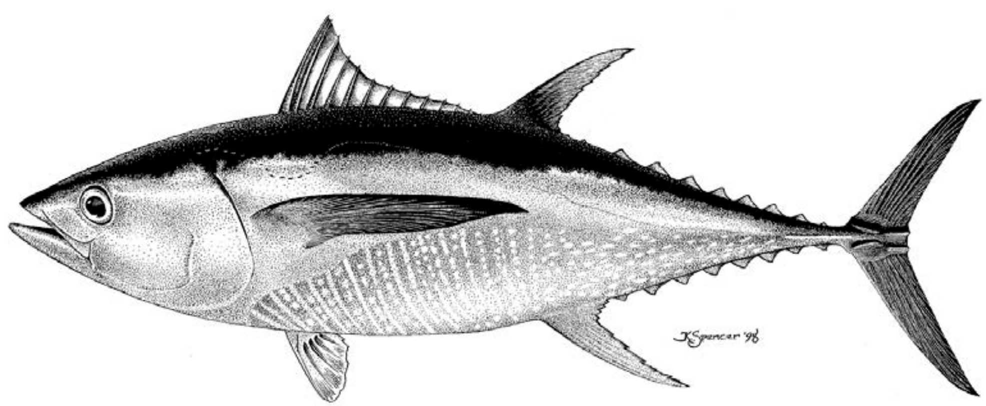
Improved growth estimates from integrated analysis of age-at-length and tag-recapture data for BET and YFT and their impact on stock assessment results

Alex Aires-da-Silva, Mark Maunder, Kurt Schaefer and Dan Fuller

External review of IATTC yellowfin tuna assessment

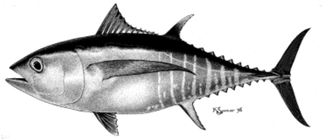
La Jolla, USA, 15-19 October, 2012



CIAT
IATTC

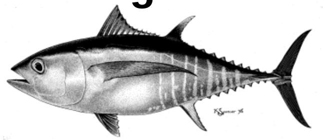
Topics

Outline



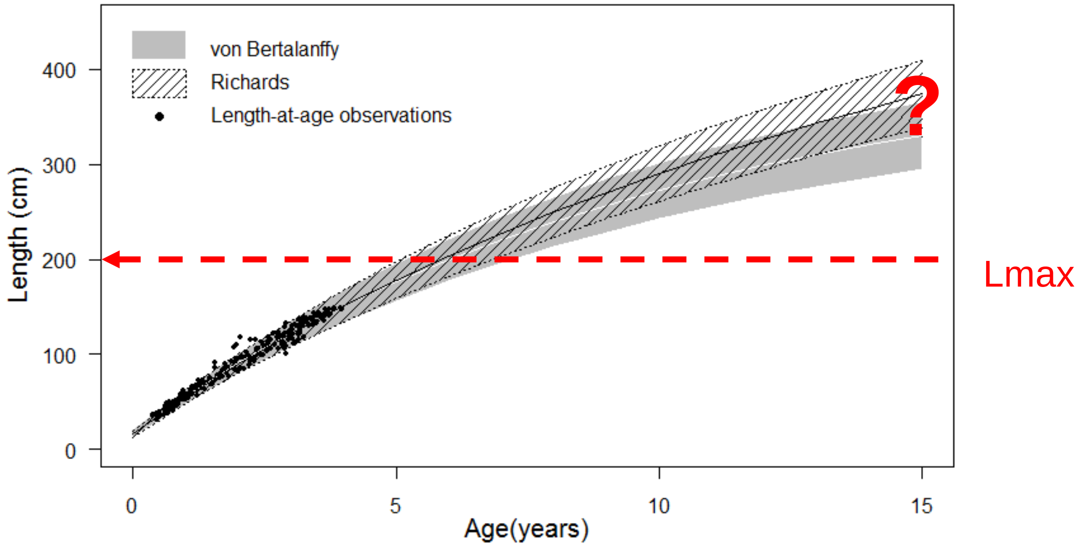
- Background:
  - Challenges with growth estimation for EPO tropical tuna (YFT and BET)
  - Approaches which could be used to integrate direct age-at-length readings and tag-recapture data
- Integrated growth analysis for BET
  - Apply and compare results from 3 estimation methods
- Integrated growth analysis for YFT
  - Apply one estimation method
  - Impact of new estimates on YFT assessment

Background



Challenges with EPO tuna growth

BET



L max observed (close to virgin population)

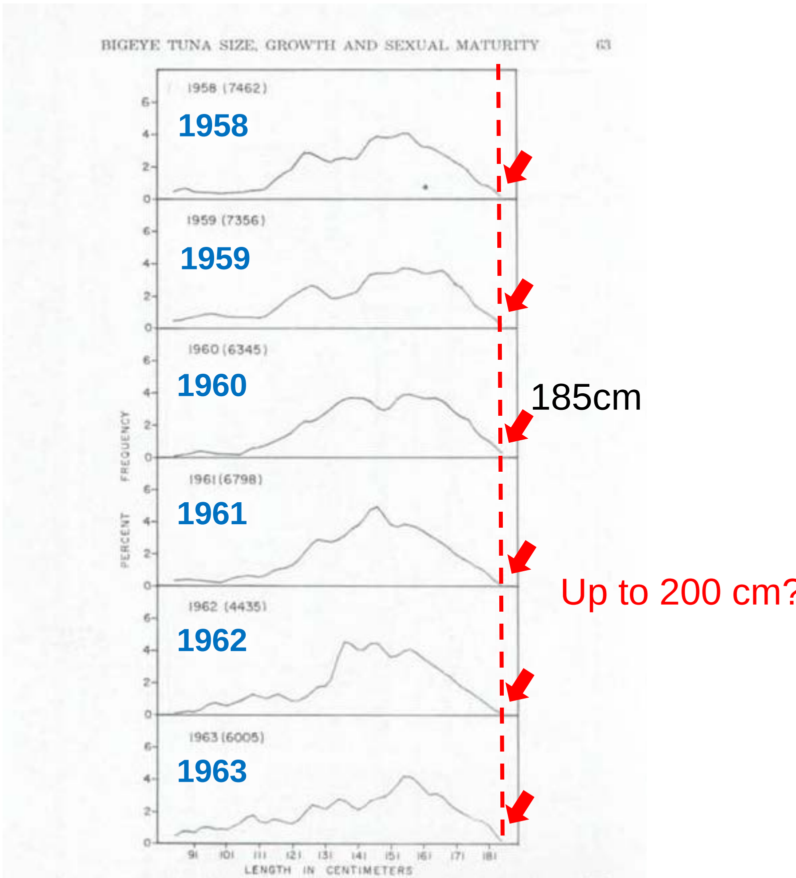
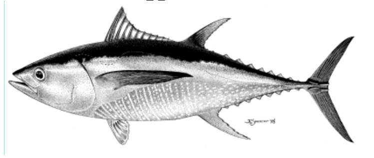


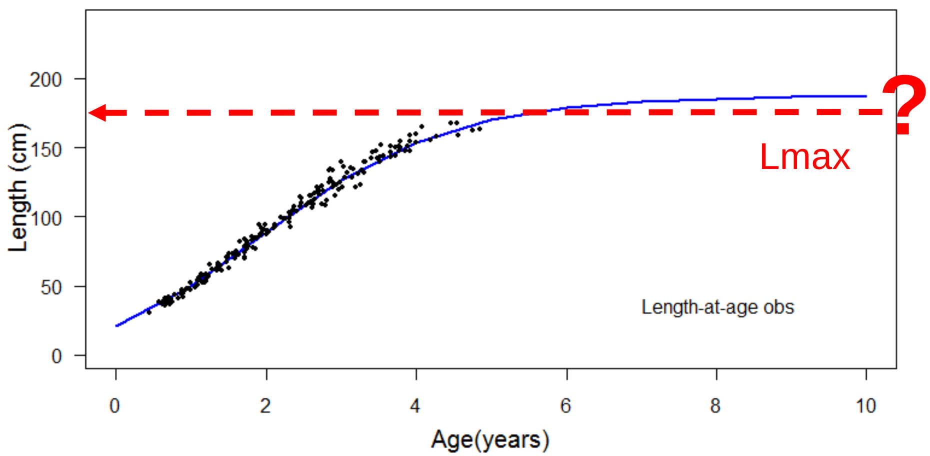
FIGURE 2. Annual length-frequency distribution of bigeye tuna caught by long-line in the southern area, during 1958-1963, expressed as a percentage. Year and number of individuals shown in upper left-hand corner of each panel.

