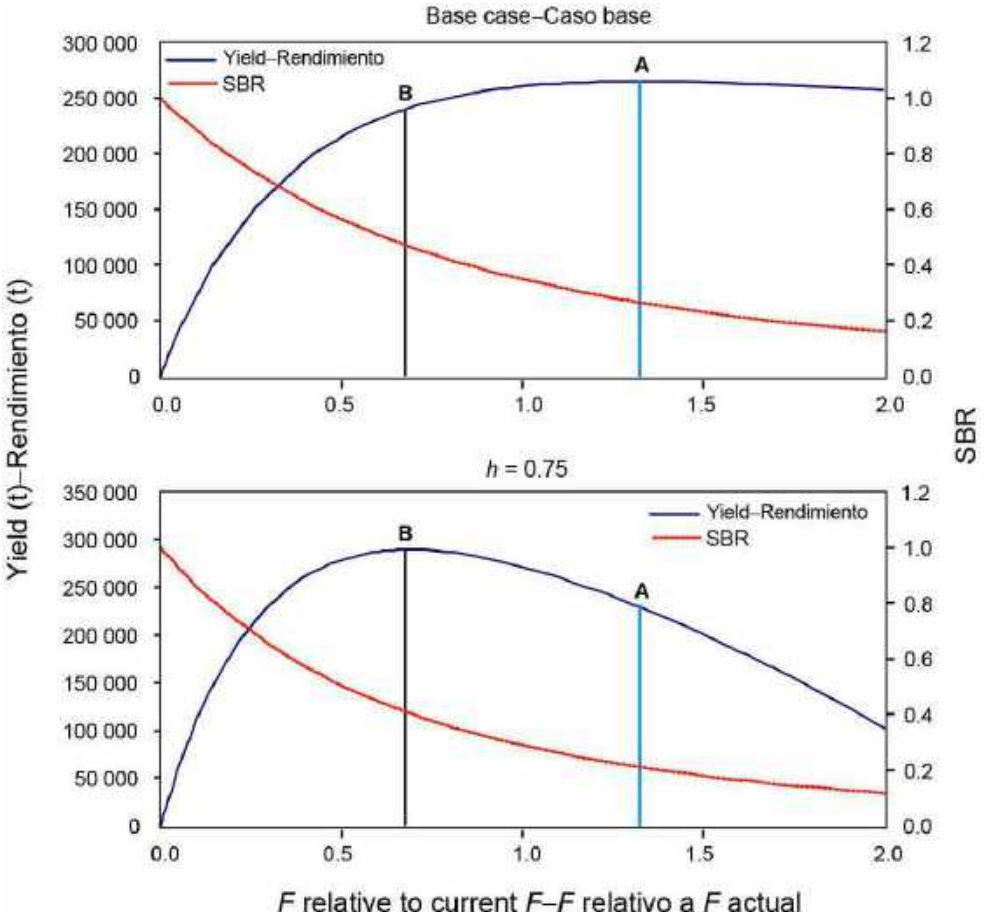

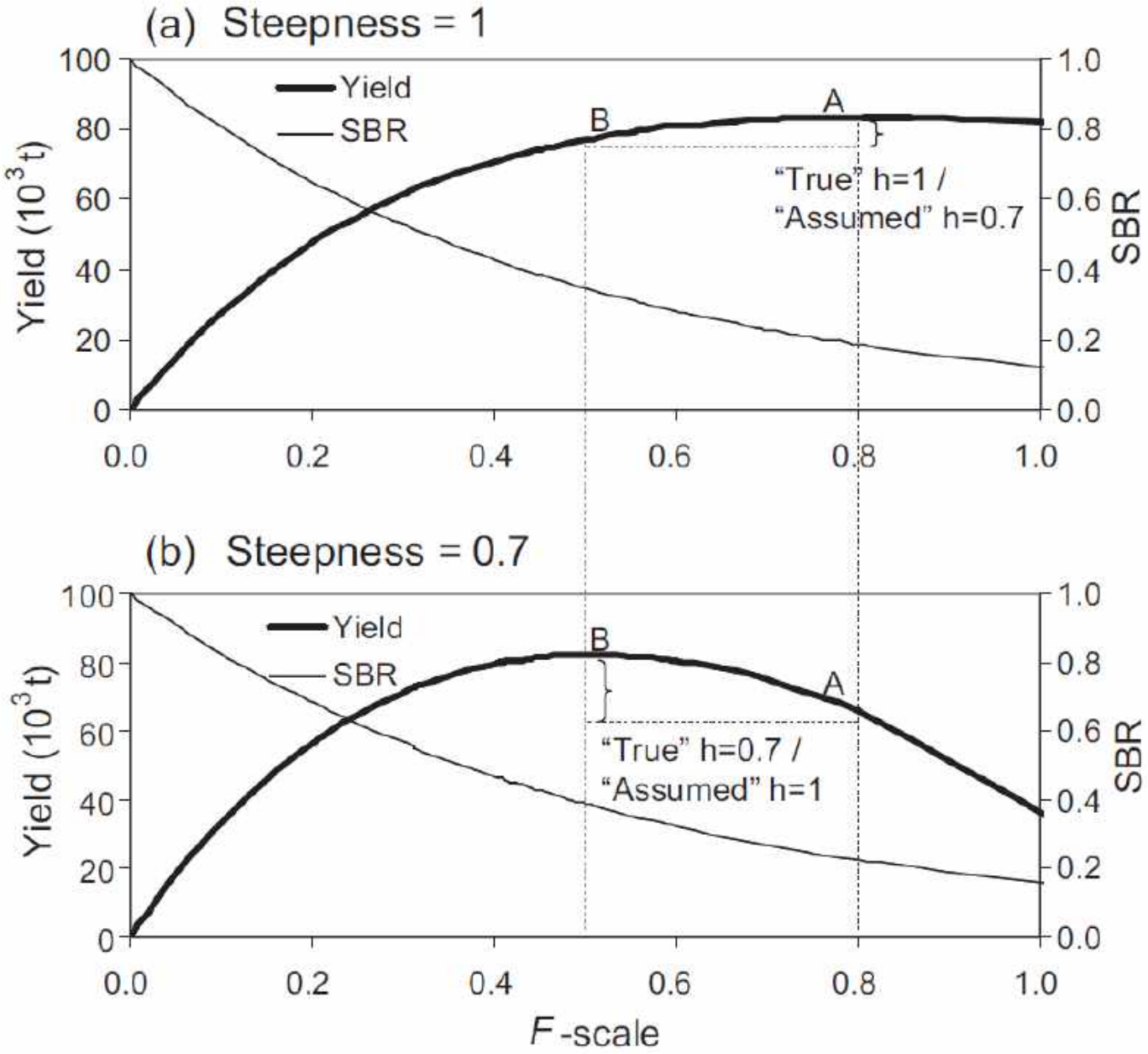

Zhu et al. 2012. Implications of uncertainty in the spawner-recruitment relationship for fisheries management: an illustration using bigeye tuna (Thunnus obesus) in the eastern Pacific Ocean. Fisheries Research, 119–120: 89–93.

Assume steepness = 1 otherwise it will drive you mad

