Growth

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 growth

- Use a flexible growth curve
- Estimate growth inside the stock assessment model
- Integrate age-length into the stock assessment as data conditional age-at-length
- Length-increment data should be analyzed outside the model and the results used to create priors to include in the assessment model (until possible to include it in the model)
- Use sex specific growth
- Need to consider spatial variation in growth and how it might be affecting the results
- Estimate Lsd inside the model

Parameters

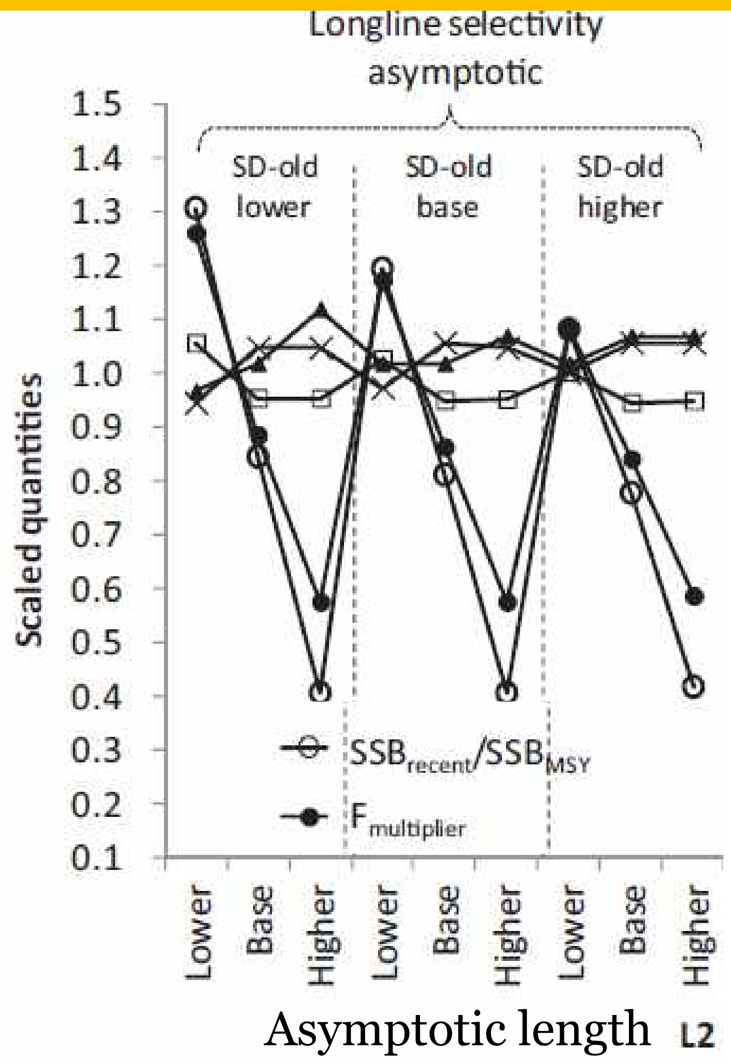
Parameter	YFT	BET	SKJ
Growth	Richards fixed parameters from previous assessment, (estimated)	Richards, fixed based on otolith and tagging, (estimated)	Growth cessation model, fixed based on tagging, Linf and L1 (2 quarters) assumed
Variation of length-at-age	Normal, coefficient of variation of 7.5%	Normal, sd assumed proportional to mean length, sd0 estimated and sd40 fixed (estimated)	Normal, linear relationship between CV and length, fixed at arbitrary values
Length-weight	Allometric Fixed (Wild 1986)	Allometric Fixed, Nakamura and Uchiyama (1966)	Allometric Fixed, (Hennemuth, 1959)

Good Practices

- Estimate growth inside the stock assessment model if you can
- Integrate age-length into the stock assessment as data conditional age-at-length to account for length-based sampling and length-based selectivity
- Length-increment data should be analyzed outside the model and the results used to create priors to include in the assessment model (until possible to include it in the model)
- Always analyze the data outside the model for comparison
- Use sex specific growth
- Model time varying growth if there is adequate data
- Deal with spatial variation by modeling separate populations (or in specific cases using age specific selectivity) until spatial structure and movement is understood.

Growth

- Often good information for most frequently caught fish and most abundant ages
  - YPR
  - ASPM
- If length comp data are influential, then growth of all fish, particularly old, is important
- Need to get growth right, including variation off length at age



Zhu et al.2016. Estimation of growth within Stock Synthesis models: Management implications when using length-composition data. Fisheries Research, 180: 87-91.

Growth

- Estimate inside stock assessment to deal with age- (ontogenetic movement) or length-based (selectivity or length categories) sampling factors.

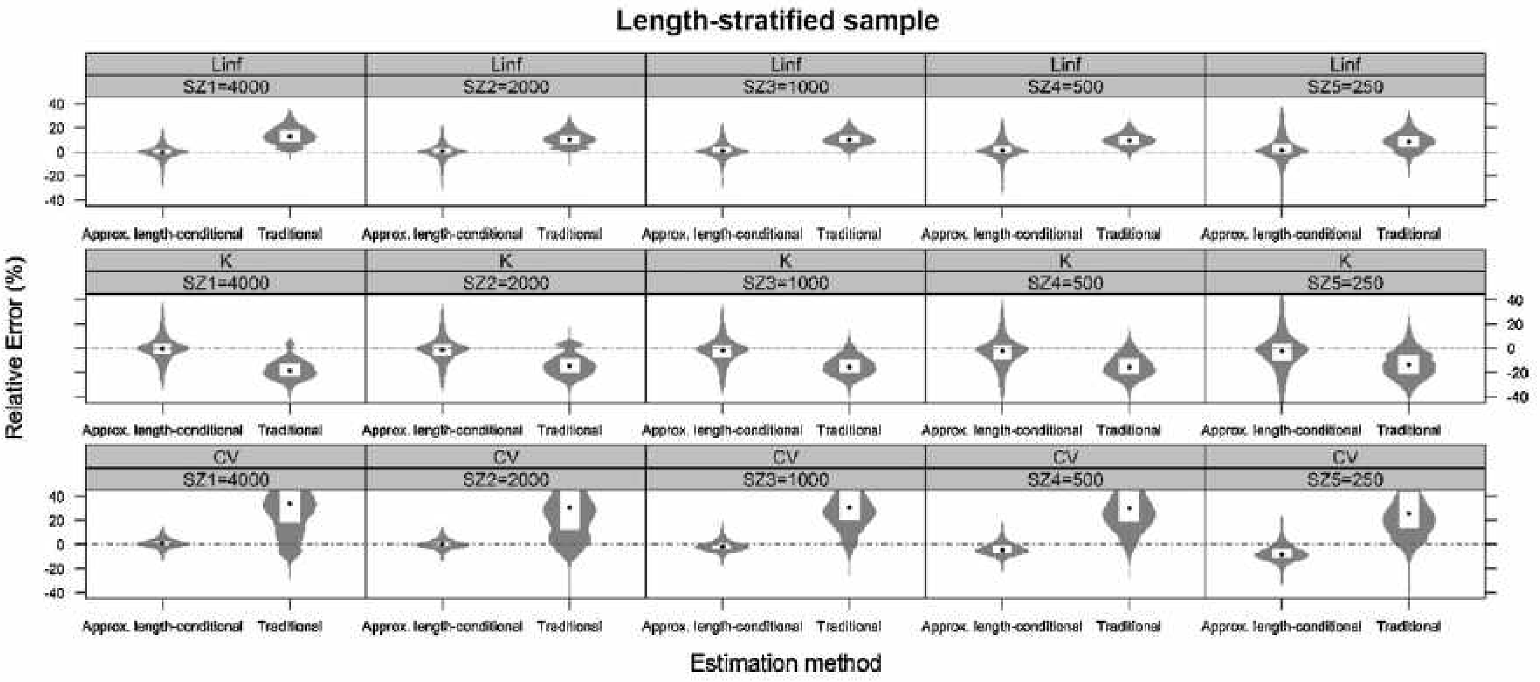
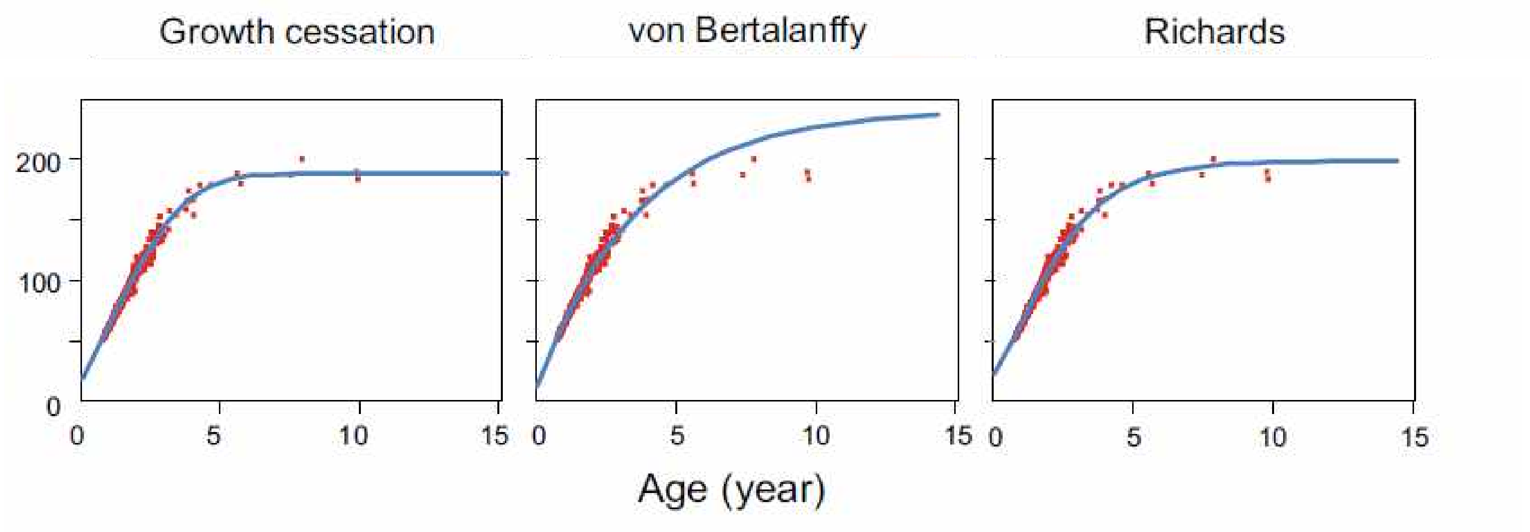


Fig. 5. Comparison of traditional and approximate length-conditional approach estimates of the von Bertalanffy growth parameters (L_{inf}, K and CV) with length-stratified sample selection. The approximate length-conditional estimates are from an equilibrium approximation to the age structure based on the approximately true total mortality (Z). Relative error is a characterization of the percent bias in the estimate from 10,000 simulated dynamics. Results are given for five sample sizes (250–4000). The height of the box within the violin corresponds to the 25th and 75th percentiles. The width of the violin represents the proportion of iterations with that percent bias and the (●) within the box the median.

Piner et al. 2016. Evaluation of using random-at-length observations and an equilibrium approximation of the population age structure in fitting the von Bertalanffy growth function, 180: 128-137.

Growth

- Functional form control estimates
- Abundant young fish influence estimates of old fish
- Need to use flexible growth curves



Maunder, M.N., Deriso, R.B., Schaefer, K.M., Fuller, D.W., Aires-da-Silva, A.M., Minte-Vera, C.V., Campana, S.E. 2018. The growth cessation model: a growth model for species showing a near cessation in growth with application to bigeye tuna (Thunnus obesus). Marine Biology (2018) 165:76.

Growth

- Use all data
  - Otolith
  - Tag growth increment
    - Model age as a parameter
  - Length frequency
    - Estimate inside assessment

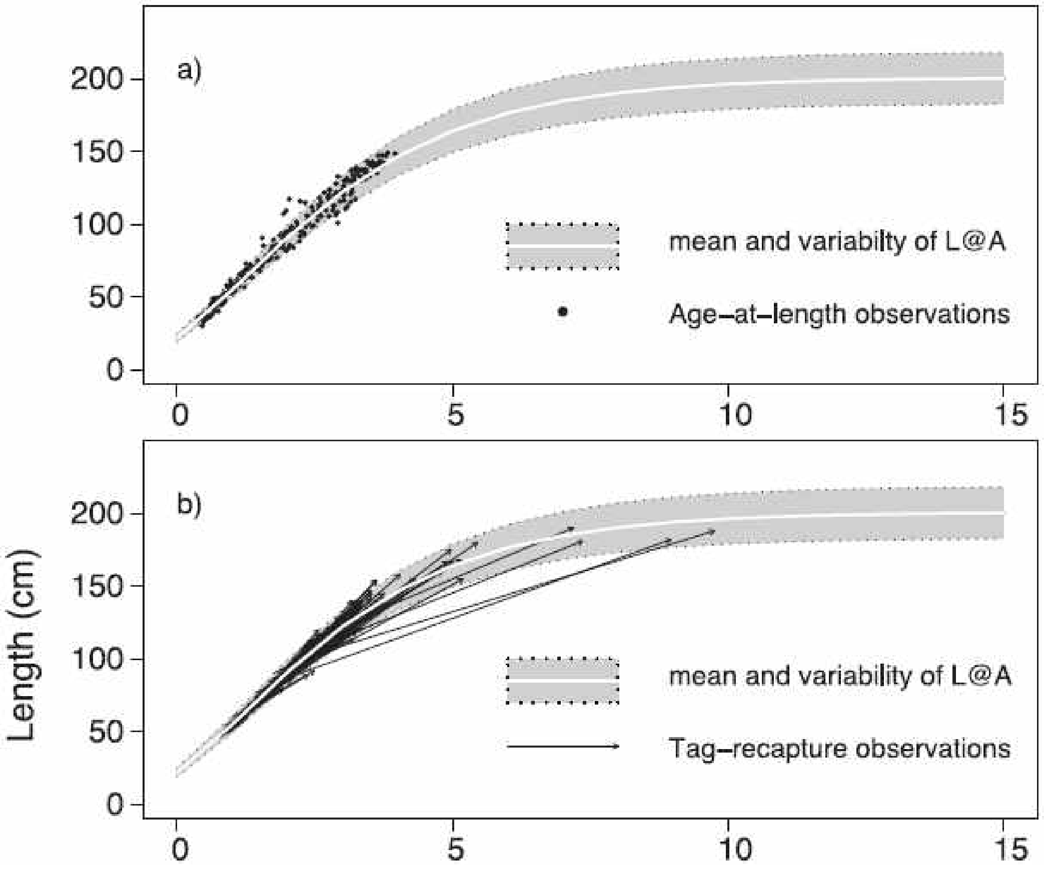


Fig. 3. Integrated growth model fit to the two data components available for bigeye: (a) age-at-length observations from otolith readings, (b) lengths at tag–release (l_1) and tag–recapture (l_2), represented by a vector. A comparison between the growth estimates obtained from the integrated model and the model fit exclusively to the otolith data (otolith model) is also shown at the bottom of (c). In each panel, the variability of the length-at-age is expressed as the 2.5 and the 97.5 percentiles of the distribution of the length-at-age.