Kume and Joseph (1966)

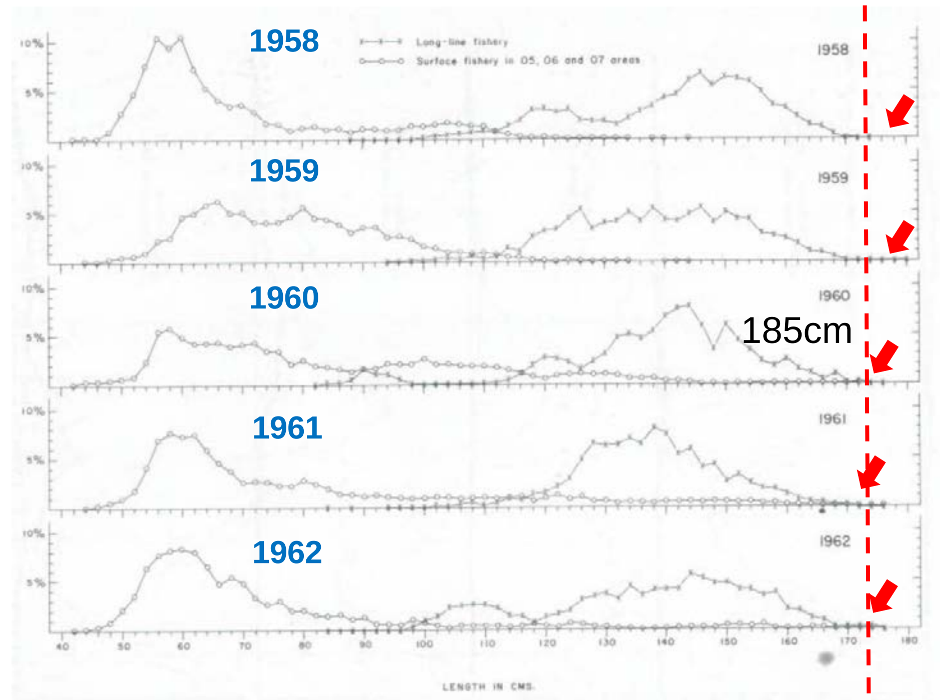


Challenges with EPO tuna growth

YFT



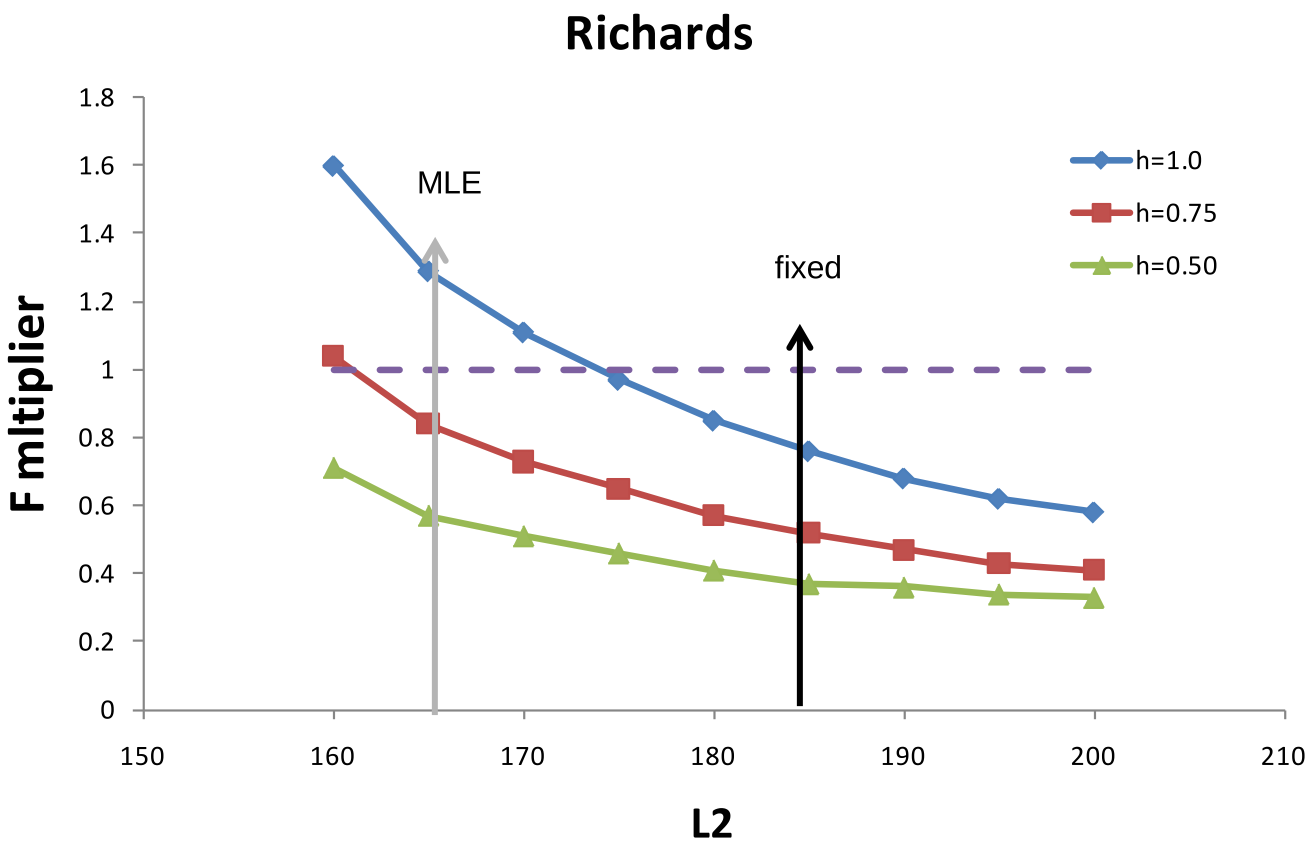
Lmax observed (close to virgin population)



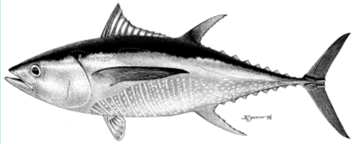
Up to 200 cm?

Suda and Schaefer (1965)

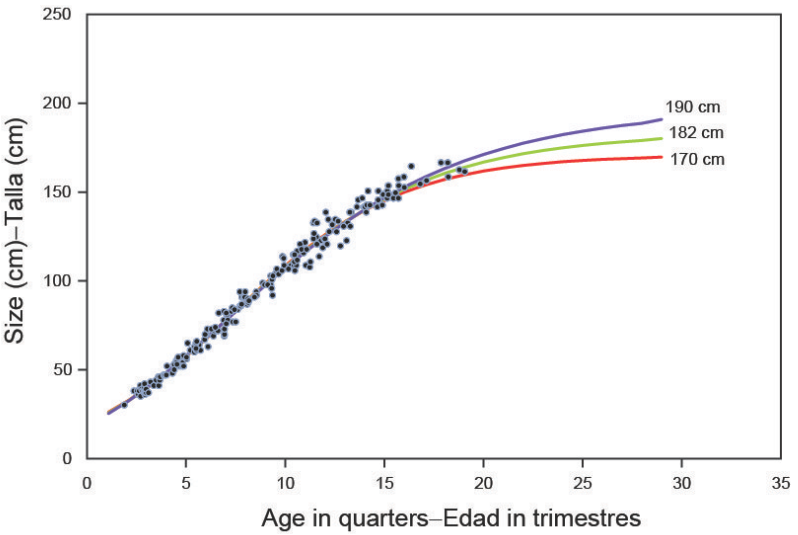
Impact of L_2 on BET management



Impact of L_2 on YFT management

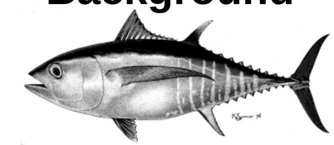


SAR 12 (2012)



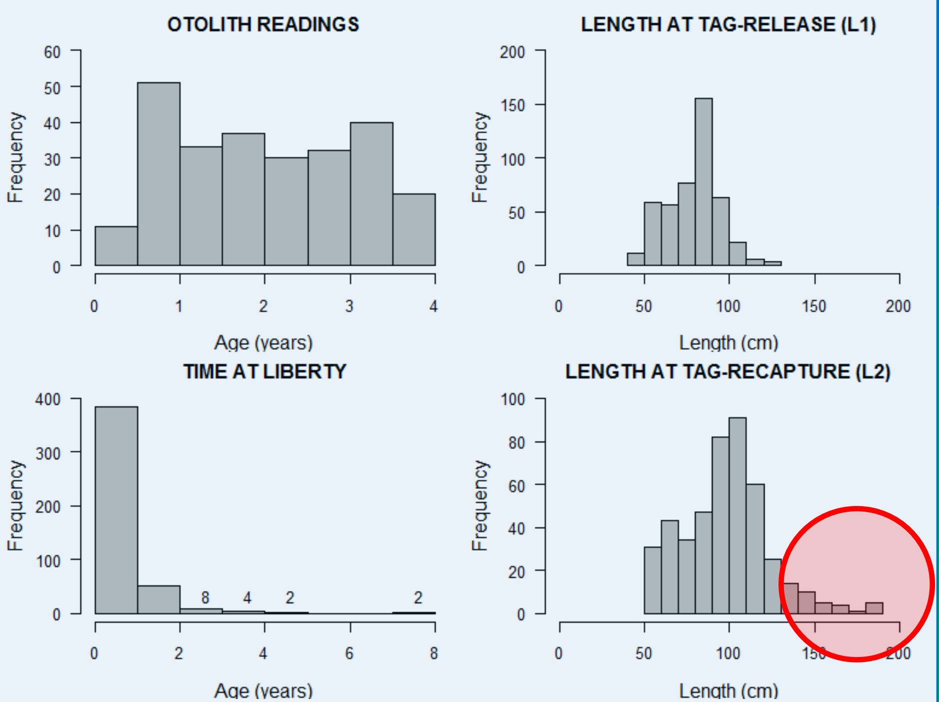
		L2	
	Basecase	**170 cm**	**190 cm**
MSY	262,857	275,310	264,704
Bmsy	354,958	370,334	359,144
Smsy	3,305	3,777	3,169
Bmsy/B0	0.31	0.31	0.31
Smsy/S0	0.26	0.24	0.27
Crecent/AMSY	0.88	0.84	0.87
Brecent/Bmsy	0.96	1.20	0.85
Srecent/Smsy	0.71	↑ 1.03	↓ 0.59
Fmultiplier	1.13	↑ 1.65	↓ 0.94