Key messages on recruitment

- Steepness = 1 for estimation
- Lognormal recruitment deviates with fixed Rsd
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- Use bias correction ramp
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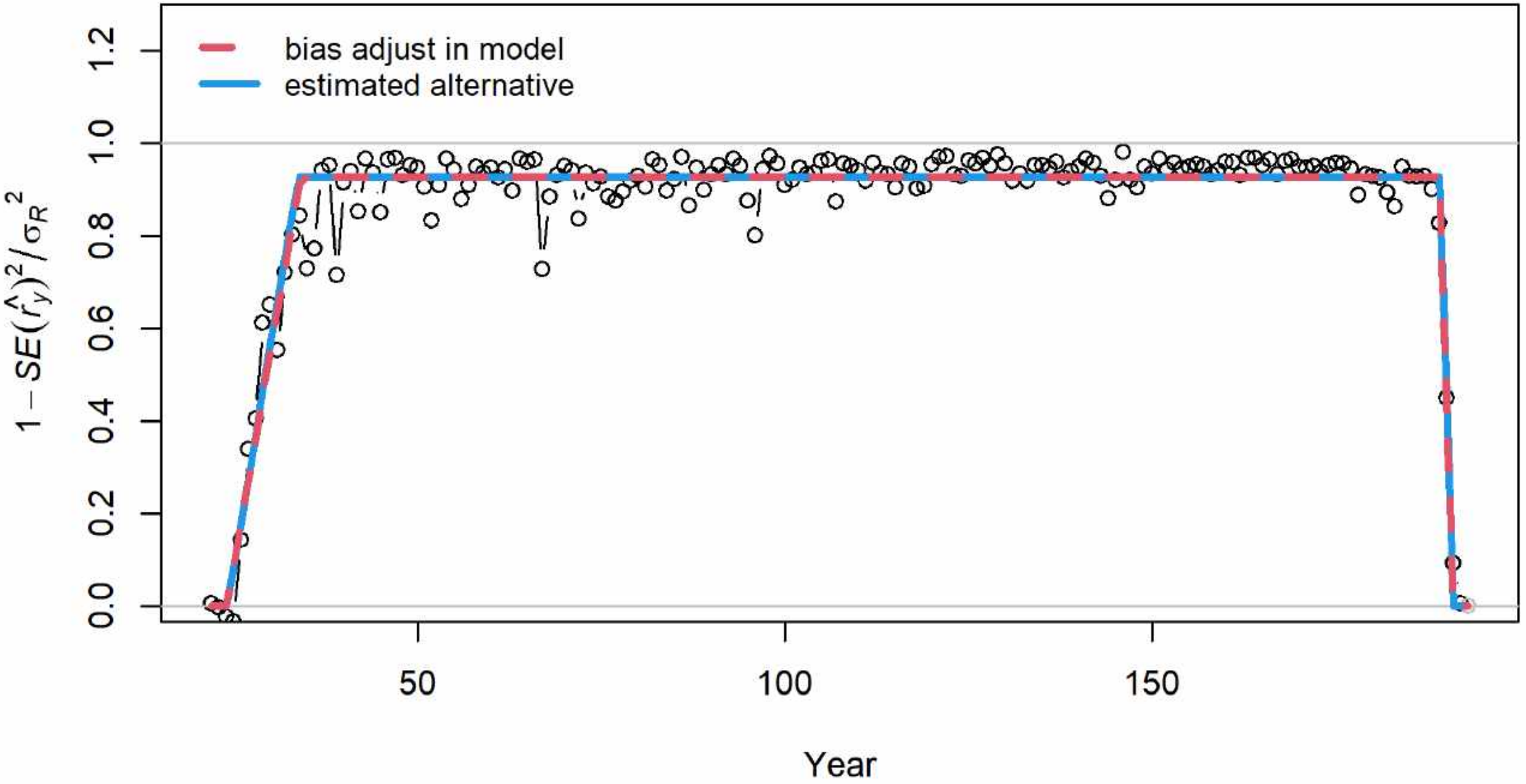
- Include precautionary assumptions about steepness in reference points and management goals