Aires-da-Silva, A.M., Maunder, M.N., Schaefer, K.M., Fuller, D.W., 2015. Improved growth estimates from integrated analysis of direct aging and tag–recapture data: an illustration with bigeye tuna (Thunnus obesus) of the eastern Pacific Ocean with implications for management. Fish. Res. 163, 119–126.

Variation of length at age

- Variation
  - Individual
  - Sex specific
  - Birth date
  - Measurement date (LF grown or shrunk)
  - Measurement error
  - Temporal/spatial variation
- Estimate inside the model
- CV or SD
- Function of age or length

Tropical tuna growth

- Growth is about linear until about age 4, then stops
- Age and growth data comes from daily rings in otolith
- Older ages (larger sizes) are difficult to age with daily rings
- Growth increments from tagging used to complement the growth information
- Tagging of older and large fish is rare
- Growth may vary by sex and in space, but assumed constant
- Observed predominance of males in large length classes is assumed to be due to natural mortality but maybe due to growth

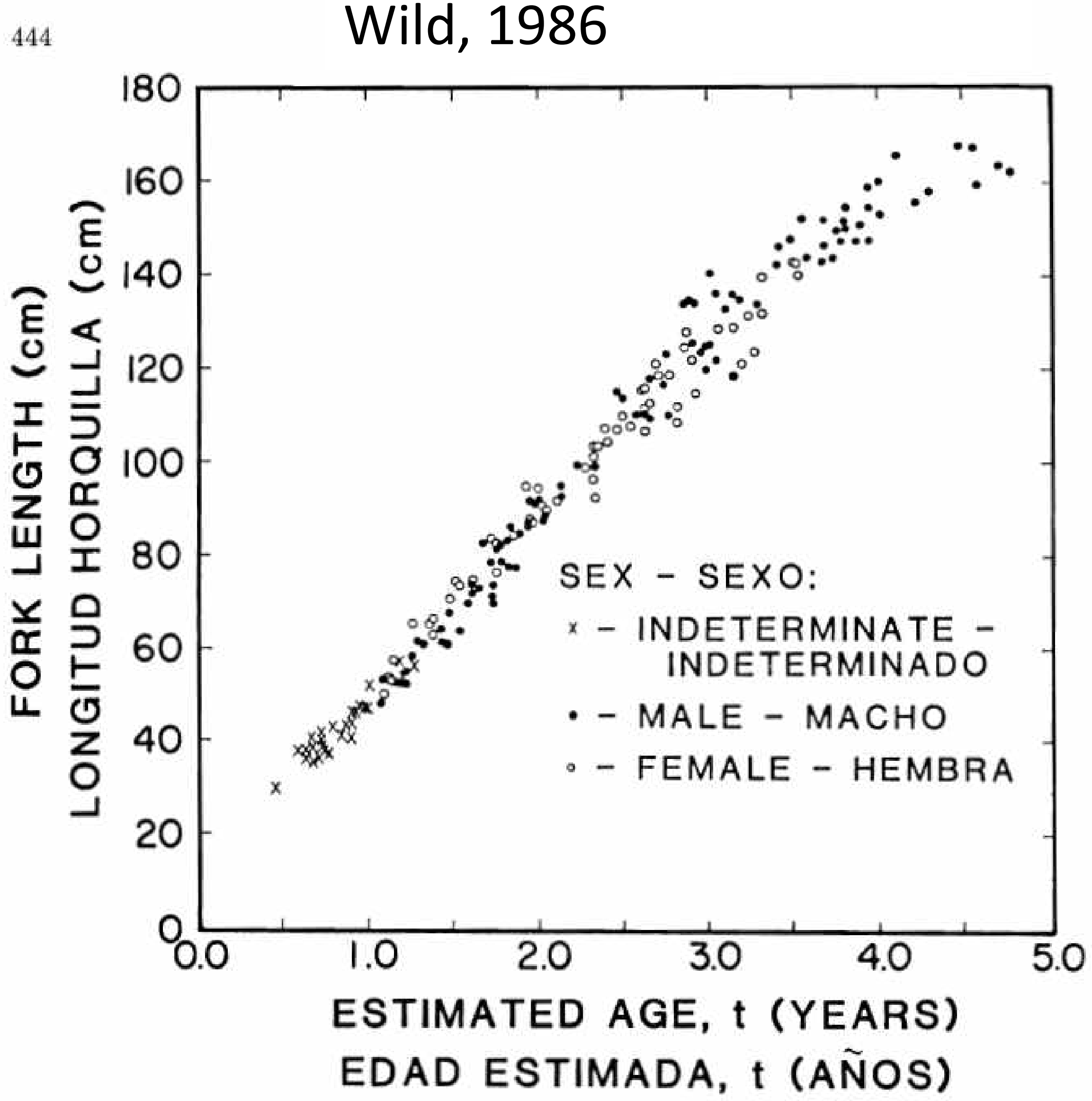
Yellowfin tuna

YFT

Yellowfin tuna: otolith data

YFT

Wild, 1986



- Sampled the American fleet operating north of the equator
- Ageing done using daily increments
- Validation of the daily increments (with OTC) from larvae stage to 140 cm
- Linear growth to about 4 years
- The maximum age in the sample was:
  - ✓ Up to about 170 cm (142.5 females, 167.9 males)
  - ✓ Up to 4 years old (3.5 females, 4.8 males)

CIAT IATTC

Yellowfin tuna: growth in the assessment

YFT

Maunder and Aires-da-Silva (2009)

Same assumptions used up to the 2019 assessment:

- Richard model parametrized as
  - ✓ L1: length at age 1 quarter
  - ✓ L2: length at age 29 quarters
- L2 for males and females is 182.8 cm
- CV of about **10%**

  (i.e. 95% of the fish 29 quarters old should have 147.1 to 218.5 cm)

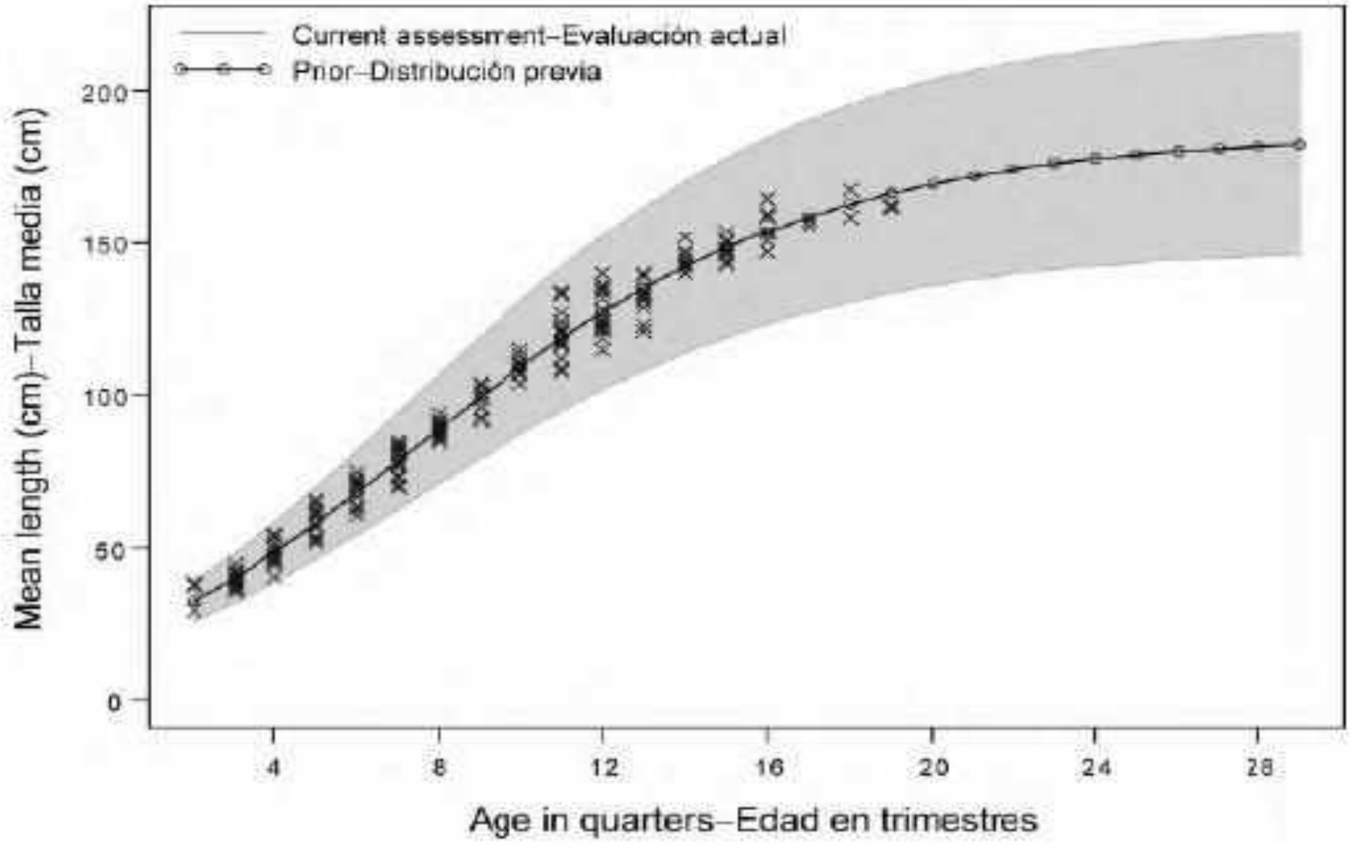
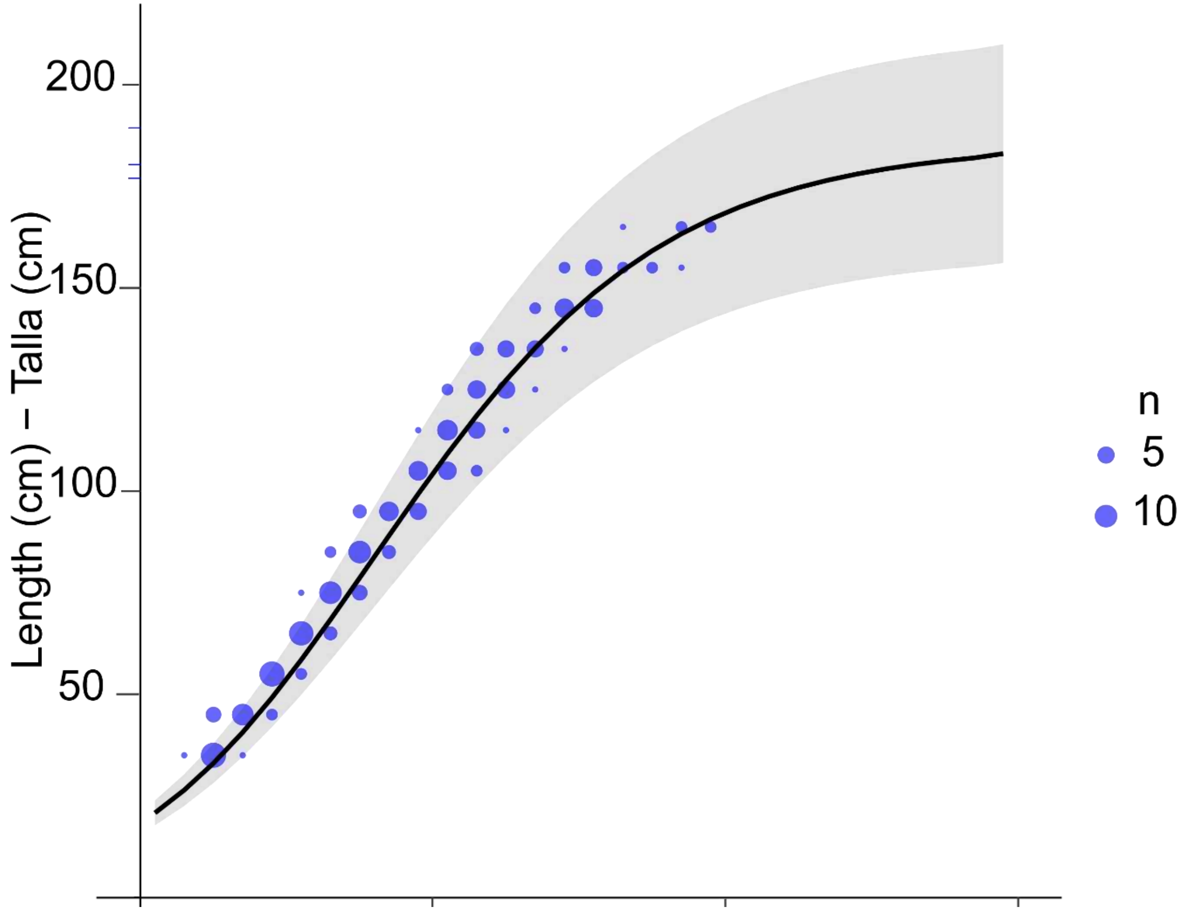


FIGURE 3.1. Growth curve estimated for the assessment of yellowfin tuna in the EPO (solid line). The connected points represent the mean length-at-age prior used in the assessment. The crosses represent length-at-age data from otoliths (Wild 1986). The shaded region represents the variation in length at age (± 2 standard deviations).