Background

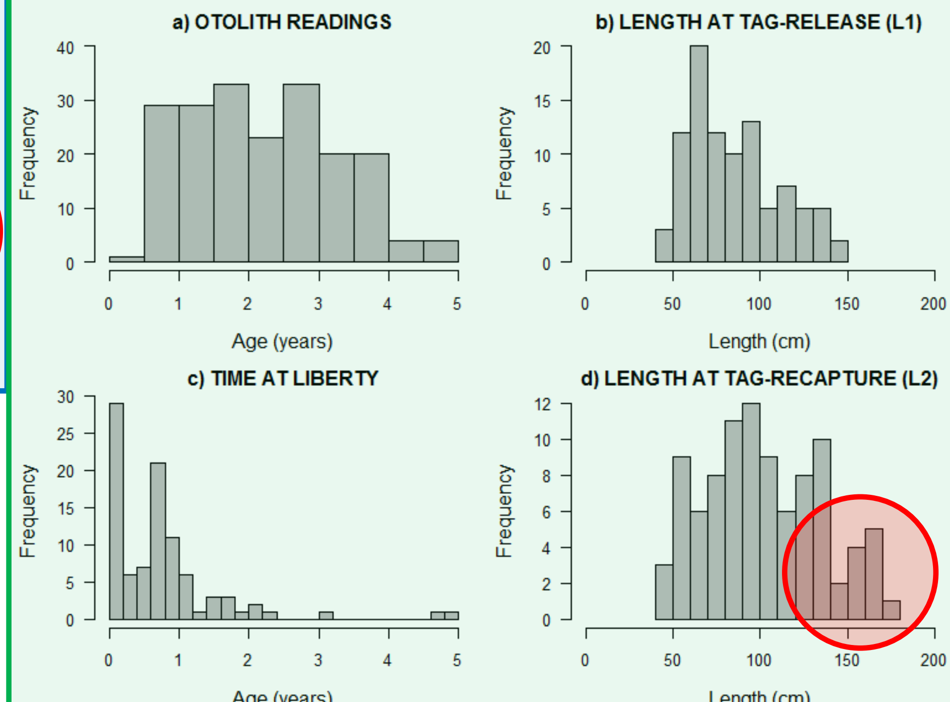


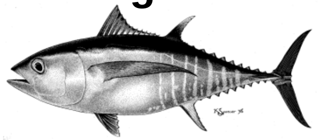
Tag-recapture data could help…

BET



YFT





Growth estimation

- Two most common ways of estimating fish growth
  - Age-at-length data (direct readings of skeletal parts)

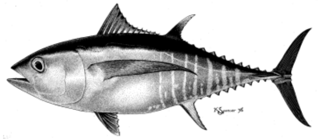
$$L = L_{\infty}\left[1 - e^{-K(t-t_0)}\right]$$

  - Length increment data from tag-recapture experiments (Fabens 1965)

$$\Delta L = (L_{\infty} - L)(1 - e^{-K\Delta T})$$

- Growth parameters generated from both methods are not comparable (Sainsbury 1980; Francis 1988)
  - Curves are fitted using different error structures
  - L@A: residuals between observed L@A and expected L@A
  - Tagging: residuals between observed size inc. and expected at different time intervals

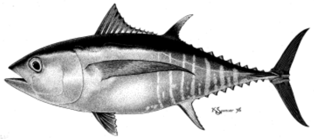
The “Laslett-Eveson-Polacheck” method



- Maximum likelihood approaches exist that can model the joint density of the release and recapture lengths (Laslett et al. 2002; Eveson 2004)
- Treat unknown ages of tagged fish as parameters to estimate in the model (random effects)
- For example, if we use the VB the assumed growth curve for the fish is:

$$L_t = L_\infty\left[1 - e^{-K(\boldsymbol{A} - t_0)}\right]$$

  - *A* = *t*, is the age of each fish and treated as a **random variable** with density p(.) and whose parameters will be estimated in the model



Tag-recapture component

- For a fish *i* tagged at time t_1 with released length L_1 and recaptured at t_2 with L_2

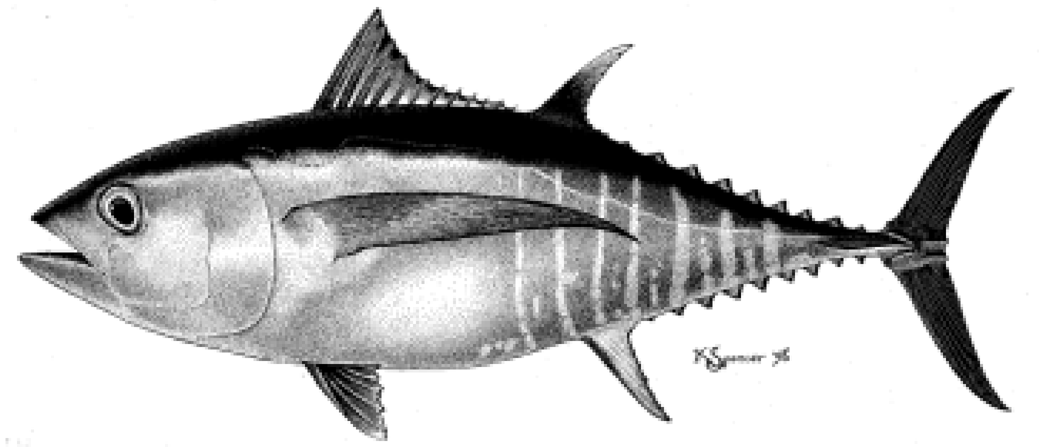
$$L_{1,i} = L_\infty\left[1 - e^{-K(\boldsymbol{A_i} - t_0)}\right]$$

$$L_{2,i} = L_\infty\left[1 - e^{-K(\boldsymbol{A_i} + \boldsymbol{t_{2,i}} - \boldsymbol{t_{1,i}} - t_0)}\right]$$

  - The joint distribution of $L_{1,i}$ and $L_{2,i}$ can be integrated over A:

$$h(L_{1,i}, L_{2,i}) = \int h(L_{1,i}, L_{2,i} | a) p(a) da$$

  - This can be done using AD Model Builder!



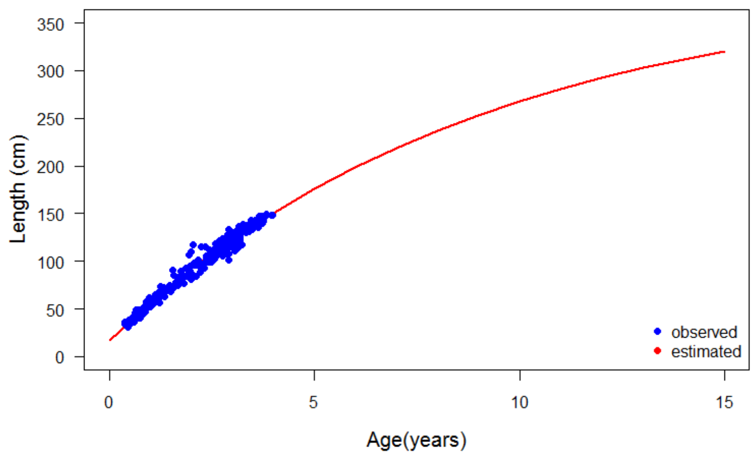
BET analysis

- Three estimation methods
  - Random effects (L-E-P method)
  - Penalized likelihood method
  - Bayesian (MCMC)