CIAT

IATTC

Yellowfin


bias adjust in model
estimated alternative
$1 - SE(\hat{r_y})^2 / \sigma_R^2$
0.0
0.2
0.4
0.6
0.8
1.0
1.2
50
100
150
Year

Spanish
English

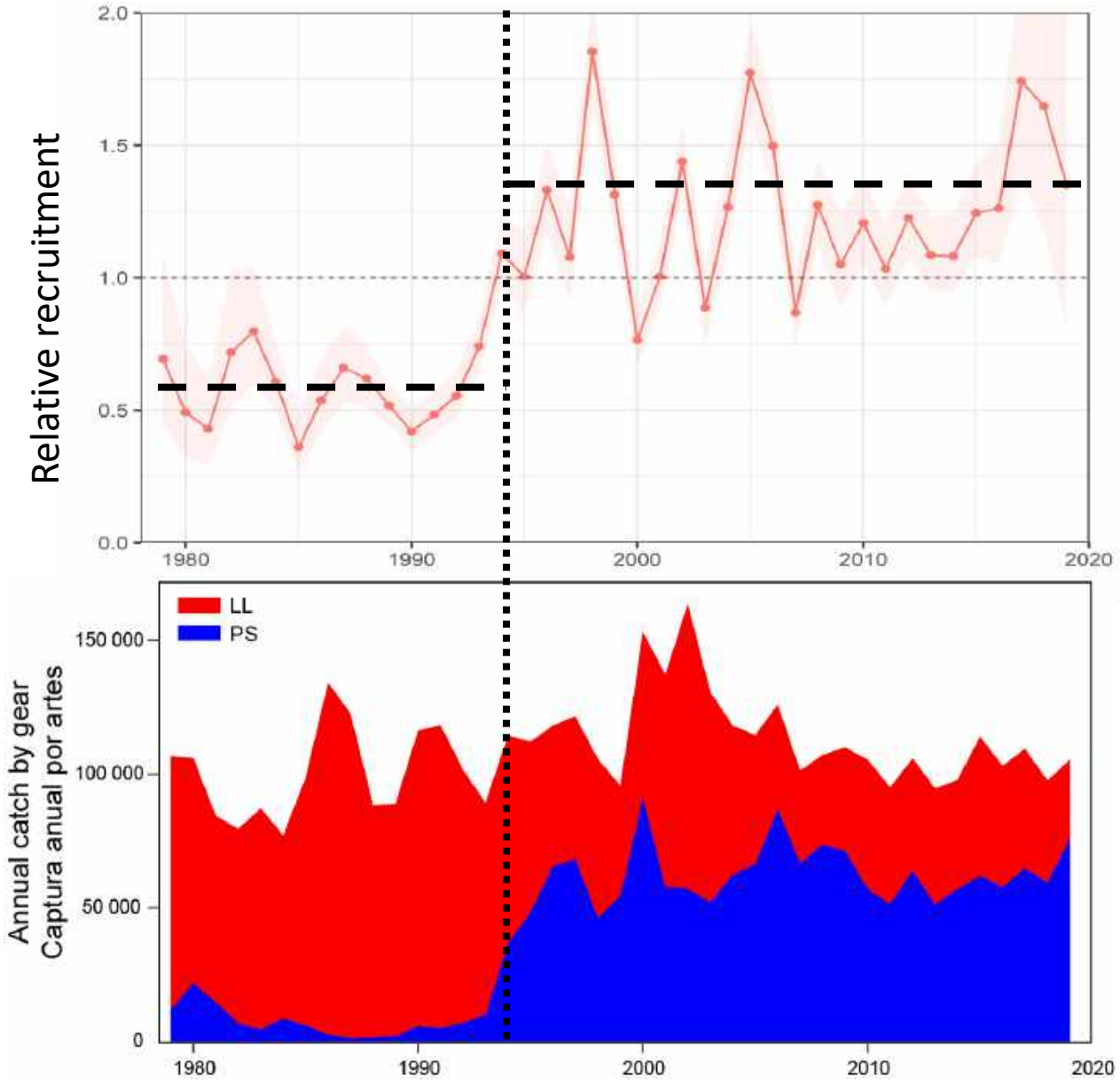
Spanish
English

From Haikun

Recruitment: overview