Yellowfin tuna: length conditional on age

YFT



- Otolith data from Wild
- Included when estimating growth
- Data from 1975-1977
- Assumed to be:
  - ✓ 1985
  - ✓ F18-DEL-C fishery
  - ✓ Sexes combined

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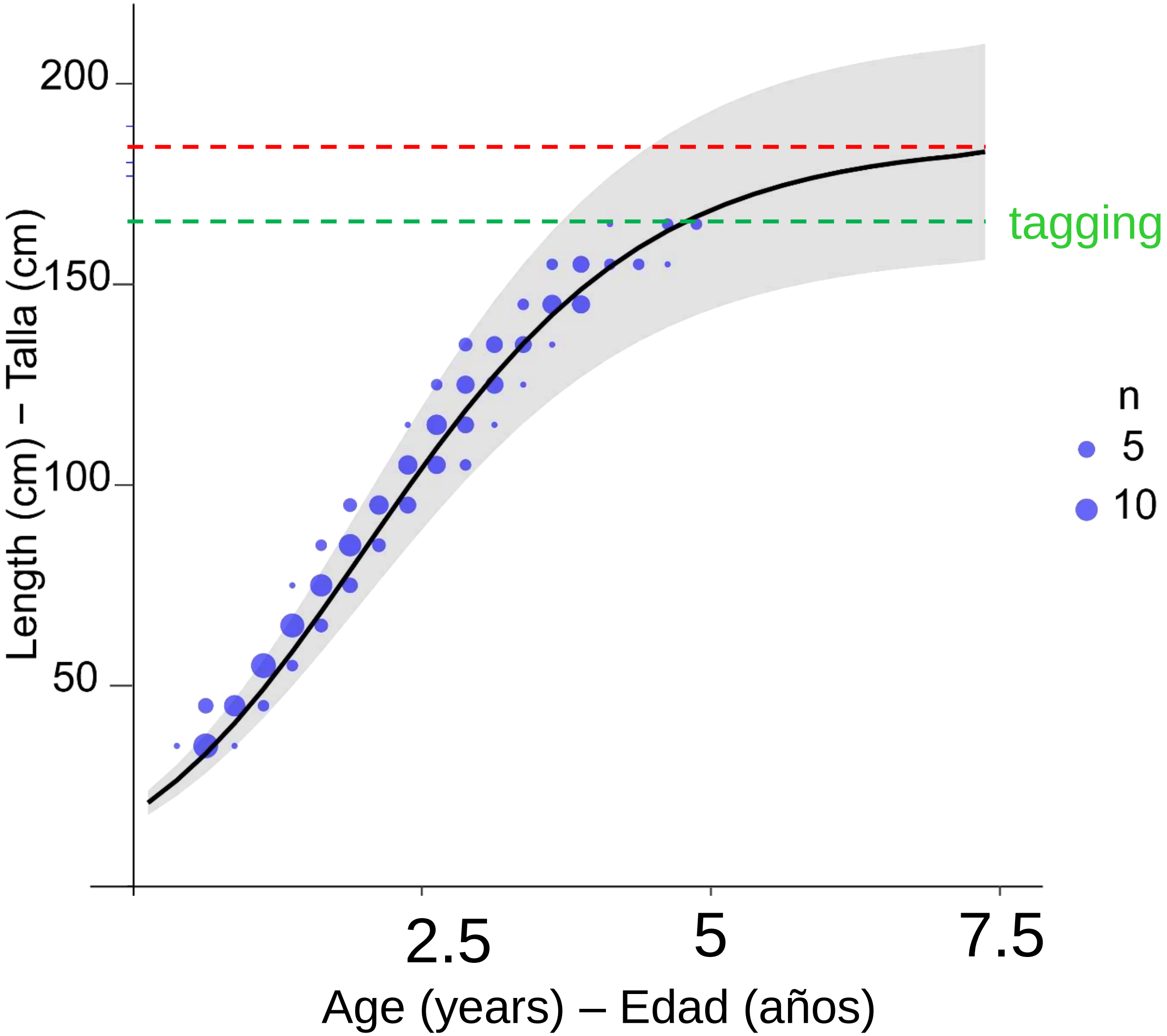
2020 benchmark fixed growth assumptions YFT



Fixed growth assumption:

- *L2* = 182 (Maunder and Aires-da-Silva , 2009)
- CV length at age **= 7.5%**

Limited tagging data:

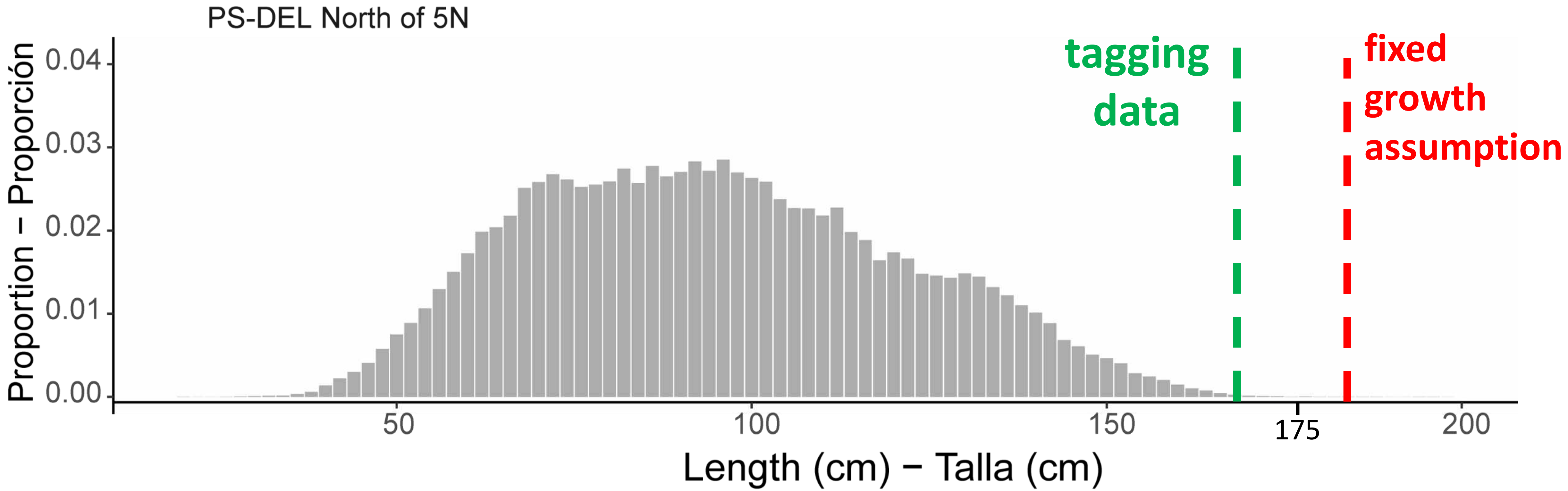
- 167.3 average size of 4+ years at liberty (n=3)
- 163.3 average size of 3+ years at liberty (n=6)

(UPDATE)

Yellowfin tuna

YFT

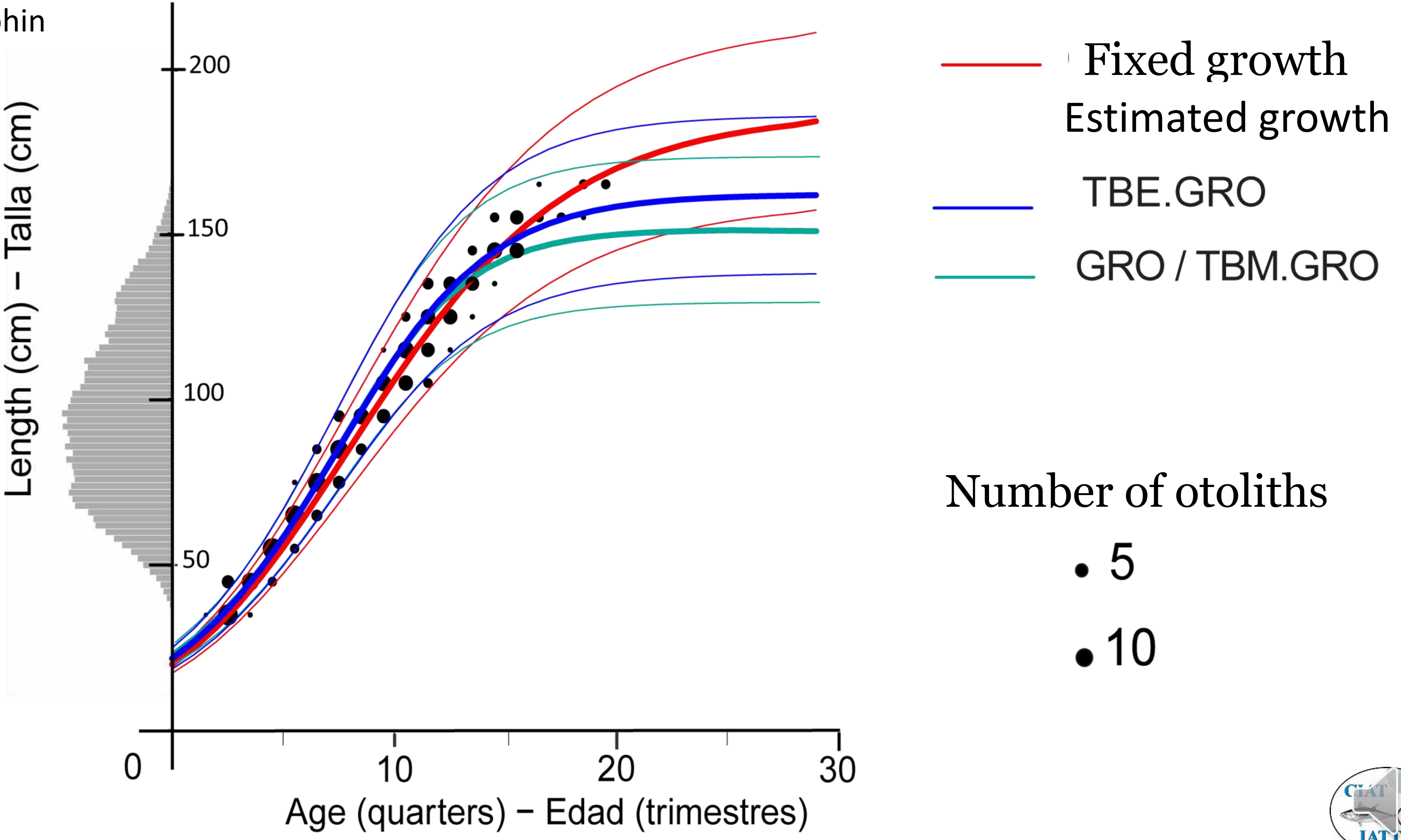
Length composition of the purse-seine fisheries set on dolphins