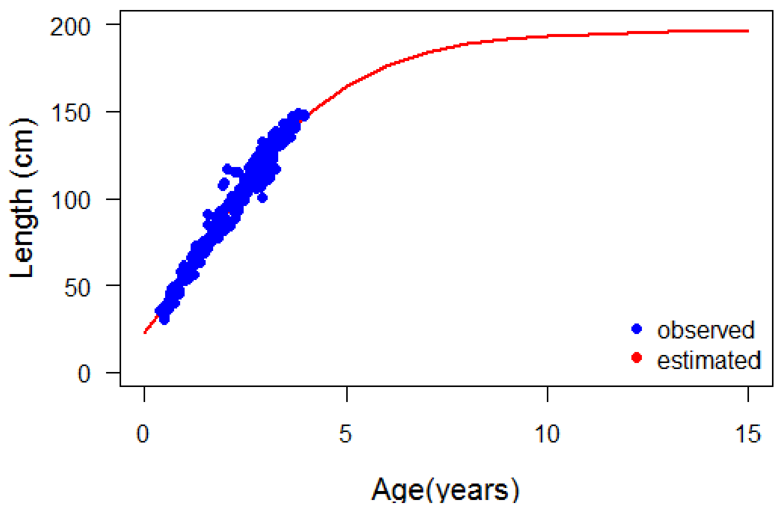
Integrated model - BET

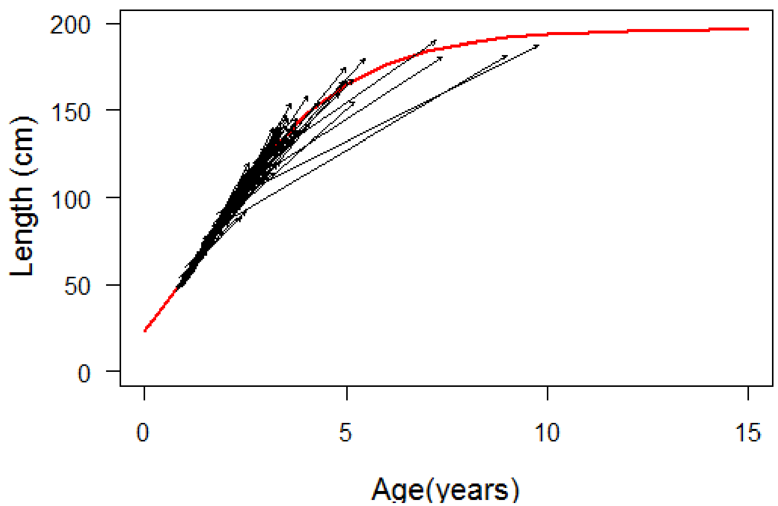
Results

Fit otolith only



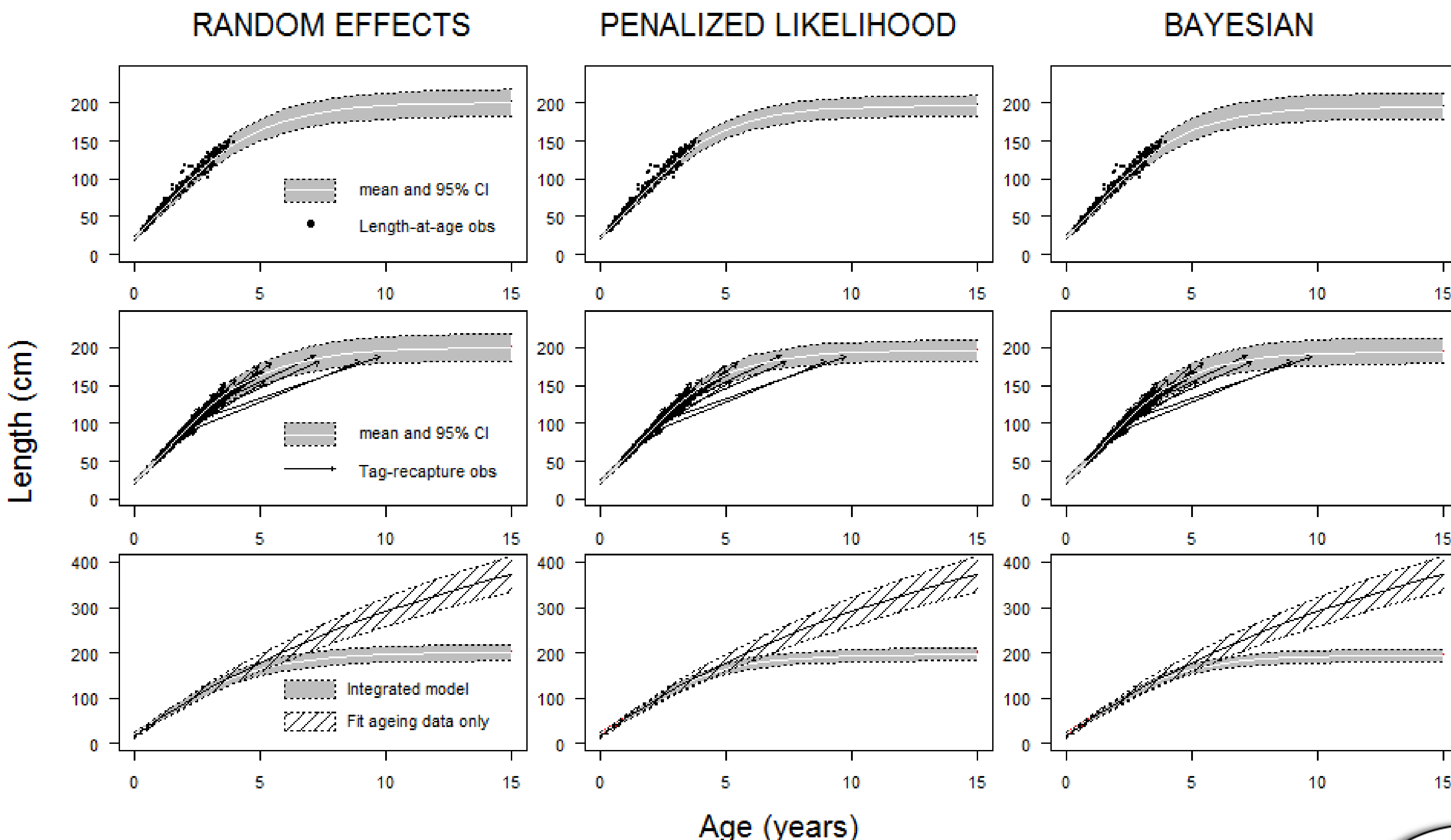
Integrated model





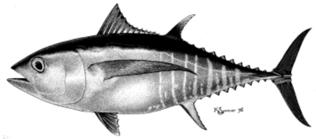
Estimation methods - BET

Results



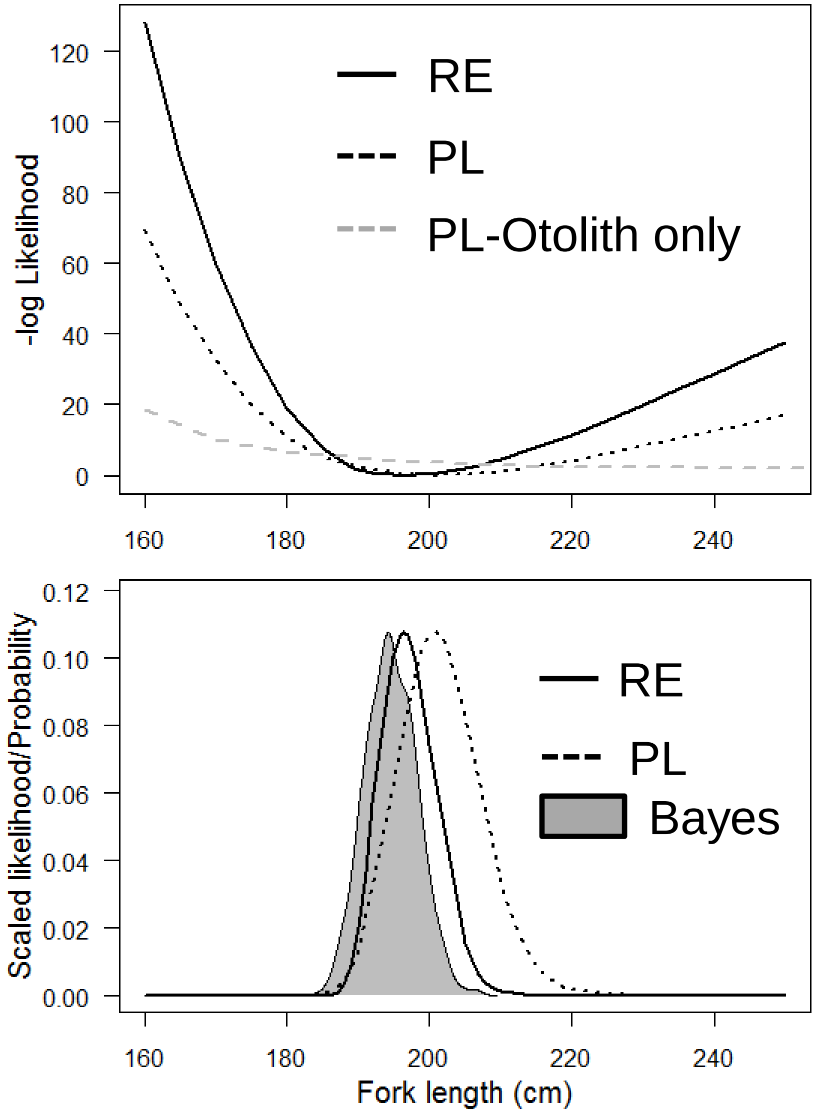
Likelihood profile on L_2 - BET

Results



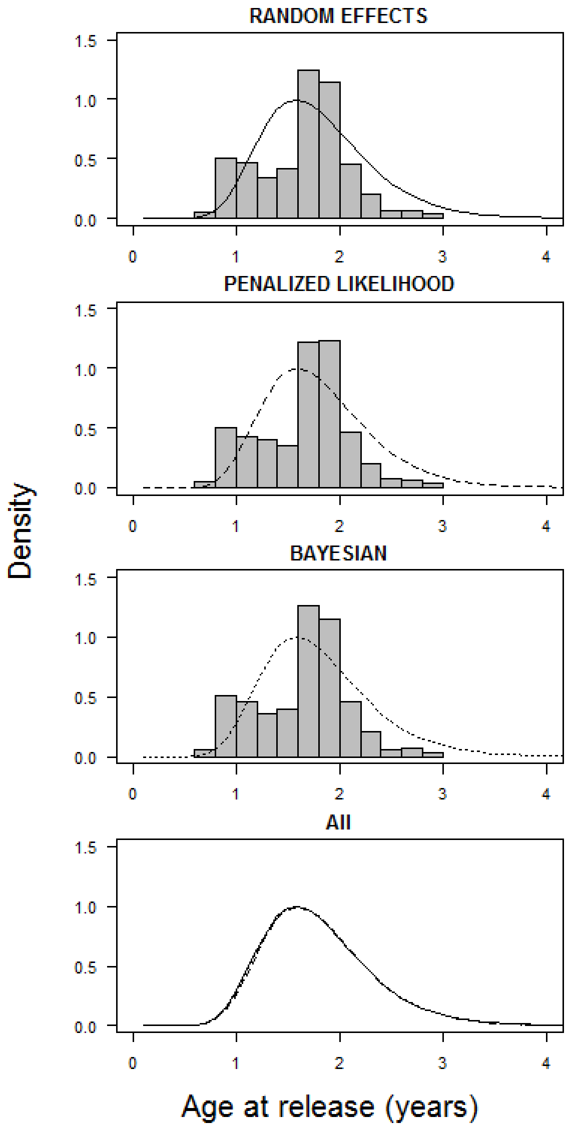
RE – Random Effects

PL – Penalized likelihood



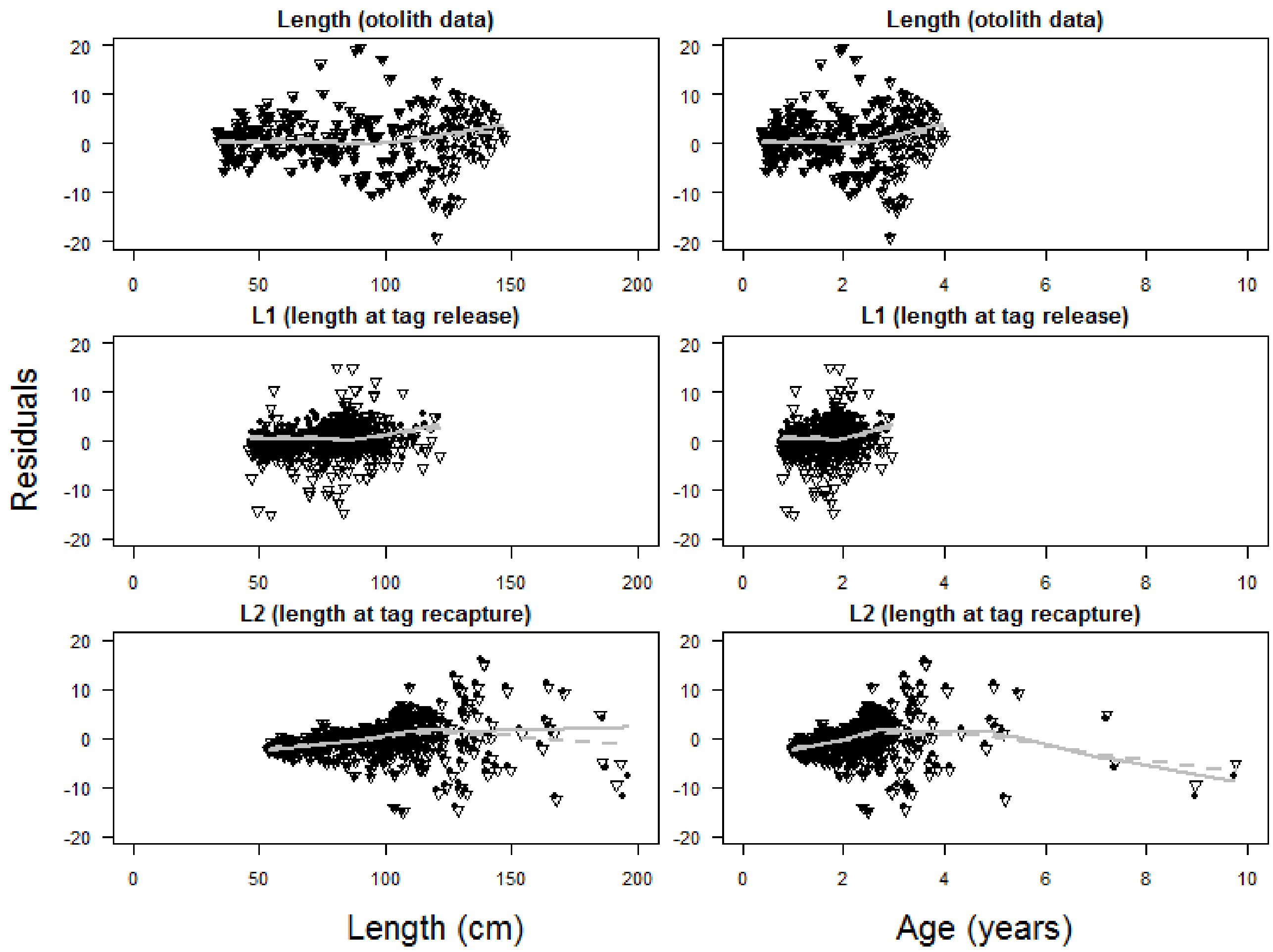
Distribution of age at release params.