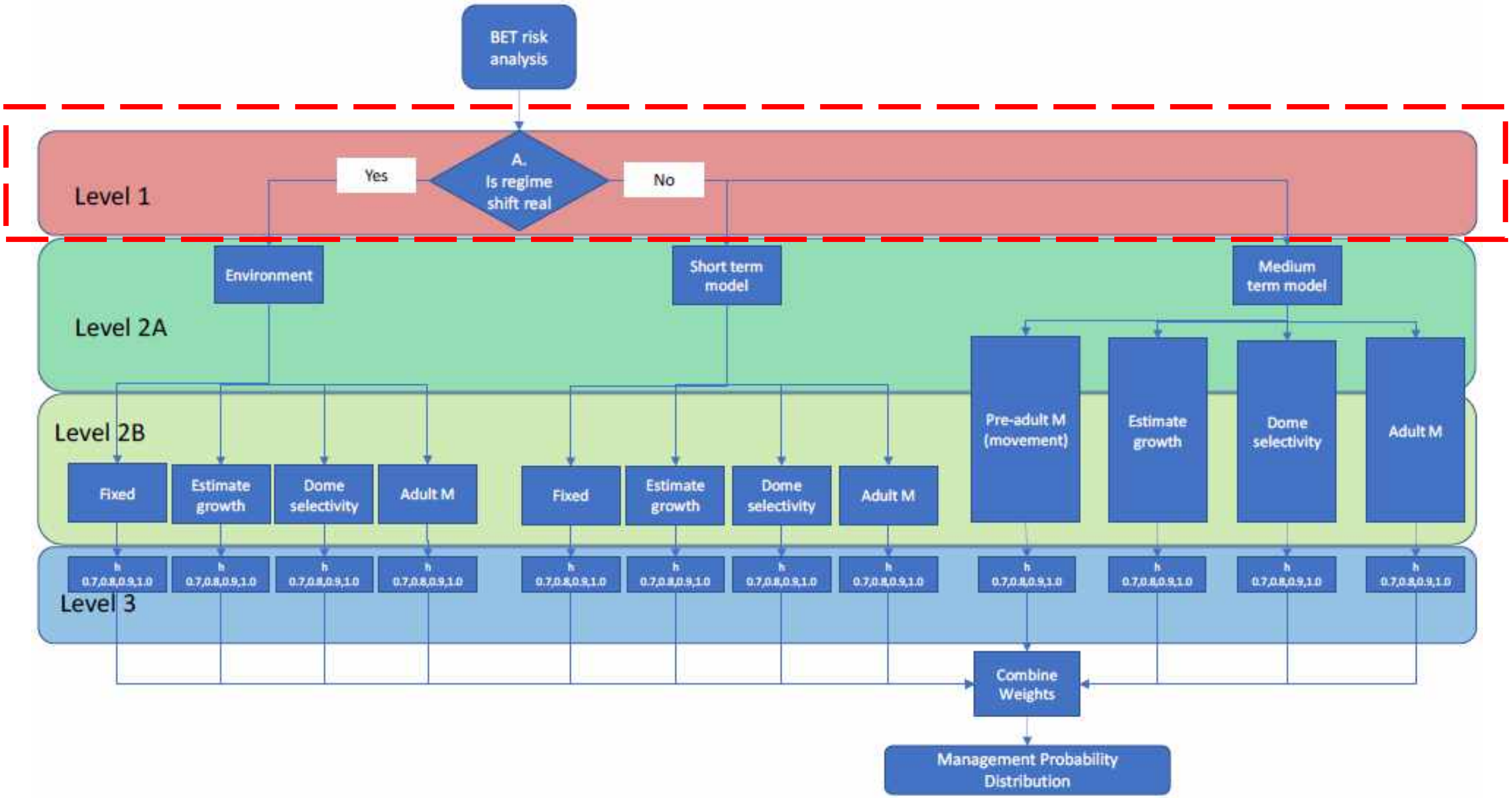
- Recruitment estimated for each quarter
- Main recruitment devs: 1979-2020 (not forced to sum to 0)
- Early recruitment devs: 1971-1978
- Steepness varies from 0.7 to 1
- Sigma R = 0.6
- Bias-correction is applied to recruitment estimates