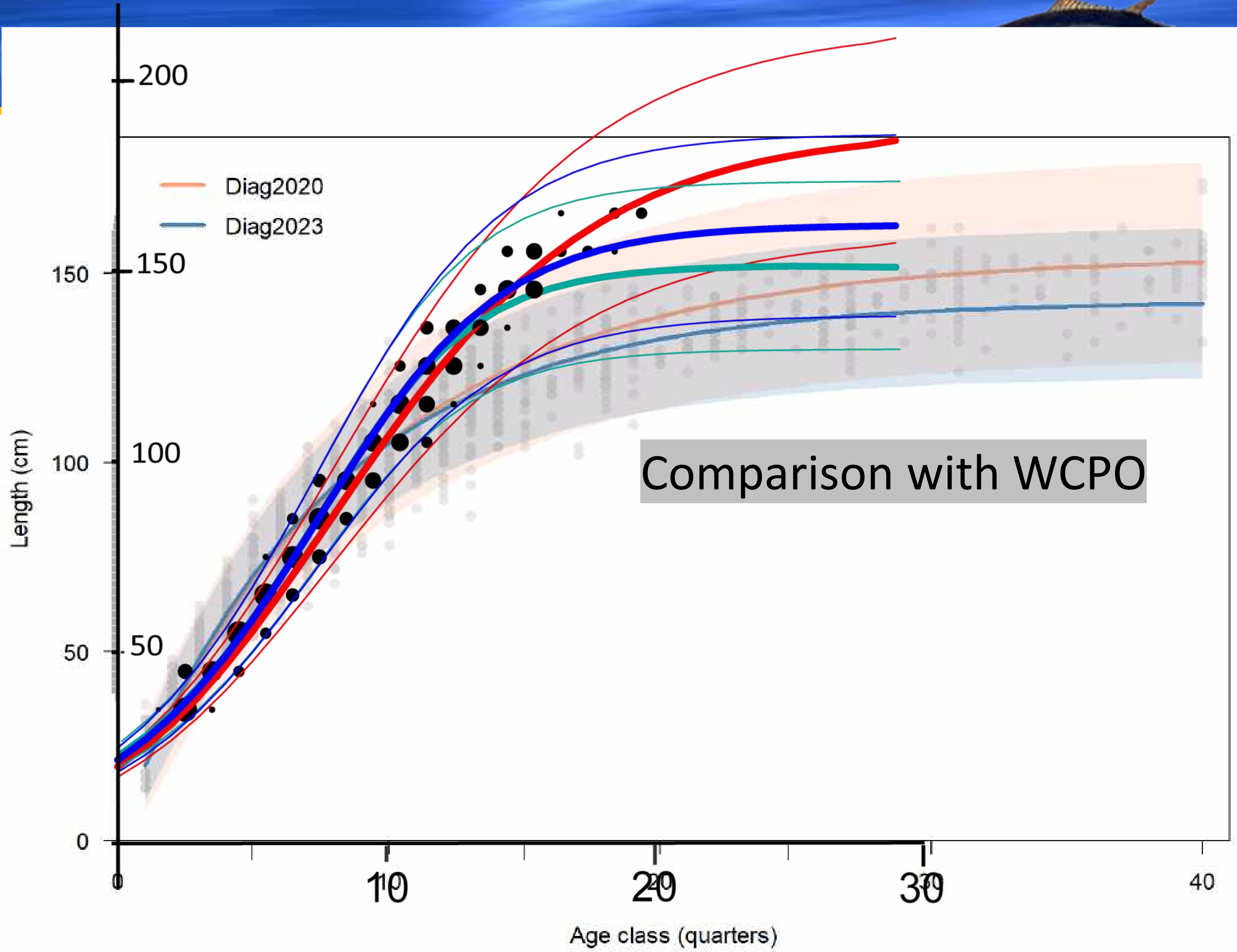
2020 benchmark estimated growth

YFT

Length frequency of dolphin associated purse-seine fisheries north of 5° N



Yellowfin tuna

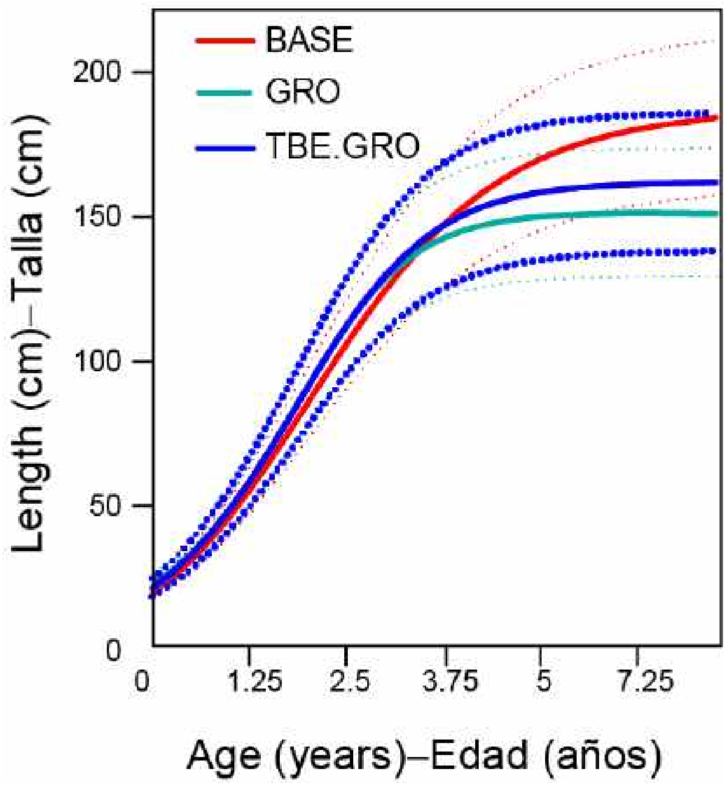


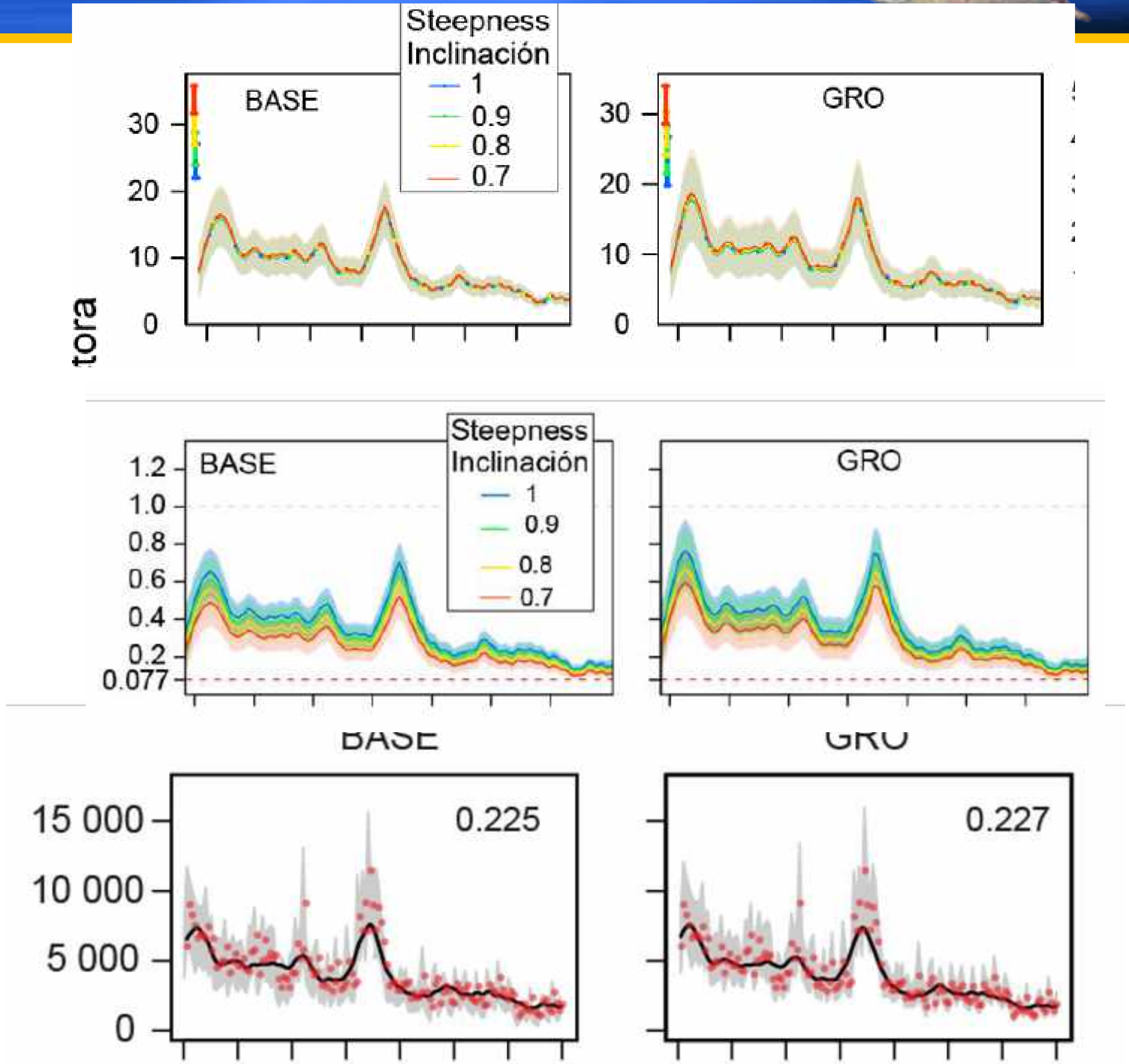
Yellowfin tuna

YFT

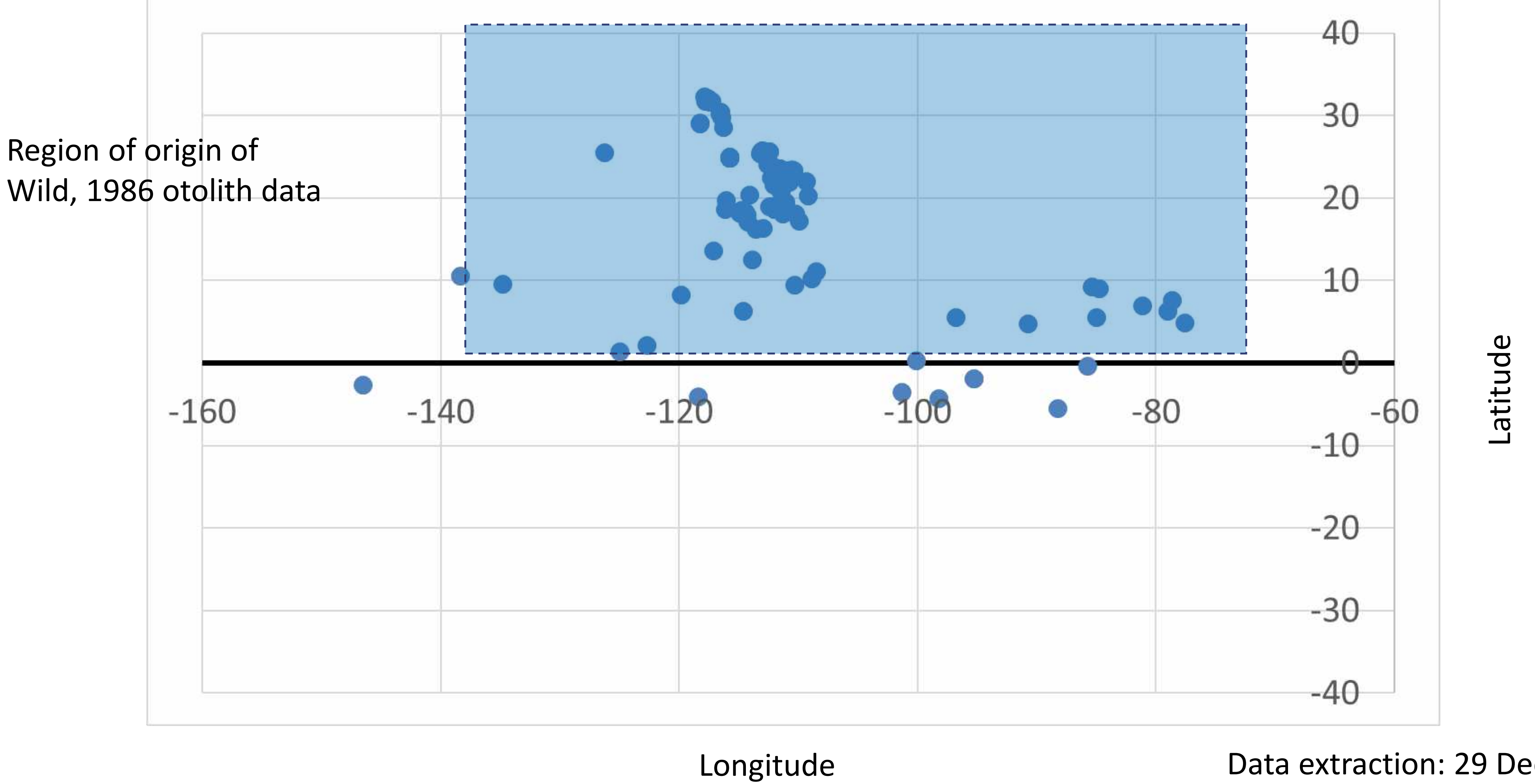
BASE: fixed growth

GRO: estimate growth





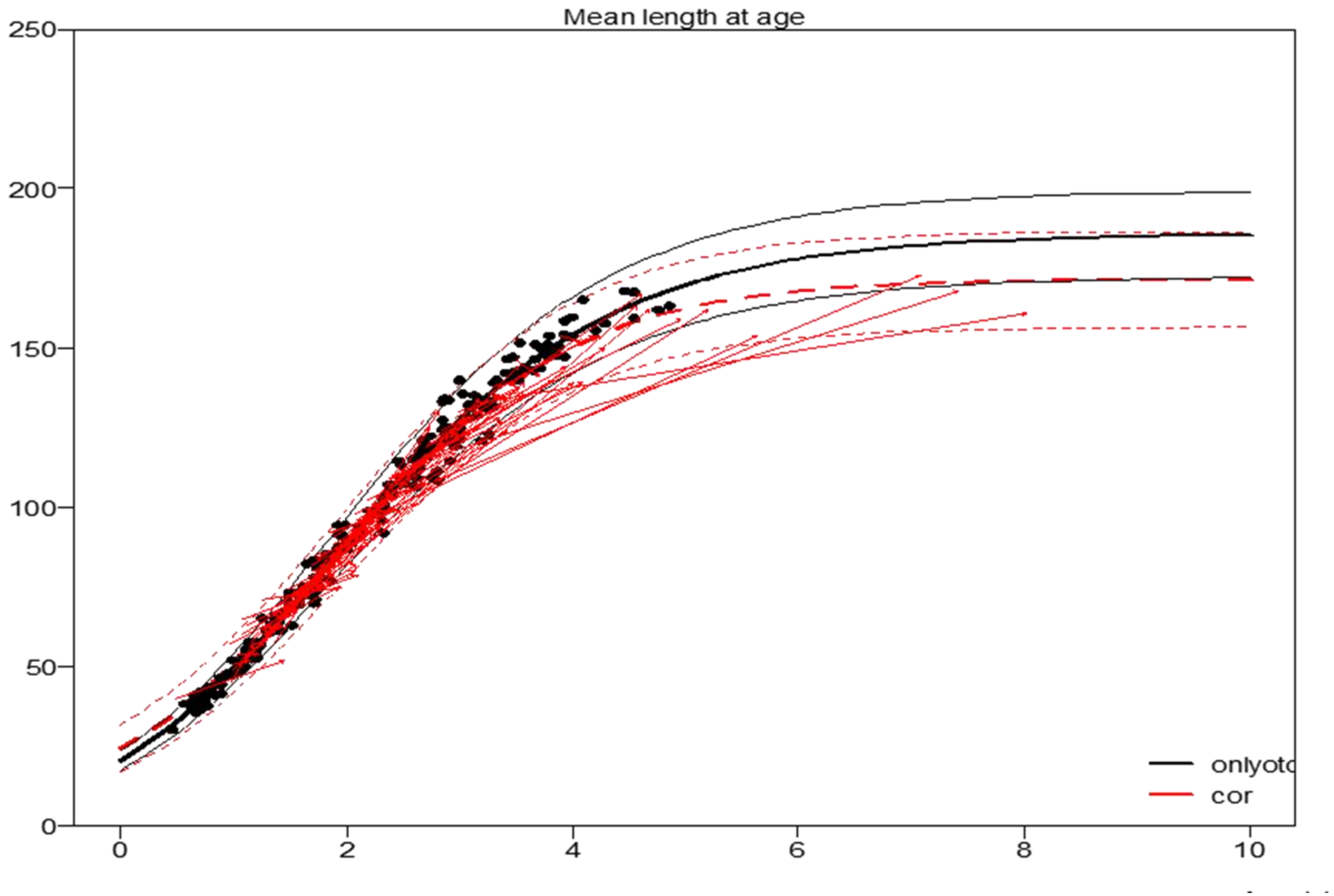
Tagging data: high confidence data

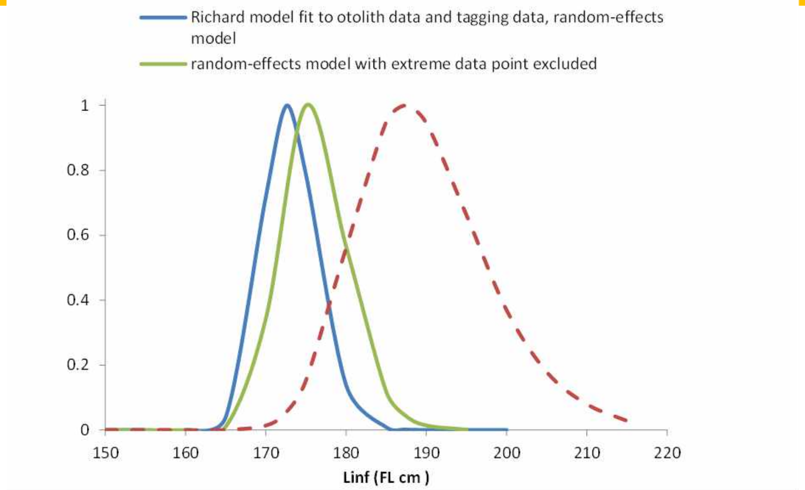


Data extraction: 29 Dec 2015
Biology group IATTC

Yellowfin tuna: adding tagging data

YFT





Otolith data only

Parameter	Fit to otolith data only (age-at-length)	Fit to otolith and tagging data (with correlation)
Growth curve		
L_∞	185.48	171.5
K	0.7514	0.9459
t_0	1.8333	1.944
p	2.0427	0.9792
Variability of length at age		
a	0.6007	2.1216
b	0.0357	0.0258

Data extraction: 29 Dec 2015

Biology group IATTC

NEW DATA!