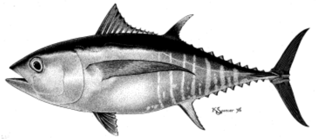
BET



Residual plots - BET

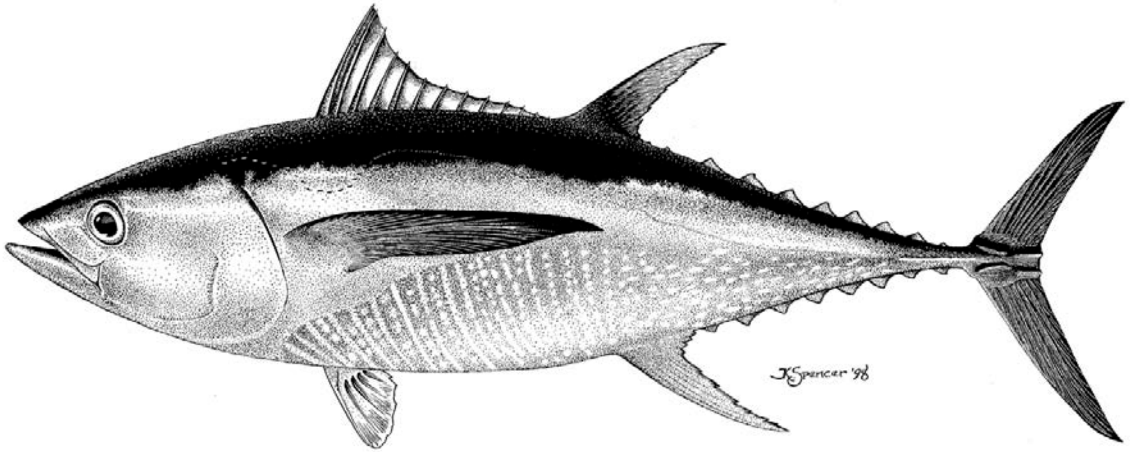
Results





Lessons from BET analysis

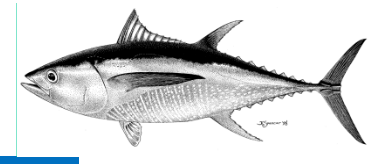
- Integrated analysis helped to reduce the uncertainty on growth
  - Average size of the older fish (L_2)
  - Variability of the length-at-age (L_{SD})
- Growth estimates were similar among 3 methods
- Penalized likelihood approach
  - Less computationally intensive
  - Could be integrated into stock assessment models (e.g., Stock Synthesis)