Recruitment: issue in the 2020 bigeye assessment

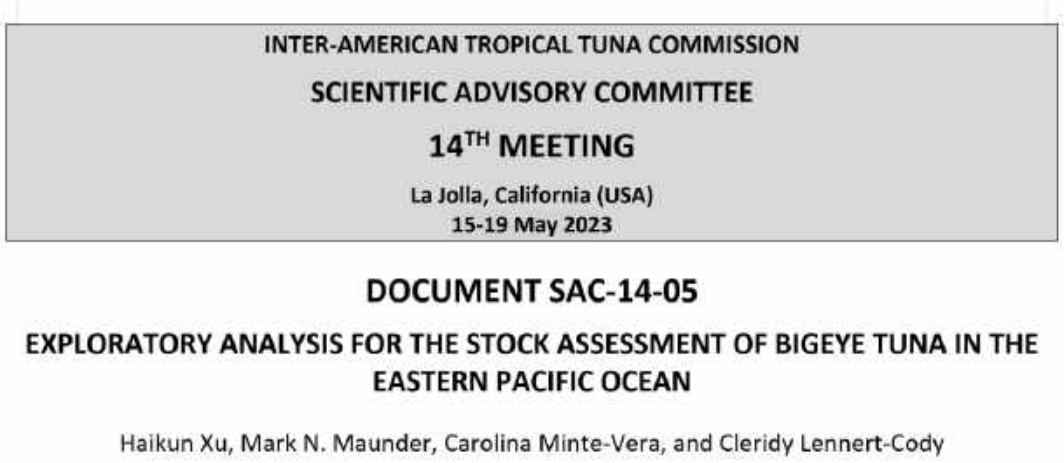


The regime shift in recruitment occurred when the OBJ fishery started to expand in the EPO - likely due to model mis-specification

Hypotheses for the bigeye 2020 assessment



The R regime shift in the new model



INTER-AMERICAN TROPICAL TUNA COMMISSION

SCIENTIFIC ADVISORY COMMITTEE

14TH MEETING

La Jolla, California (USA)
15-19 May 2023

DOCUMENT SAC-14-05

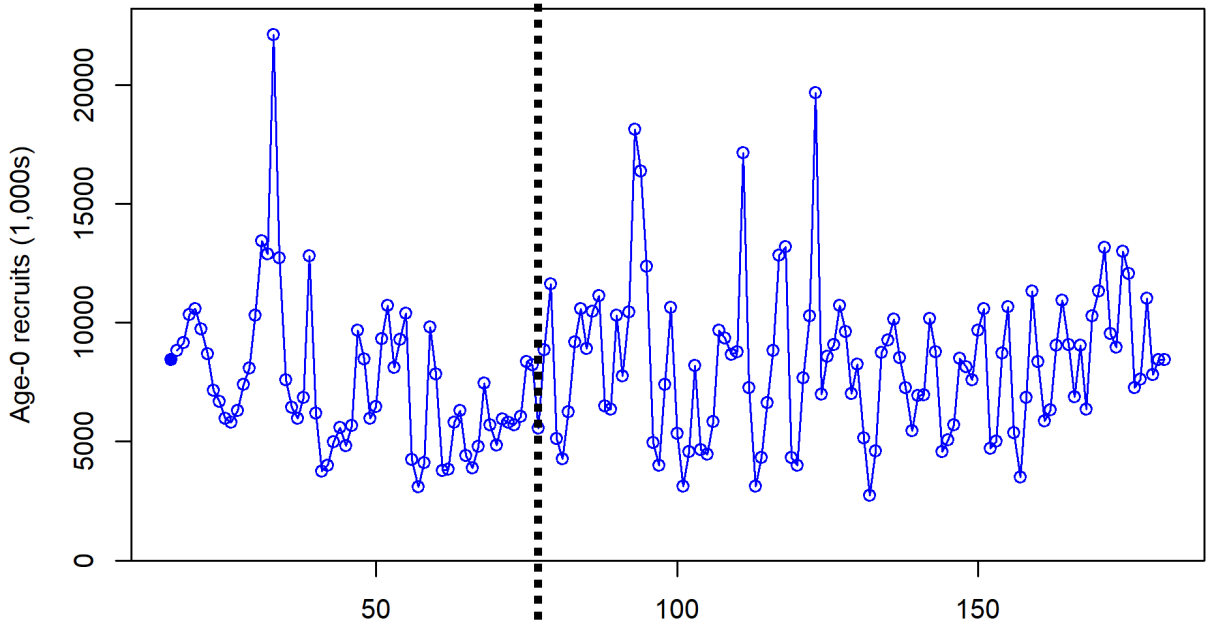
EXPLORATORY ANALYSIS FOR THE STOCK ASSESSMENT OF BIGEYE TUNA IN THE EASTERN PACIFIC OCEAN