Bigeye tuna

BET

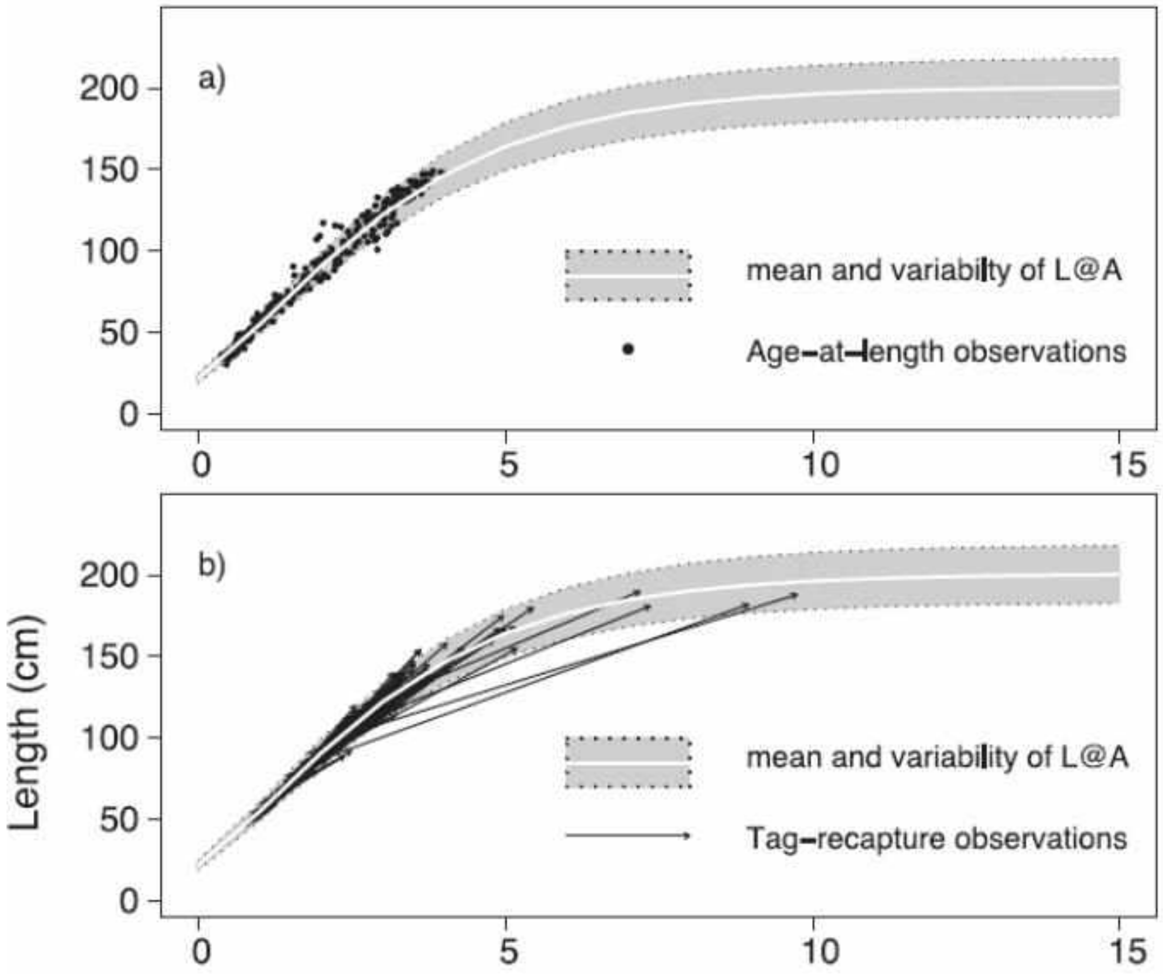
Mean length at age: the current model

BET

- Richards growth curve
- Parameters fixed based on Aires da Silva et al. (2015) approach
- Fit to both otolith age-length data and tagging growth increment data

Mean length at age: the current model

BET



Aires da Silva et al. (2015)

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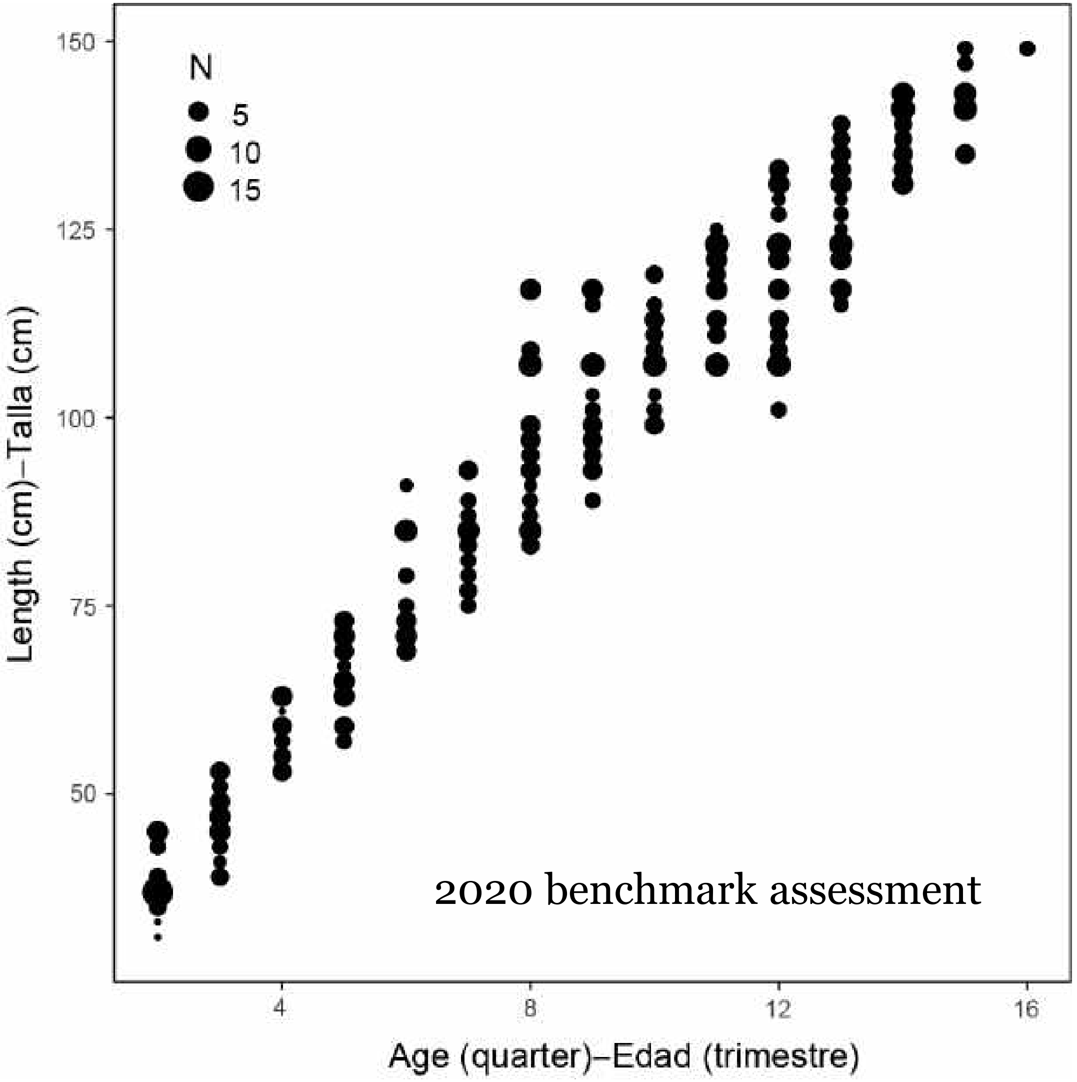
Conditional age-at-length data

BET



The conditional age-at-length data includes 254 bigeye (30 to 149 cm), captured by purse-seine vessels in the EPO between 2000 and 2004

ESTIMATES OF AGE AND GROWTH OF BIGEYE TUNA

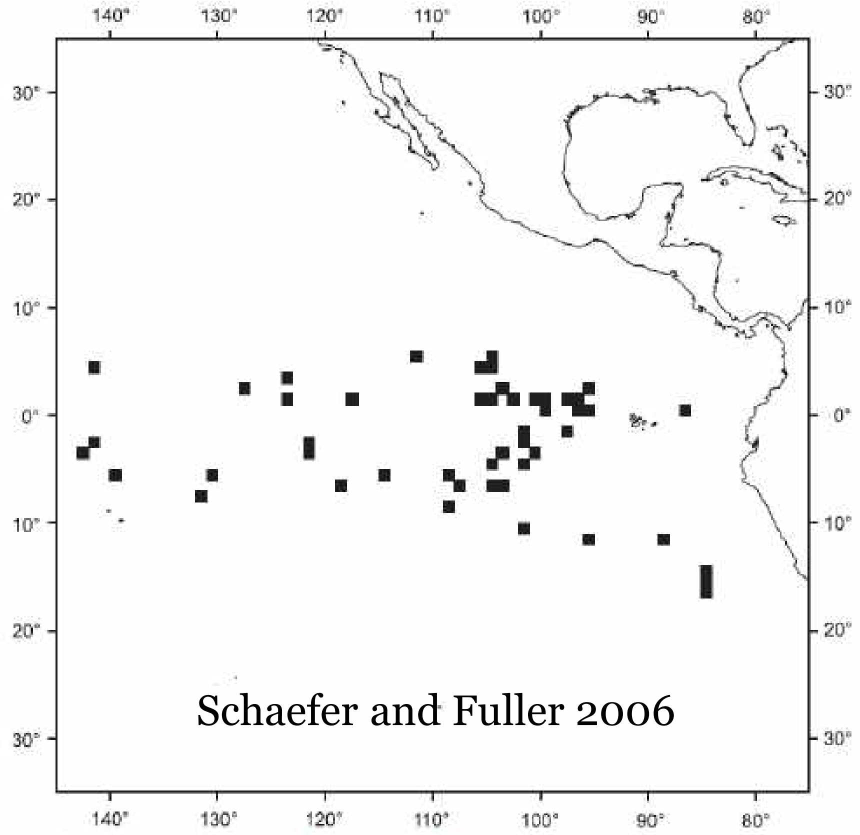


FIGURE 3. Geographical distribution of bigeye sampled.