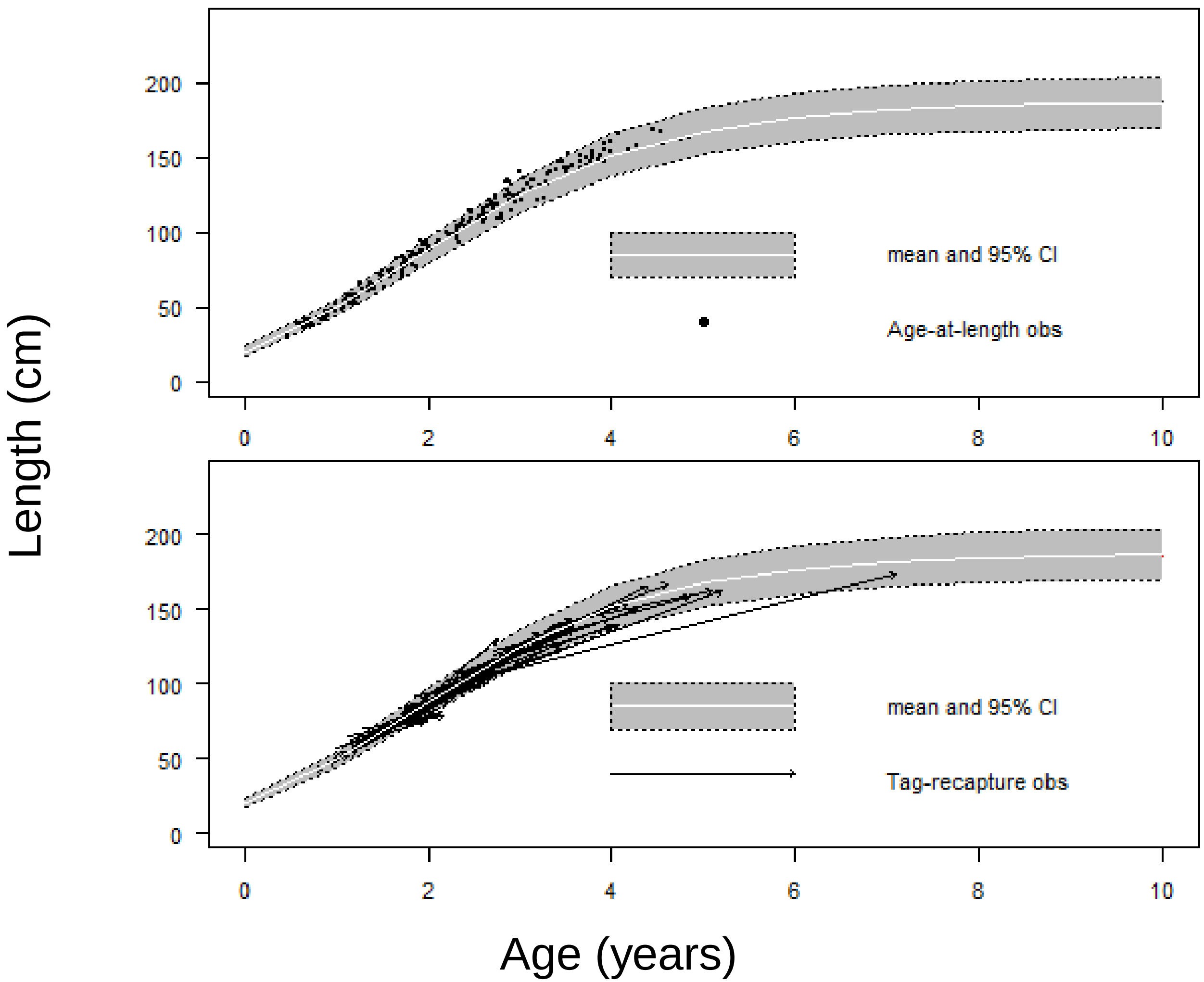


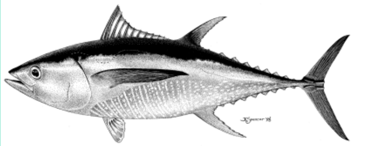
YFT analysis

- Penalized likelihood approach
- Impact of new estimates on stock assessment results and management