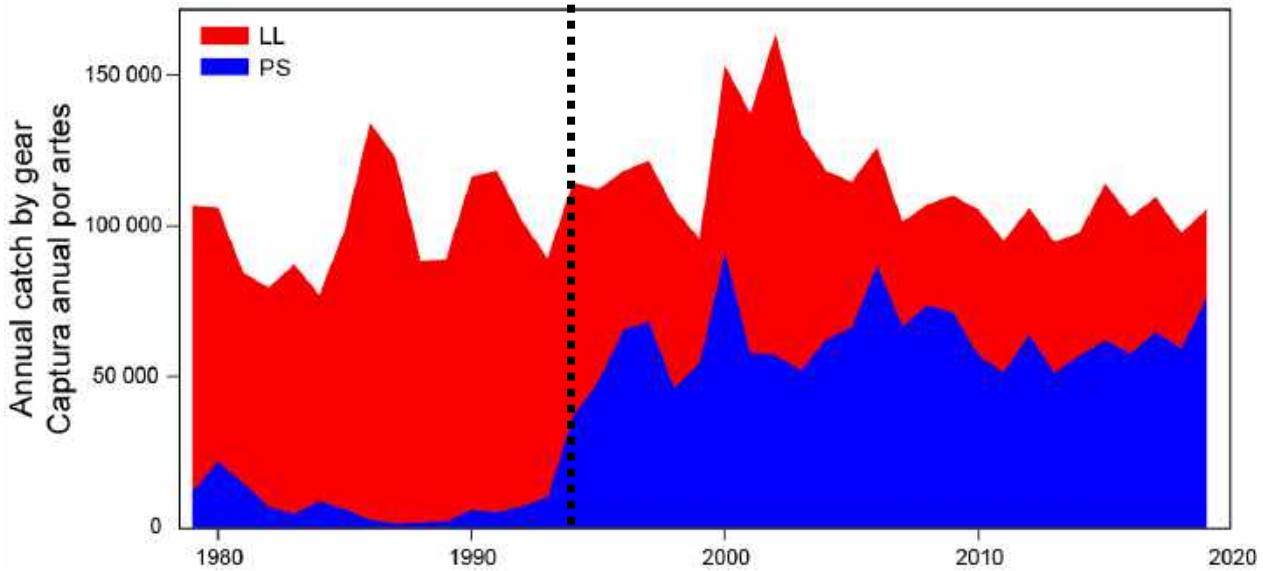
Haikun Xu, Mark N. Maunder, Carolina Minte-Vera, and Cleridy Lennert-Cody

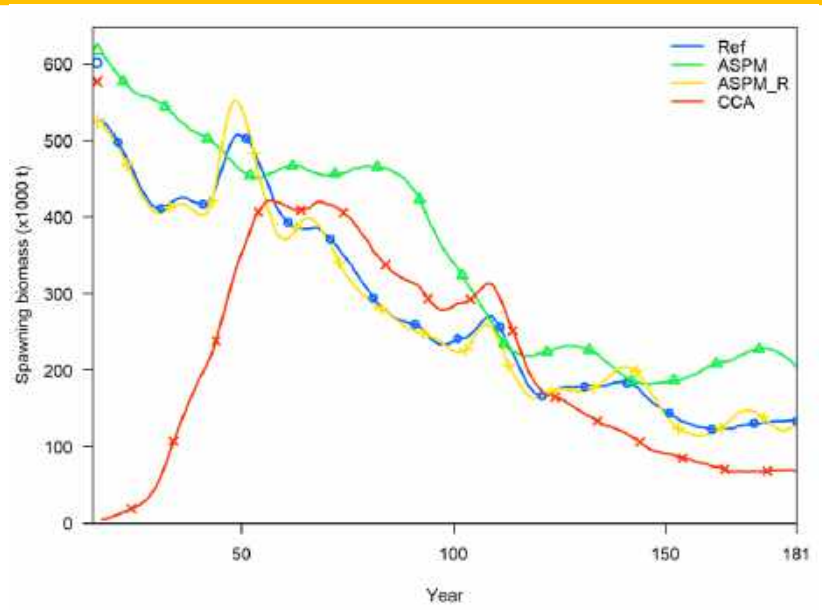
Six changes are made to the bigeye model in a stepwise manner: bridging analysis

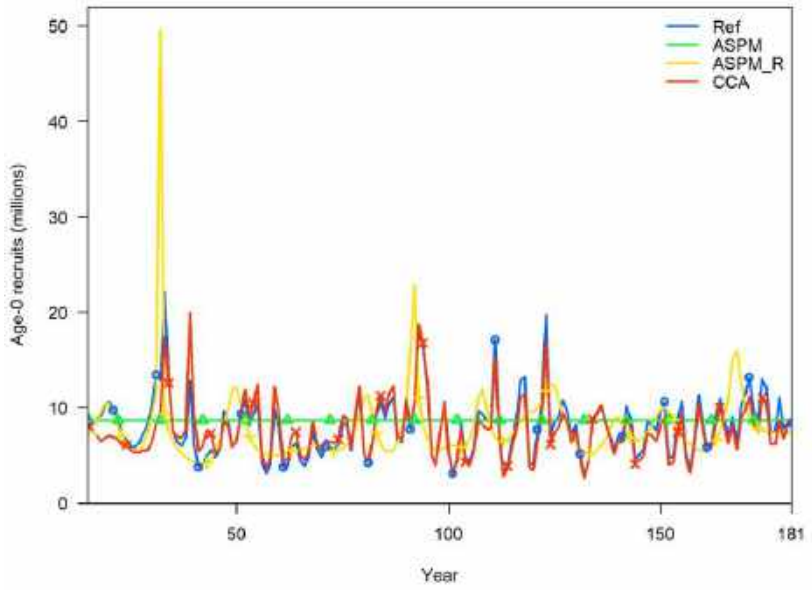
Model	Component	Description
M0		SAC11 model (Env-Fix)
M1	Fishery definition	New fishery definitions and remove poorly-sampled LF
M2	Survey fleet	Remove the time block in the abundance index and associated length composition data
M3		New abundance index and the associated LF
M4	Fishery fleets	Add Korean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