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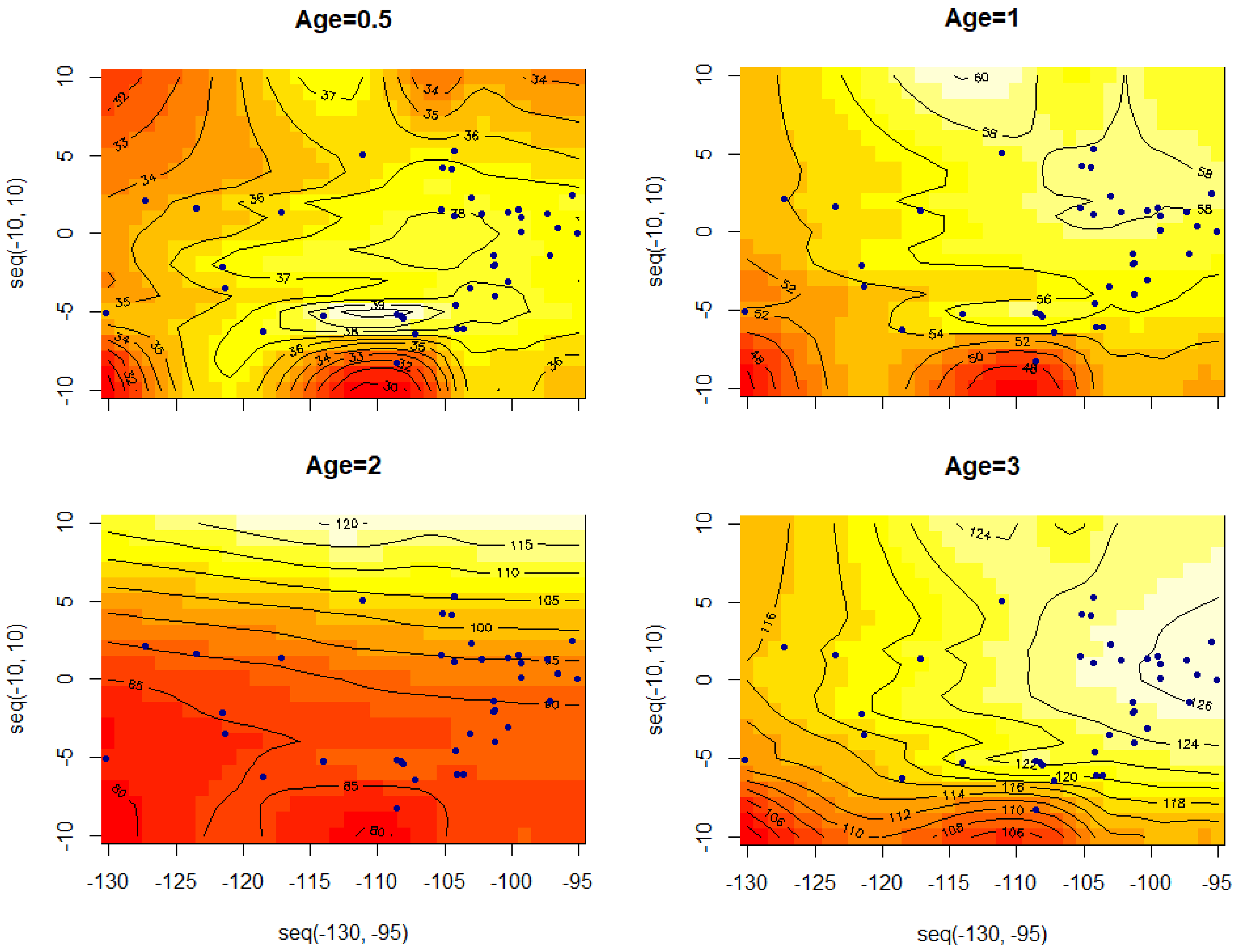
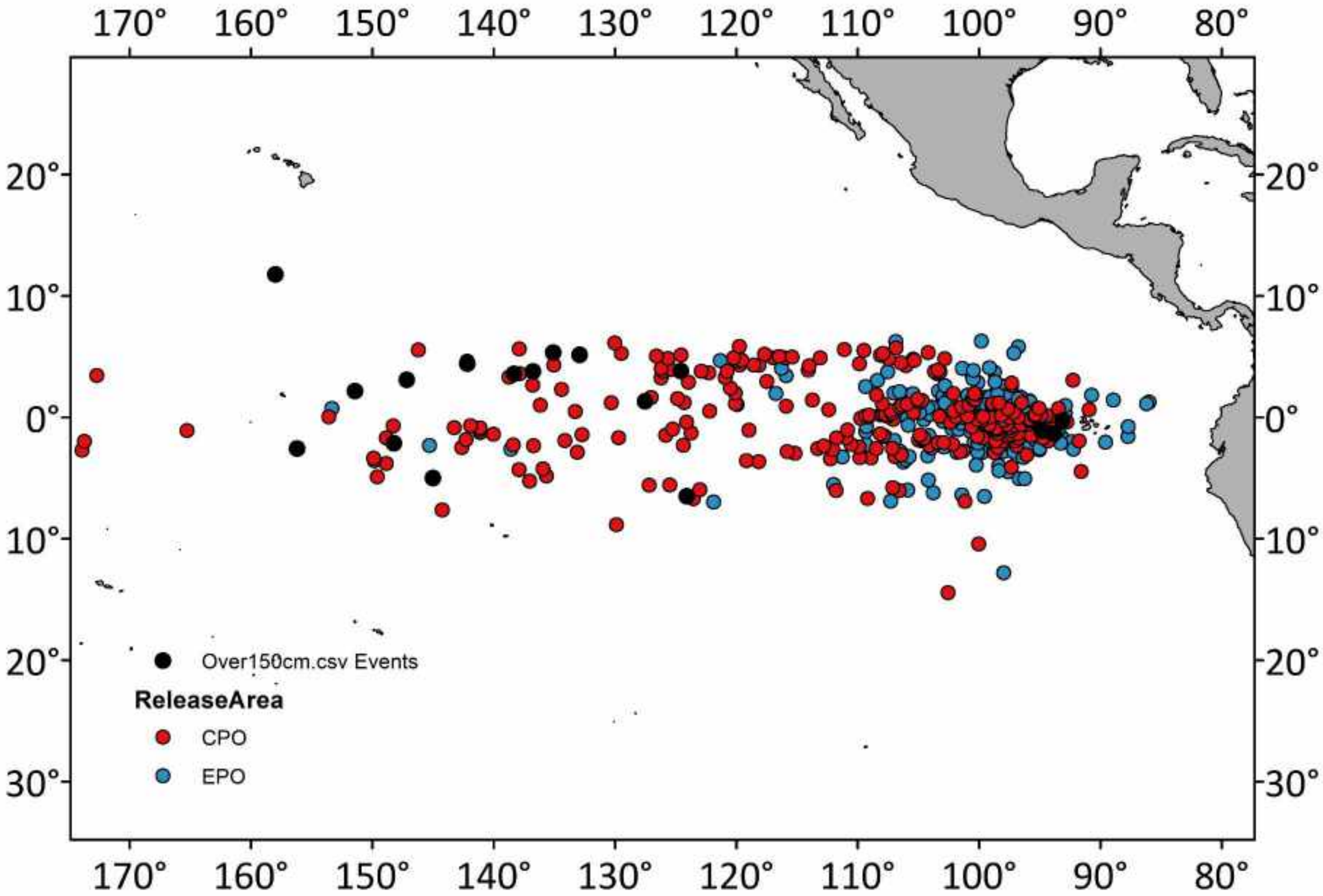
Predicted length at age using GAM

BET



Tagging data: Large recaptures (black)

BET



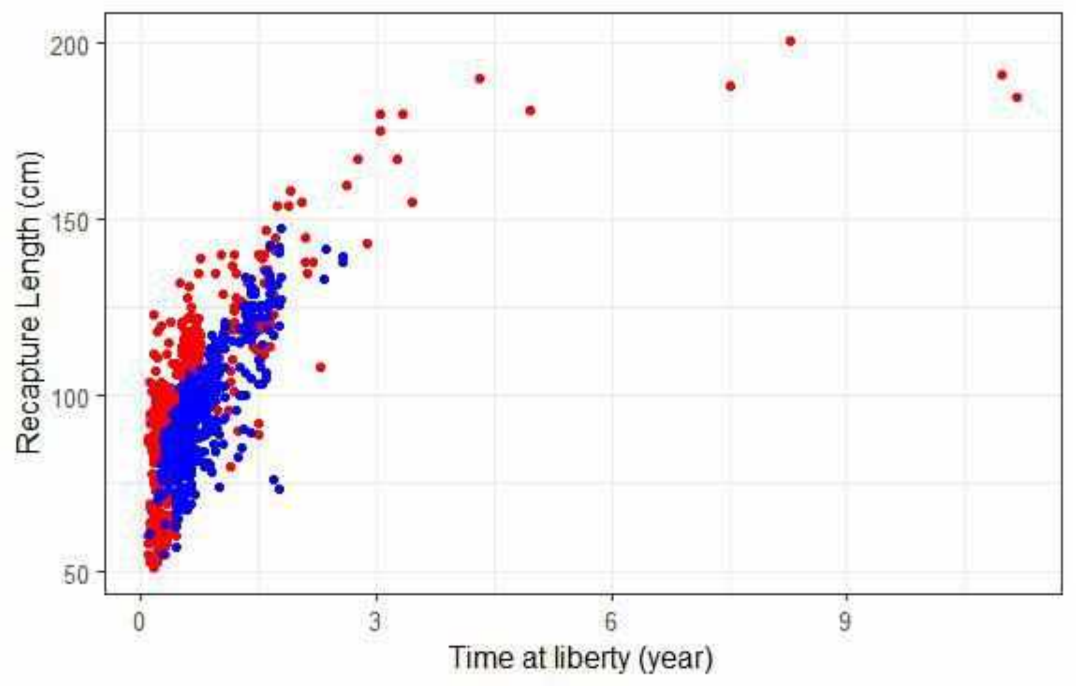
Growth rate based on tagging data at 95W and 140W

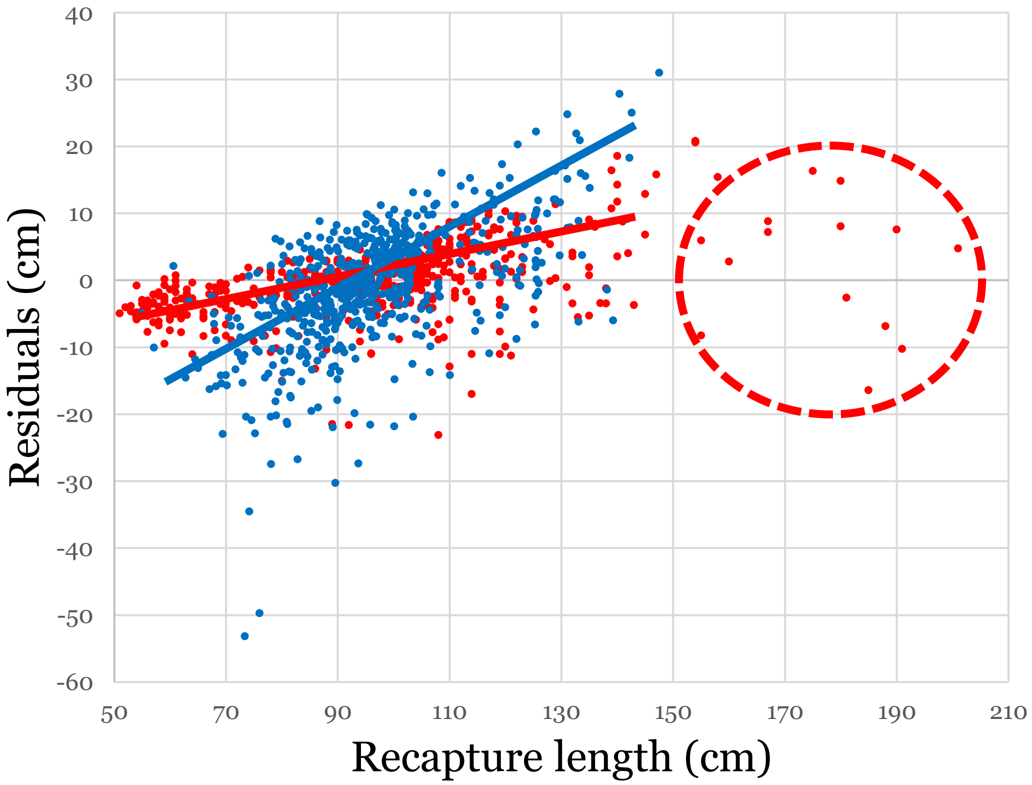
BET

The von Bertalanffy growth curve: $L_{rec} = L_{rel} + (L_\infty - L_{rel})\left(1 - e^{-K(t_{rep} - t_{rel})}\right)$

where $L_\infty = 208.8$ and $K = 0.313$

Bigeye were tagged at 95W and 140W





Data summary

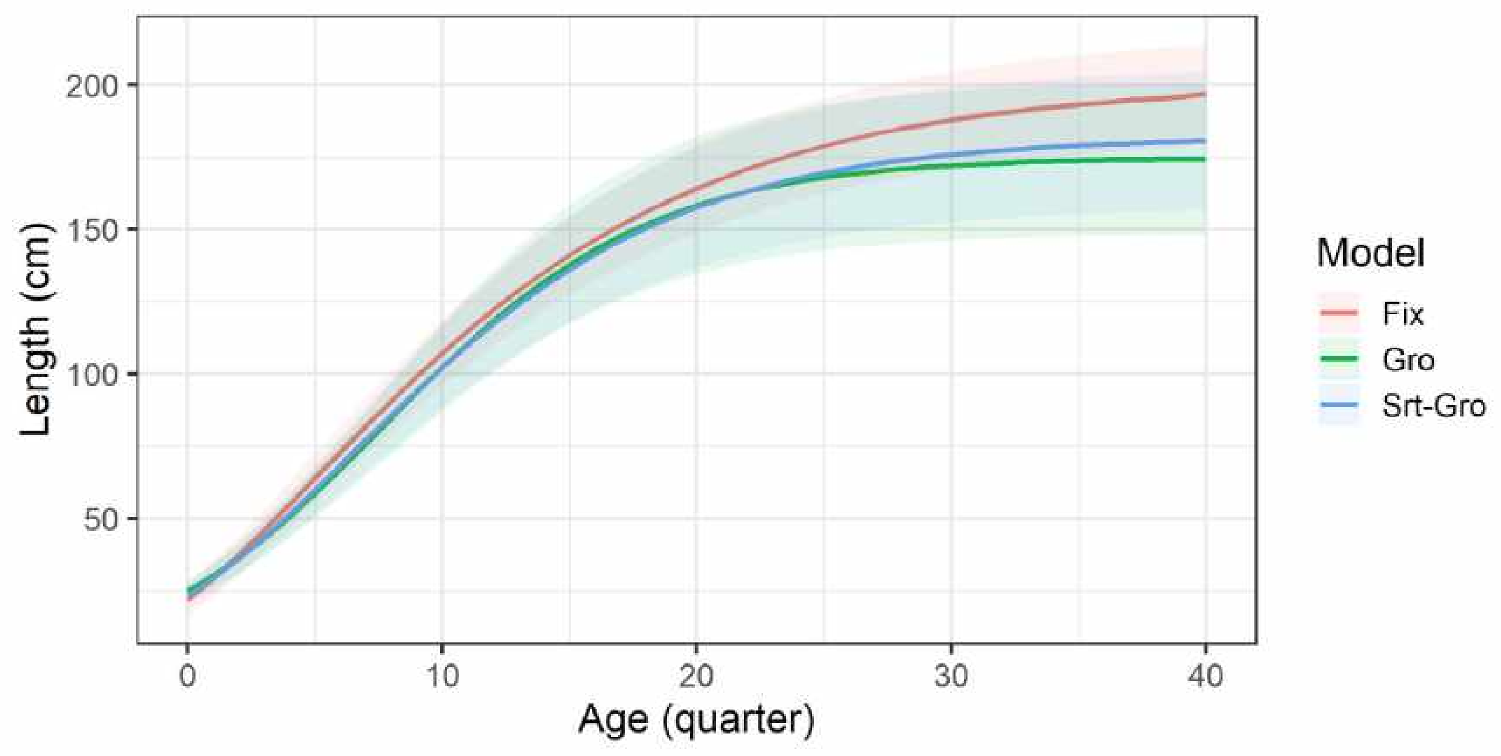
BET

- Otoliths data covers both east and west EPO (more on the east)
- Tagging data at 95W and 140W show different residual pattern, indicating the growth rate at the two locations may be different
- All >150cm recaptured bigeye that are important for estimating Linf are tagged at 95W
- The integrated model on which the current growth curve is based is fits to otoliths data from the EPO and length increment data from only 95W-tagged bigeye