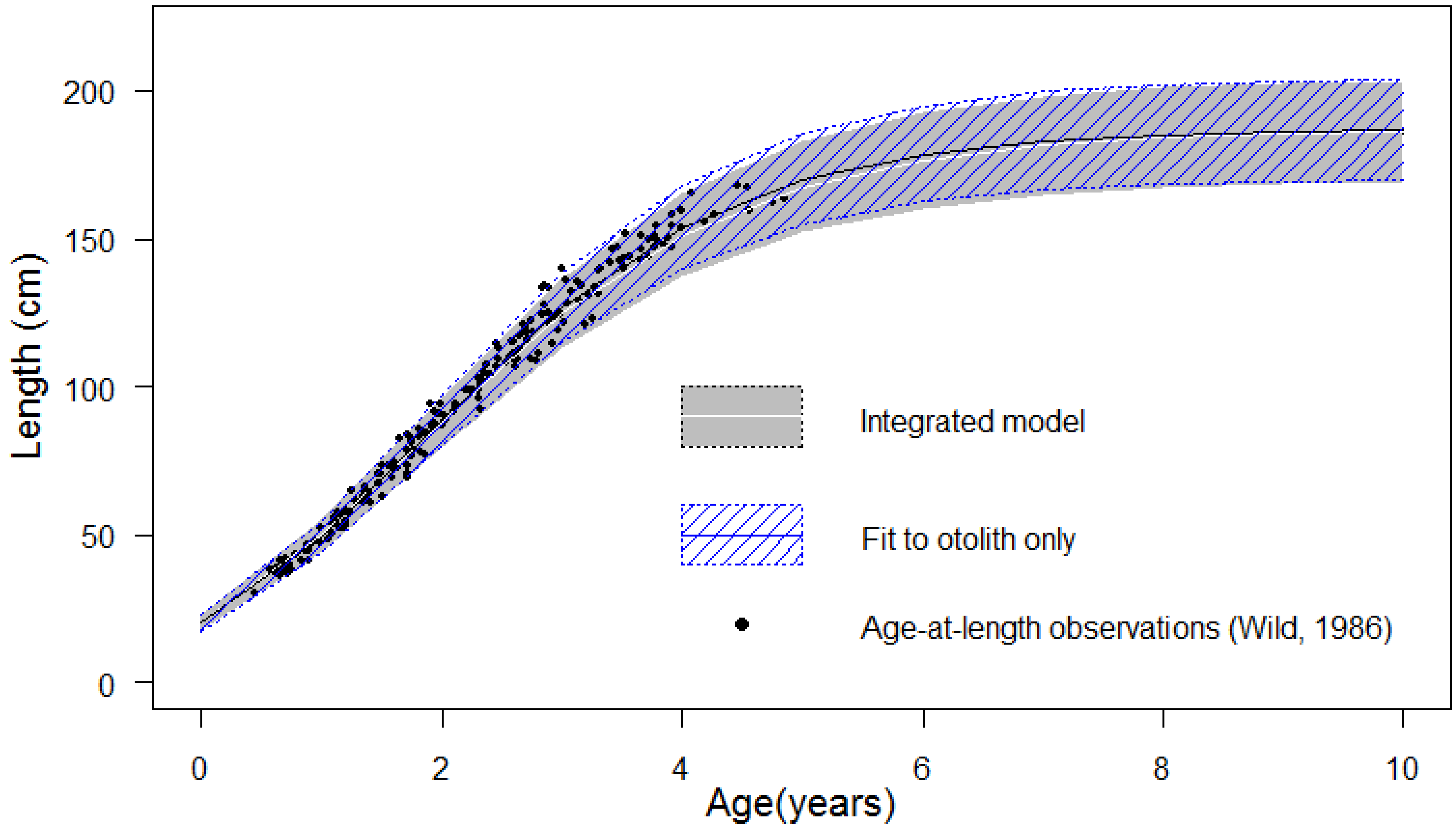
Integrated model - YFT



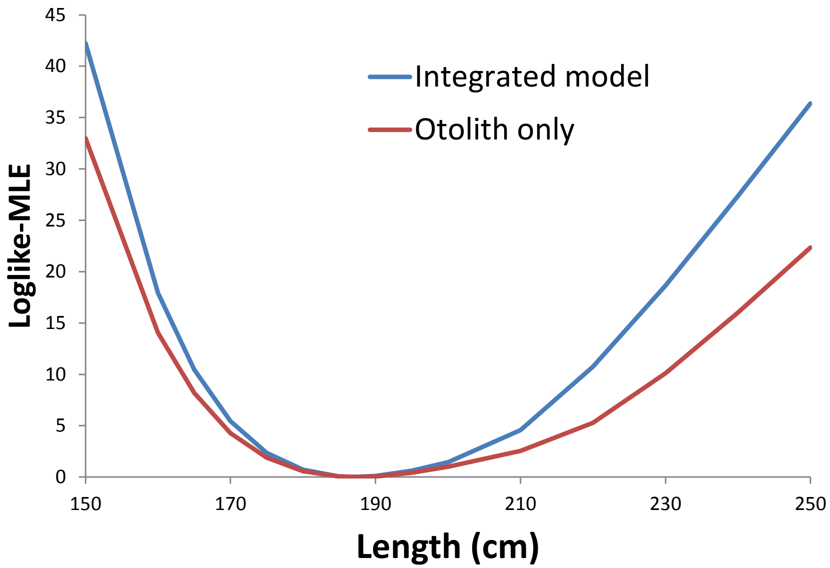


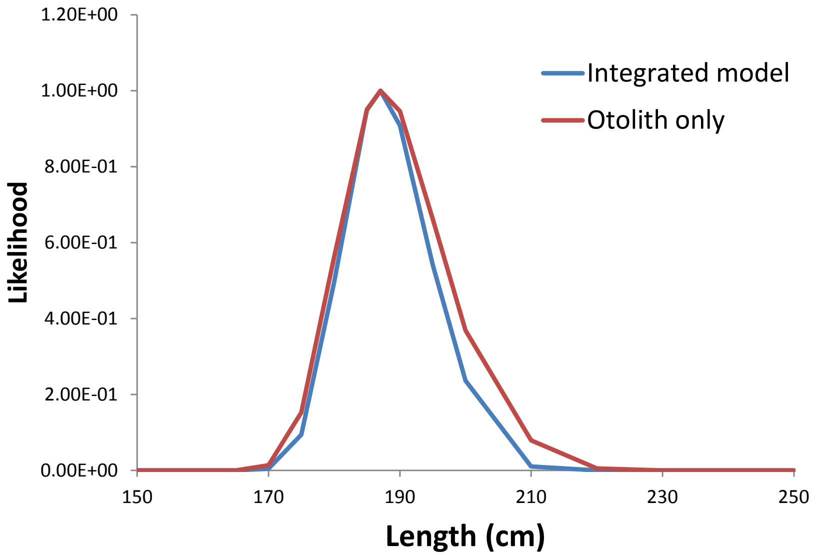


IM vs fit to otolith only



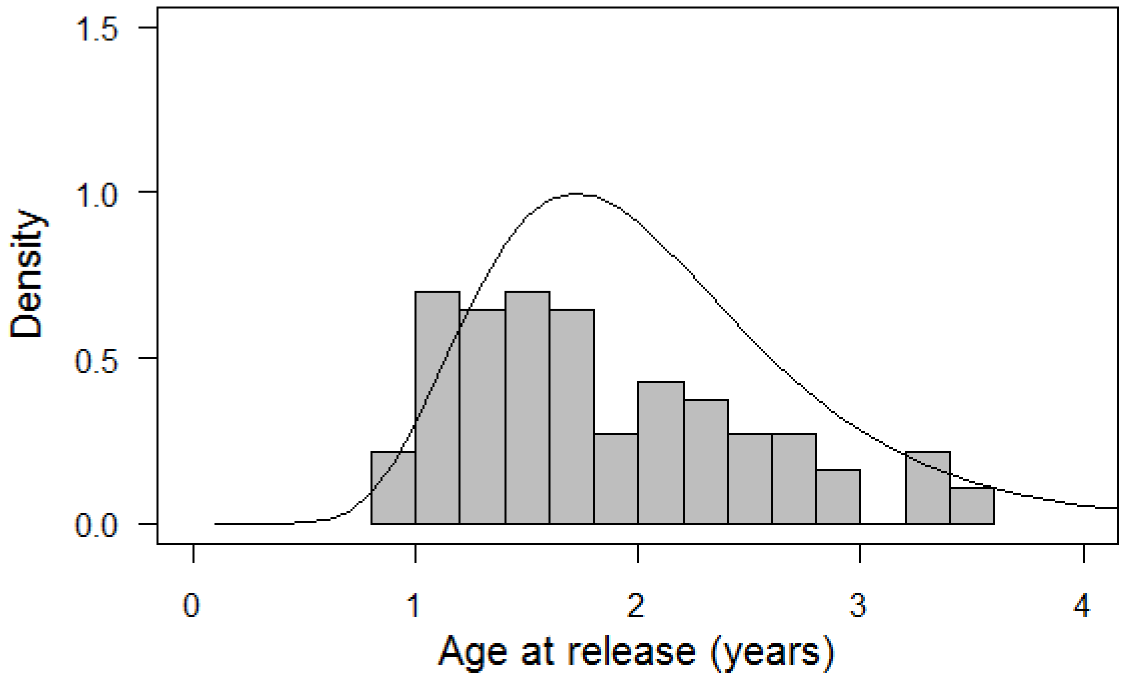
Likelihood profile on L_2 - YFT



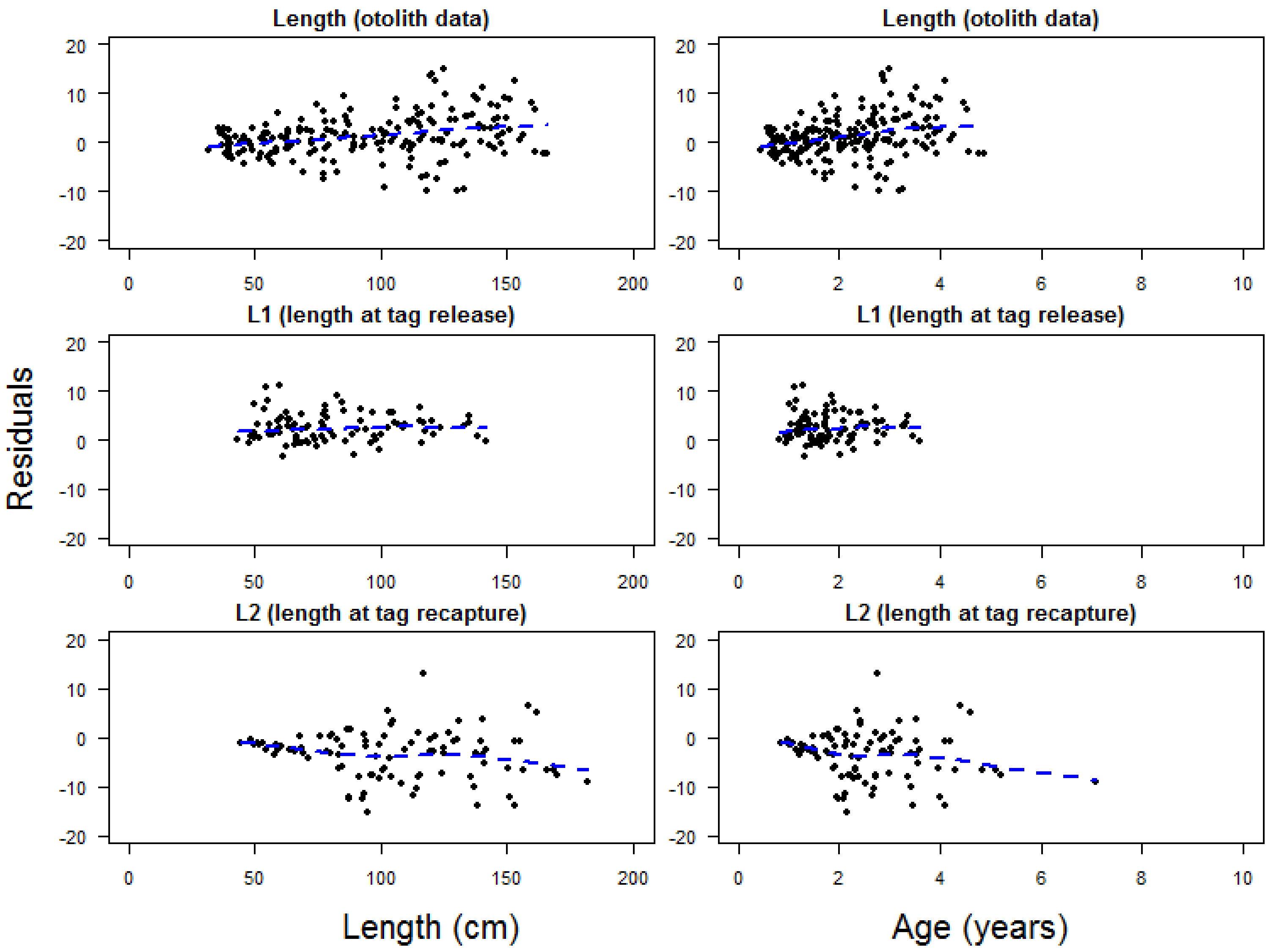


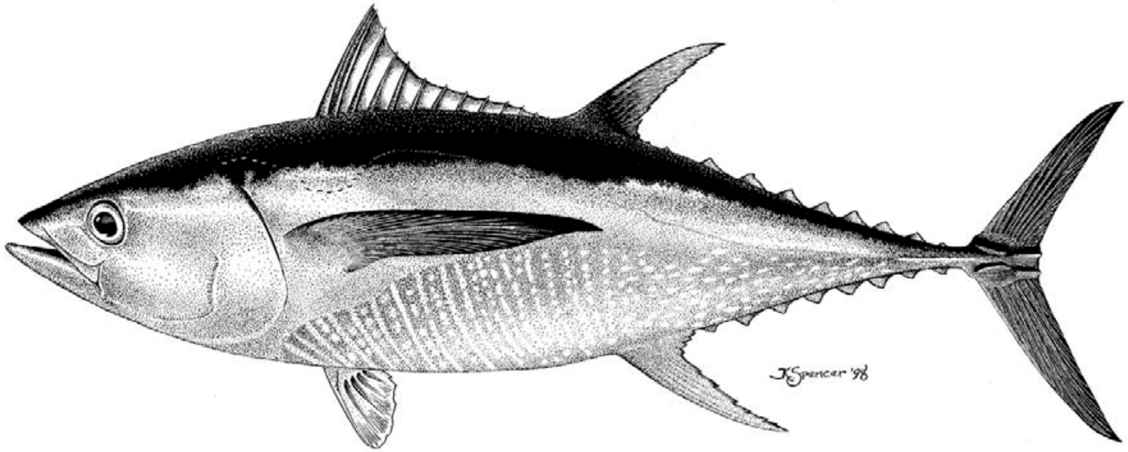
CIAT IATTC

Distribution of age at release params



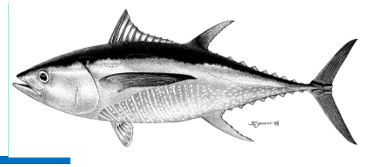
Residual plots - YFT





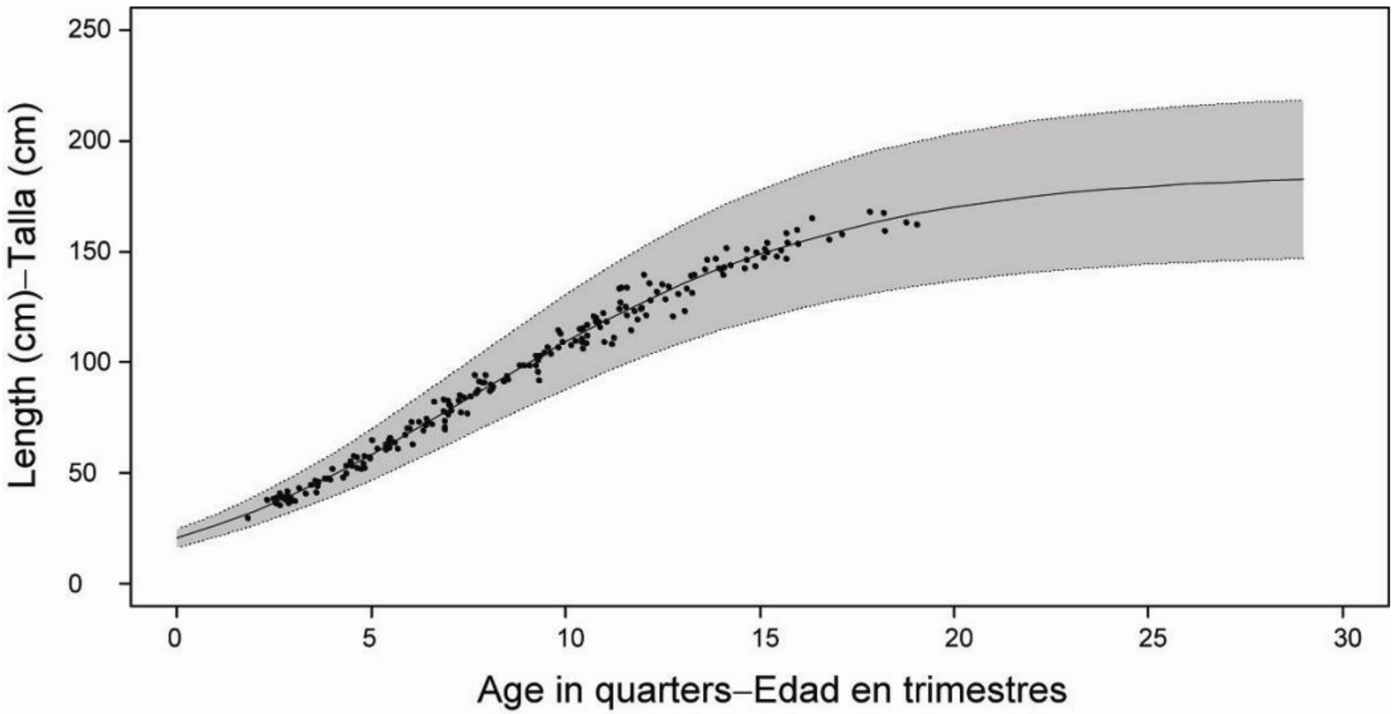