The R regime shift is not obvious in the new model









Main reasons for the reduced regime shift in R

Model	Component	Description
M0		SAC11 model (Env-Fix)
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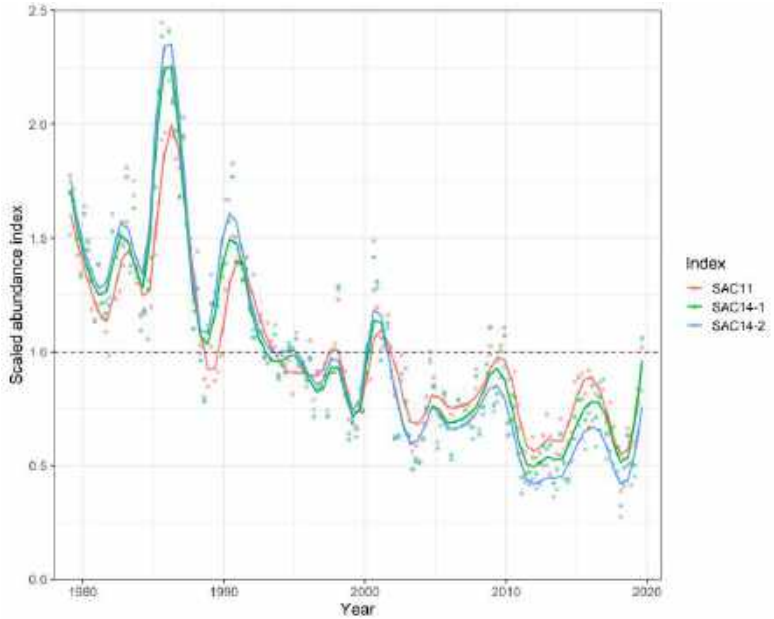
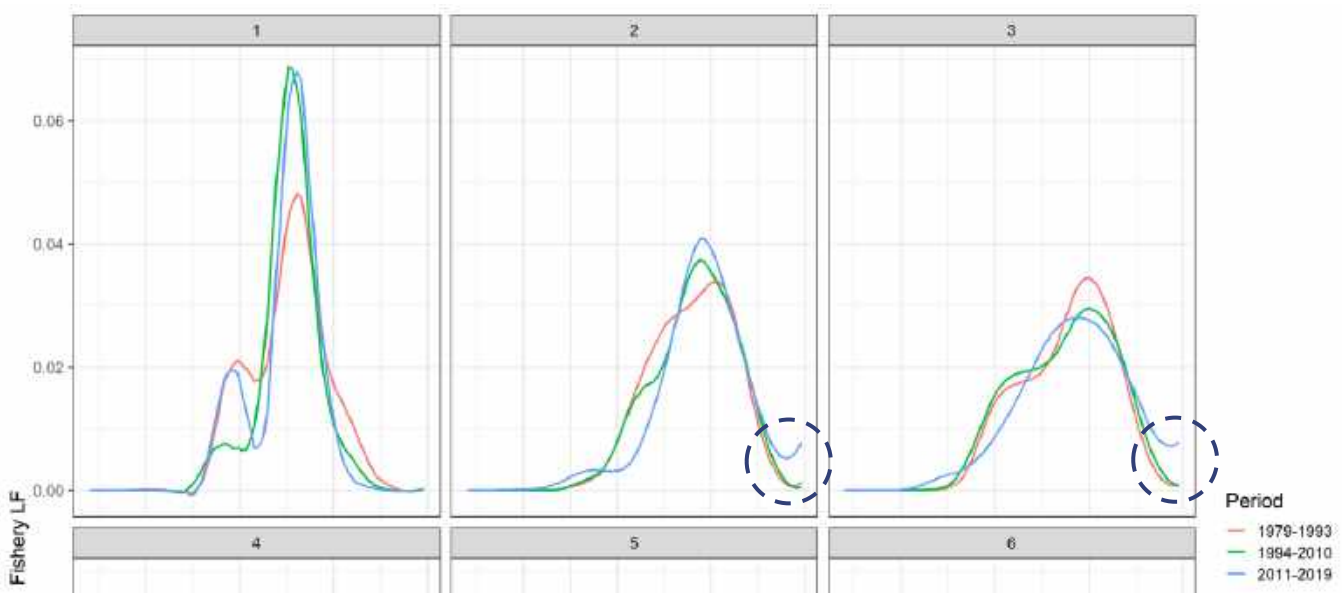
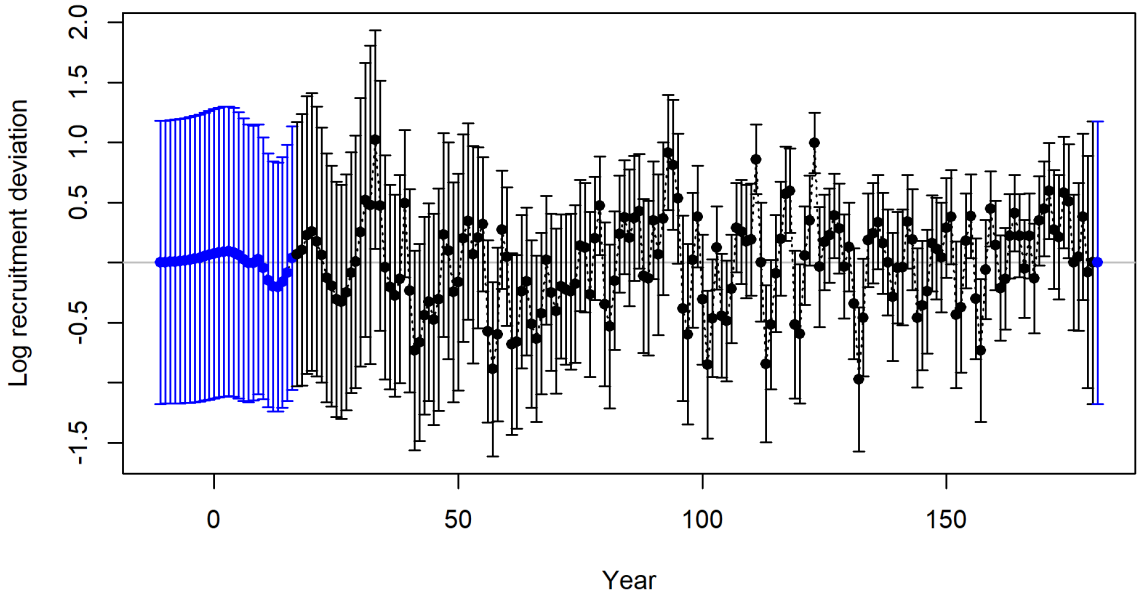
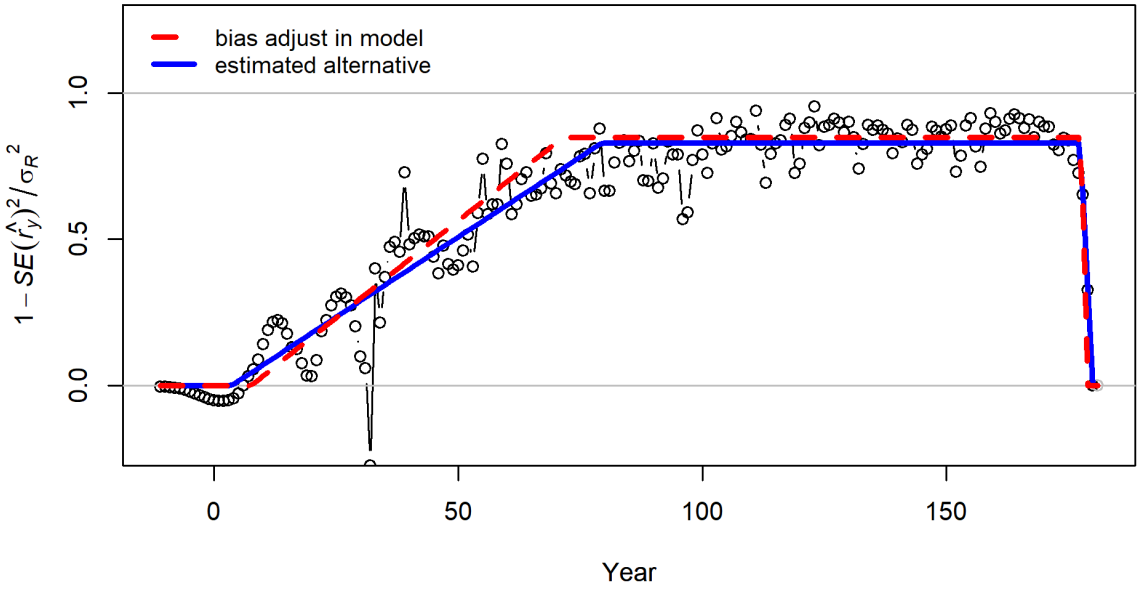




Recruitment in the ancestral model





Preguntas -Questions