CIAT IATTC

Estimating G in bigeye reference models

BET



SAC14 reference models

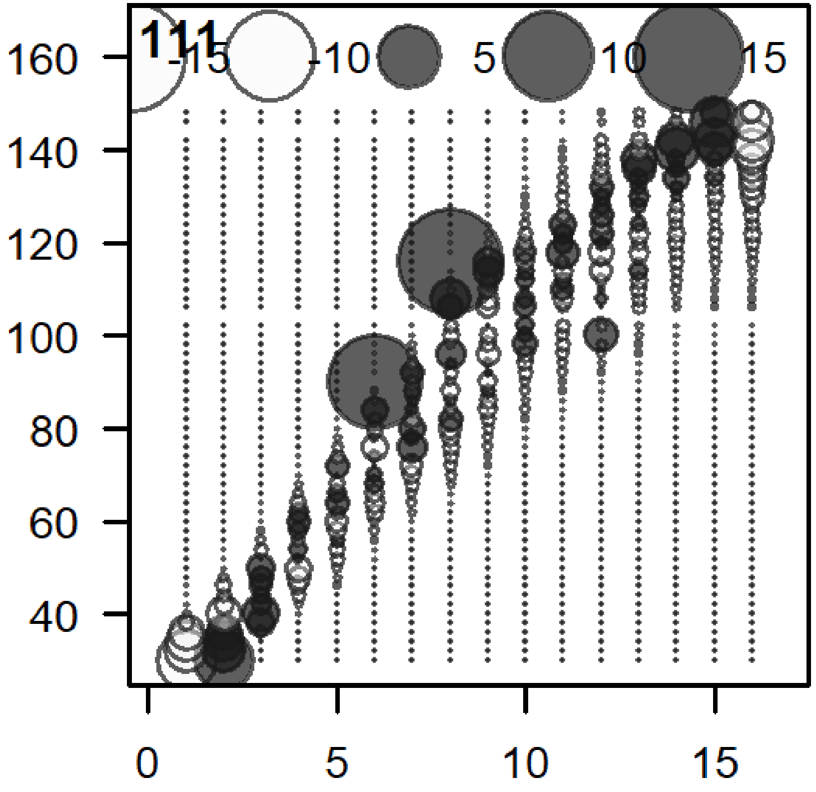
Model name	Description
Env-Fix	Environment, Fixed
Srt-Fix	Short-term, Fixed
Srt-Gro	**Short-term, Estimate growth**
Srt-Sel	Short-term, Dome selectivity
Srt-Mrt	Short-term, Adult mortality
Mov	Pre-adult movement
Gro	**Estimate growth**
Sel	Dome selectivity
Mrt	Adult mortality

CIAT IATTC

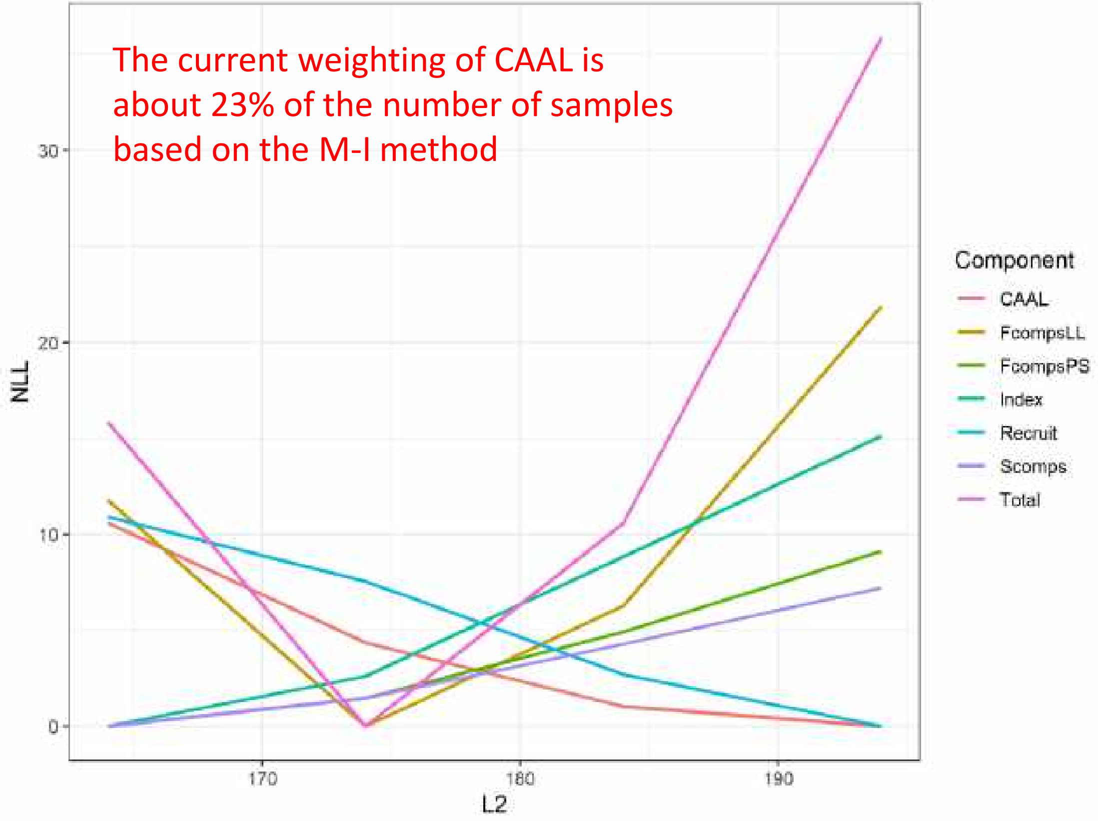
Fit to conditional age-at-length

BET

Does not fit well the CAAL data

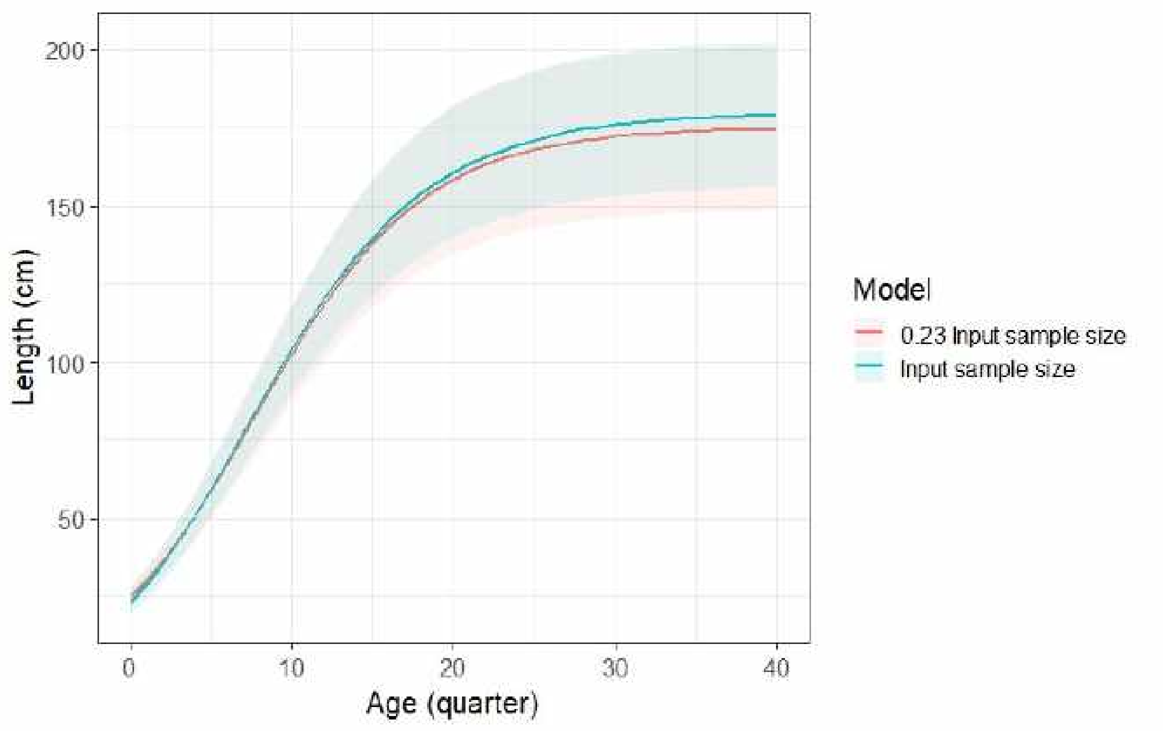


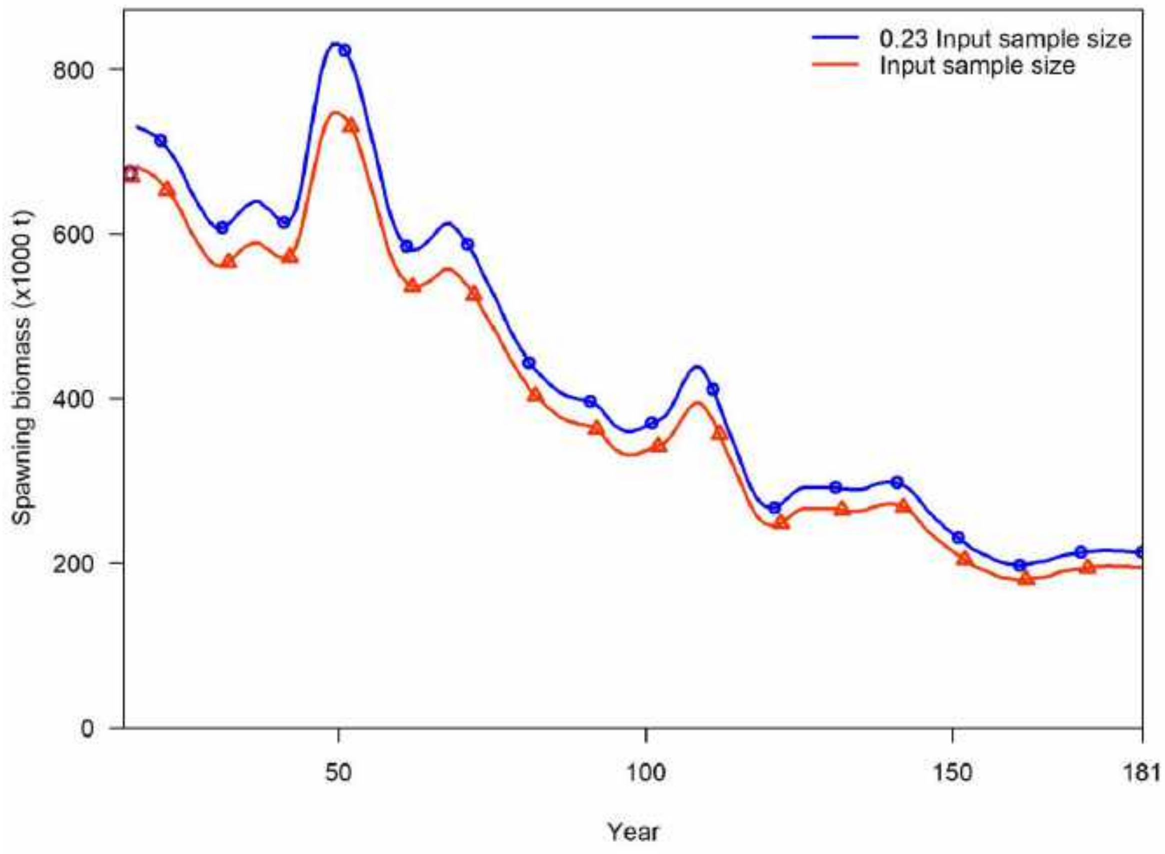
Likelihood profile on L2 for a model where G is estimated (L2 is fixed at 196cm in most models)



Different weights on the CAAL data

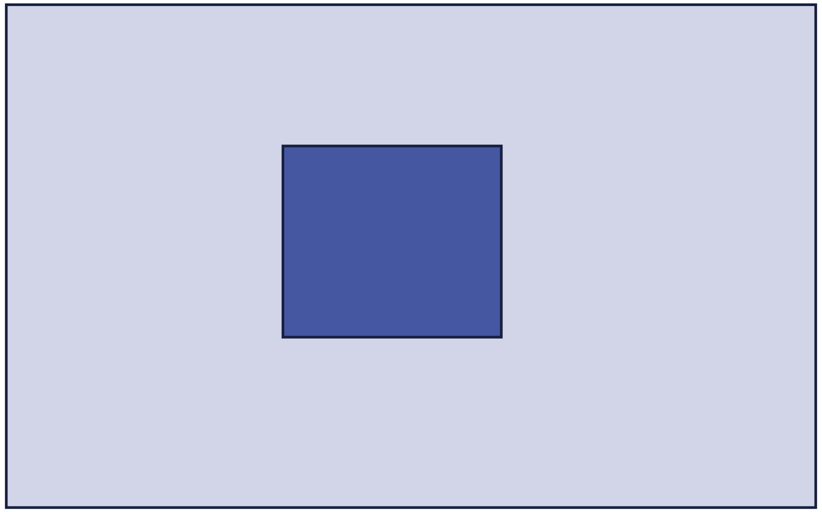
BET





Dealing with spatial/temporal variation in growth

- No information on temporal variation
- Spatial variation
  - Areas as fleets (ontogenetic movement)
  - Separate assessments (isolated stocks)
  - Down weight length comp data outside growth curve derived area and borrow age-specific selectivity (mixing)
  - Index expansion



B=C/F

F=f(Linf,LF)

Key messages on growth

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- Estimate growth inside the stock assessment model
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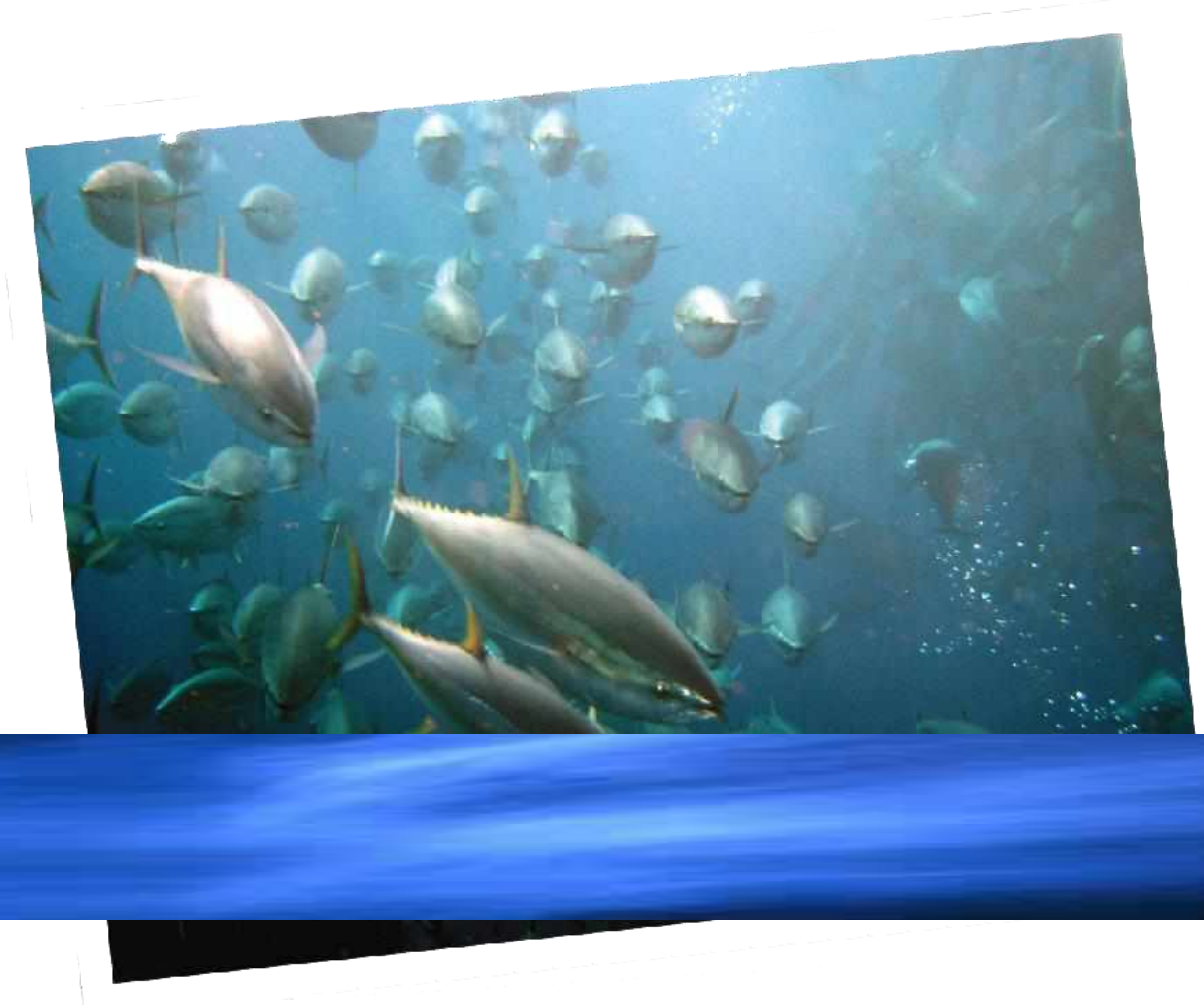
- Length-increment data should be analyzed outside the model and the results used to create priors to include in the assessment model (until possible to include it in the model)
- Use sex specific growth
- Need to consider spatial variation in growth and how it might be affecting the results
- Estimate Lsd inside the model

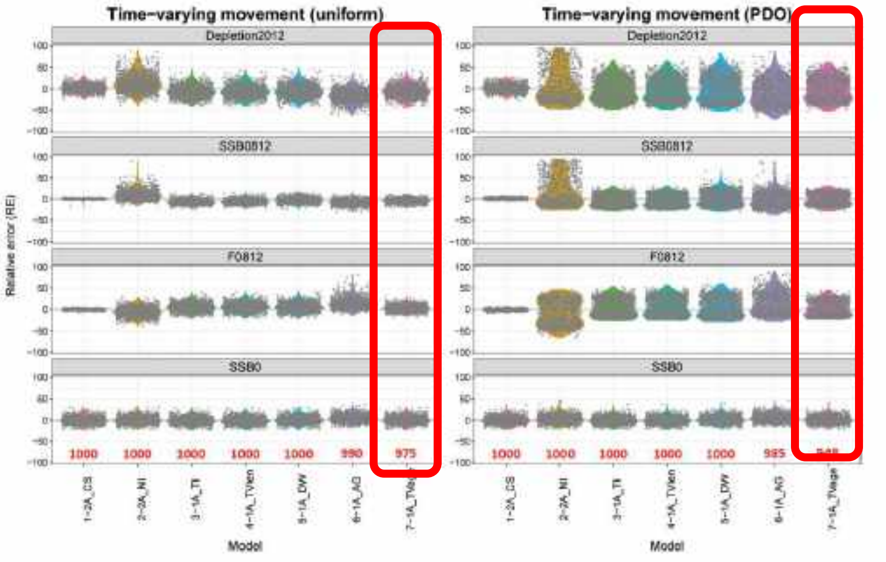


Preguntas -Questions

Growth: temporal variation

- Empirical weight-at-age
  - Needs catch-at-age data
  - Sampling error
  - Missing years/gears
  - Model outside assessment to fill in gaps
- Model time varying growth
  - Functional form
    - Parameters vary over time
    - Growth increment approach
    - Cohort or annual effects
  - Non- or semi-parametric approach
  - Estimating smoothness penalty
- Density dependence
- Needs lots of age-length data

Fig. 5. Relative error values of estimated derived quantities for the seven estimation models applied to simulated populations for uniform (left panels) and PDO-like (right panels) movement. The open grey circles indicate converged estimates, and the violin depicts kernel probability density of all converged runs. Depletion2012 is the ratio of spawning biomass in 2012 to unfished level. SSB0812 is the mean of estimated spawning biomass in the last 5 years. F0812 is the mean of the instantaneous fishing mortalities in the last 5 years. SSB0 is the estimated unfished spawning biomass. The number of runs where final Hessian matrix is positive-definite for each of estimation models is given in the bottom of each panel. [Colour online.]



Growth: spatial variation

- Spatial differences in length compositions due to
  - Sampling
    - Make sure the differences are not due to an artifact of the sampling
      - Time differences in the sample
      - Differences in Length measurements or conversion factors
  - Age
    - Ontogenetic movement
      - Spatial model
      - Use age selectivity for availability and length-based contact selectivity (Lee et al. 2017)
    - Differences in exploitation rates (spatial structured model)
  - Growth
    - Spatially structured model
    - Assess areas separately
    - Collect data to determine stock structure, movement, and growth
    - Need to develop methods to model area specific growth curves in interacting sub-populations
  - Selectivity
      - Expected for different gears
      - Why would it differ for the same gear?
- Age data would help differentiate the cause of differences in length composition.

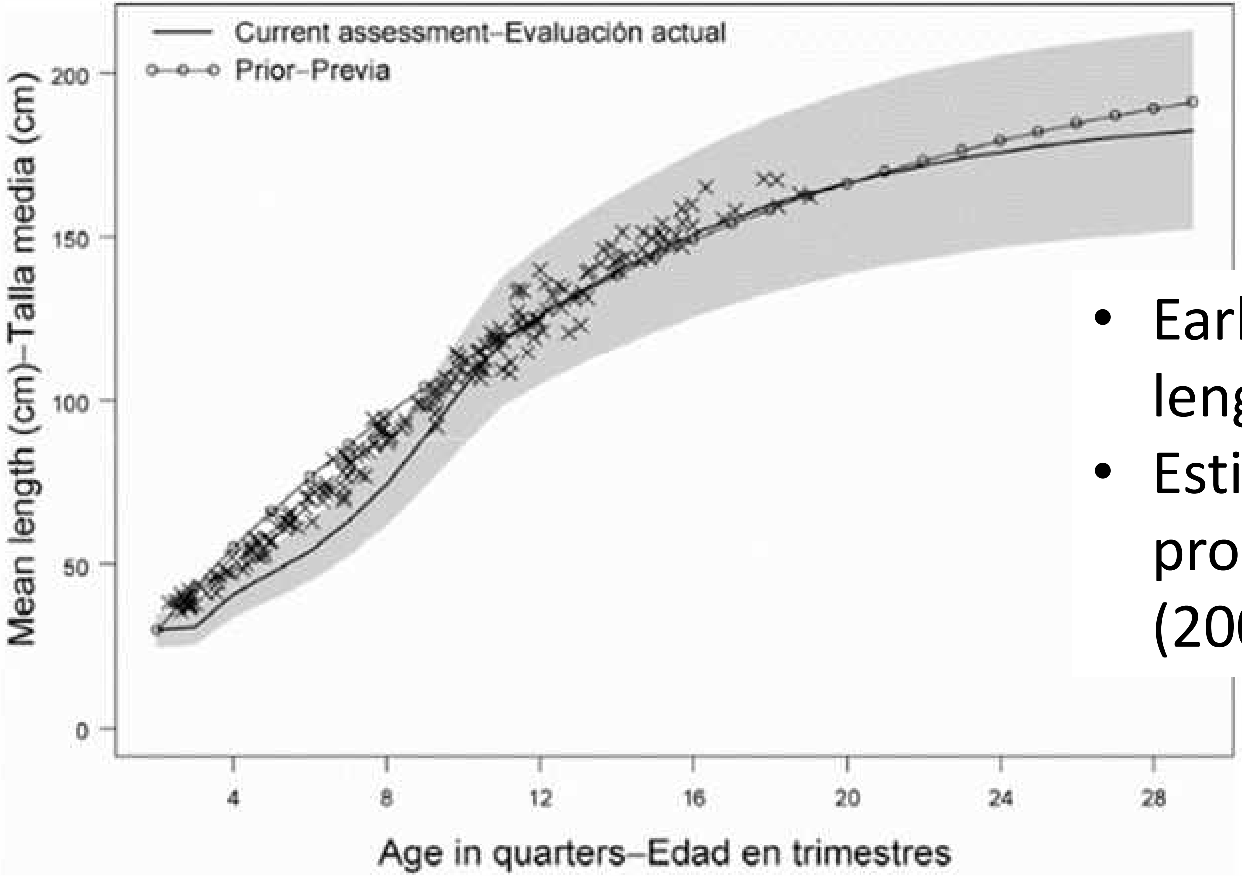
Lee, H-H., Piner, K.R., Maunder, M.N., Taylor, I.G., Methot Jr., R.D. 2017. Evaluation of alternative modelling approaches to account for spatial effects due to age-based movement. Canadian Journal of Fisheries and Aquatic Sciences, 2017, 74(11): 1832-1844

Yellowfin tuna: growth in the assessment

YFT

Hoyle and Maunder (2006)

A - SCALA



- Early growth too fast to follow the length frequency modes
- Estimation within the assessment proposed by Hoyle and Maunder (2006) using a prior distribution

FIGURE 3.1. Growth curve estimated for the assessment of yellowfin tuna in the EPO (solid line). The connected points represent the mean length-at-age prior used in the assessment. The crosses represent length-at-age data from otoliths (Wild 1986). The shaded region represents the variation in length at age (± 2 standard deviations).

Specification of growth in the **current** stock assessment

Maunder and Aires-da-Silva (2009)

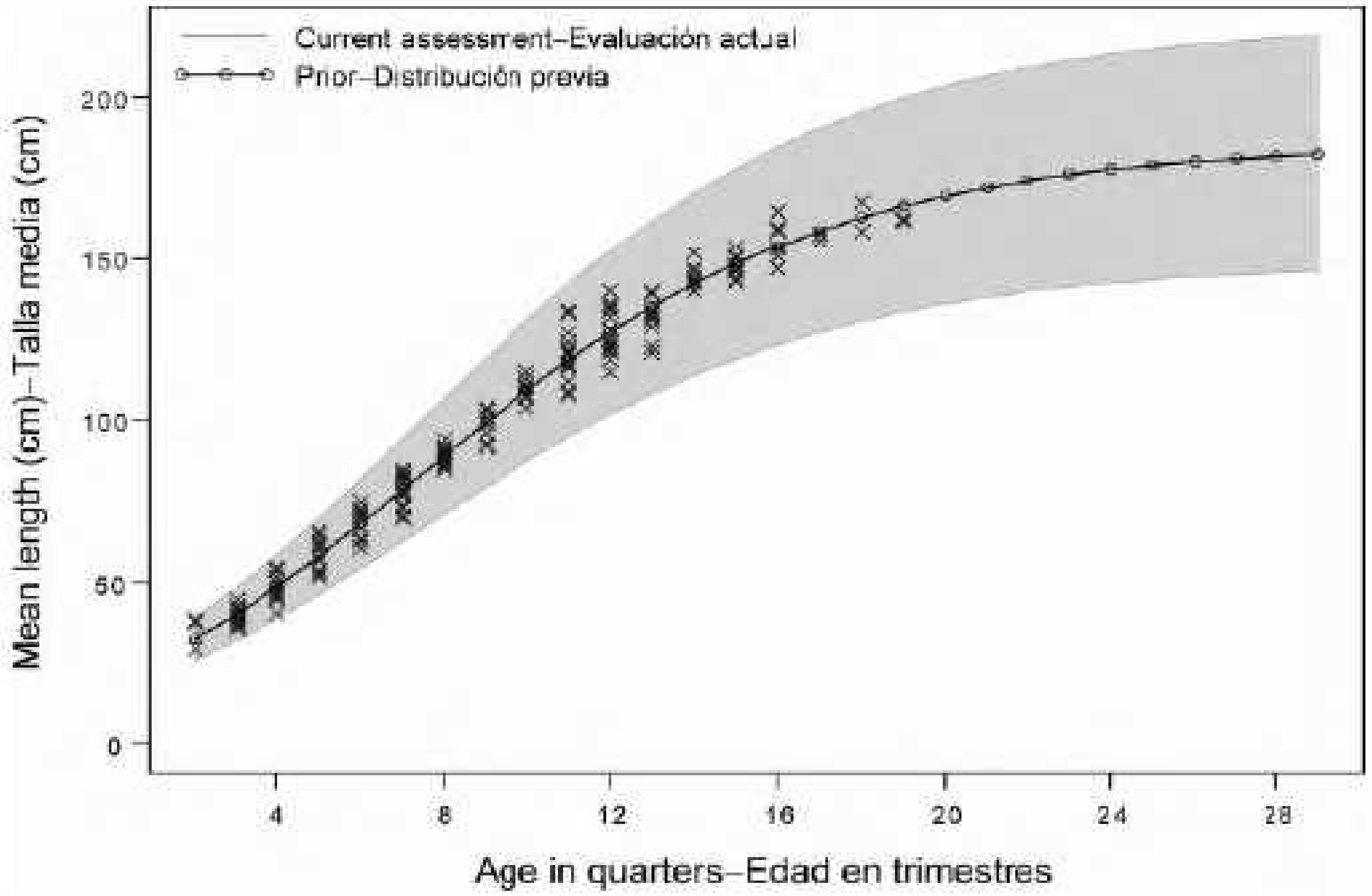


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FIGURA 3.1. Curva de crecimiento usada para la evaluación del atún aleta amarilla en el OPO (línea

Outline

- What is currently assumed
- Good Practices
- The functional form
- Estimation
  - Data
    - Age-length, daily/annual
    - Tag growth increment
  - Inside/outside
- Variation of length-at-age
  - Individual variation, birth date, measurement date (adjusted)
  - Estimate inside or outside