YFT analysis

- Penalized likelihood approach
- Impact of new estimates on stock assessment results and management

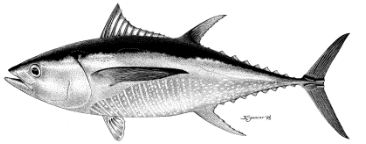


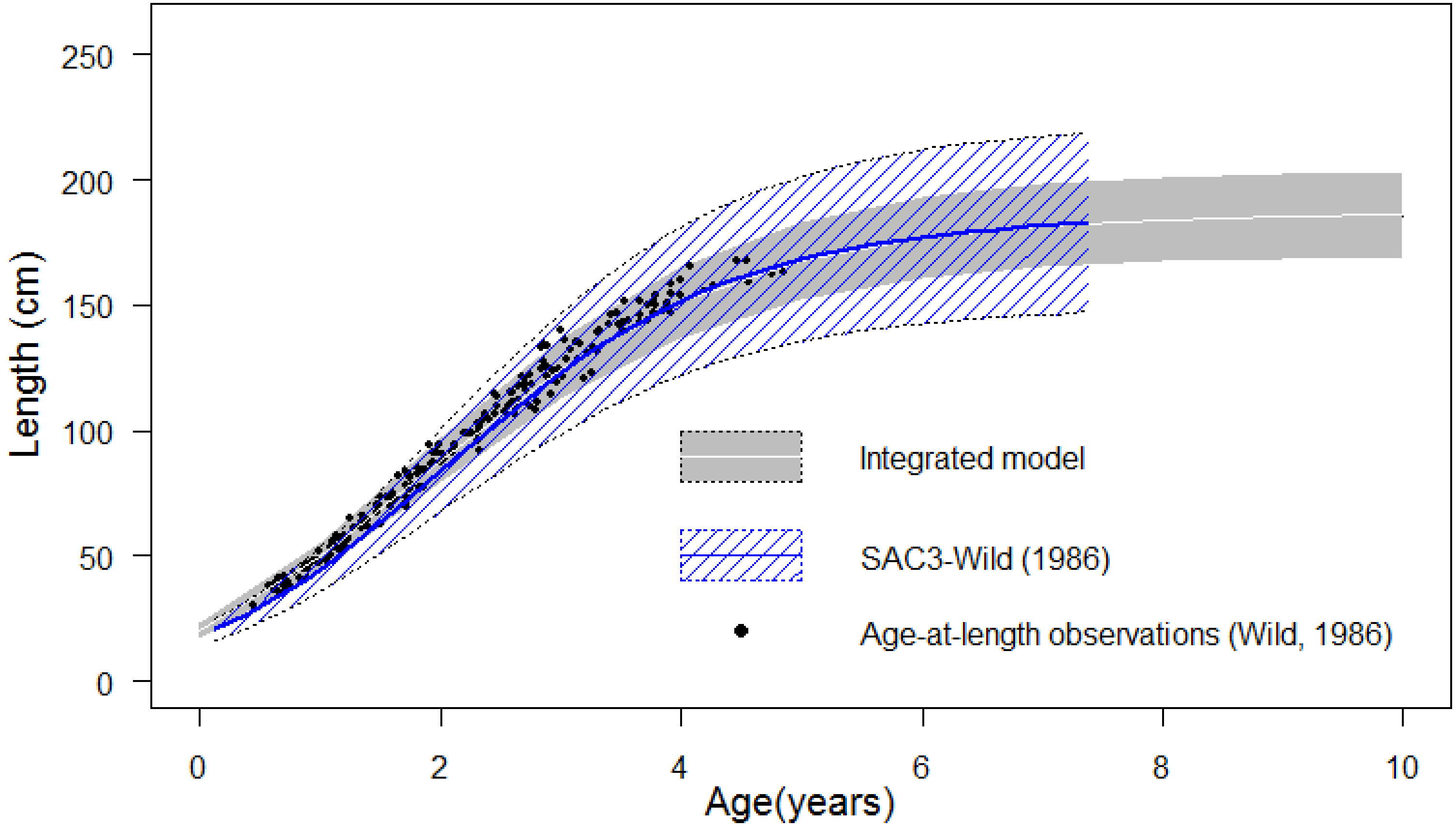
YFT base case – growth assumptions

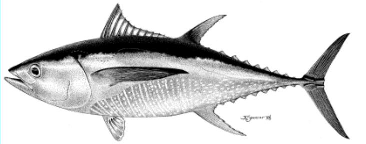
- Richards growth curve
  - Growth parameters fixed (Maunder and Aires-da-Silva, 2009)
  - L_2 fixed at 182.3 cm
  - Variability of length-at-age (LSD) fixed



Base case vs IM estimates



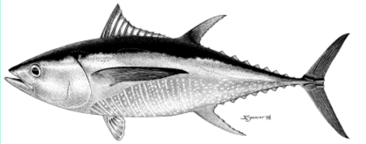


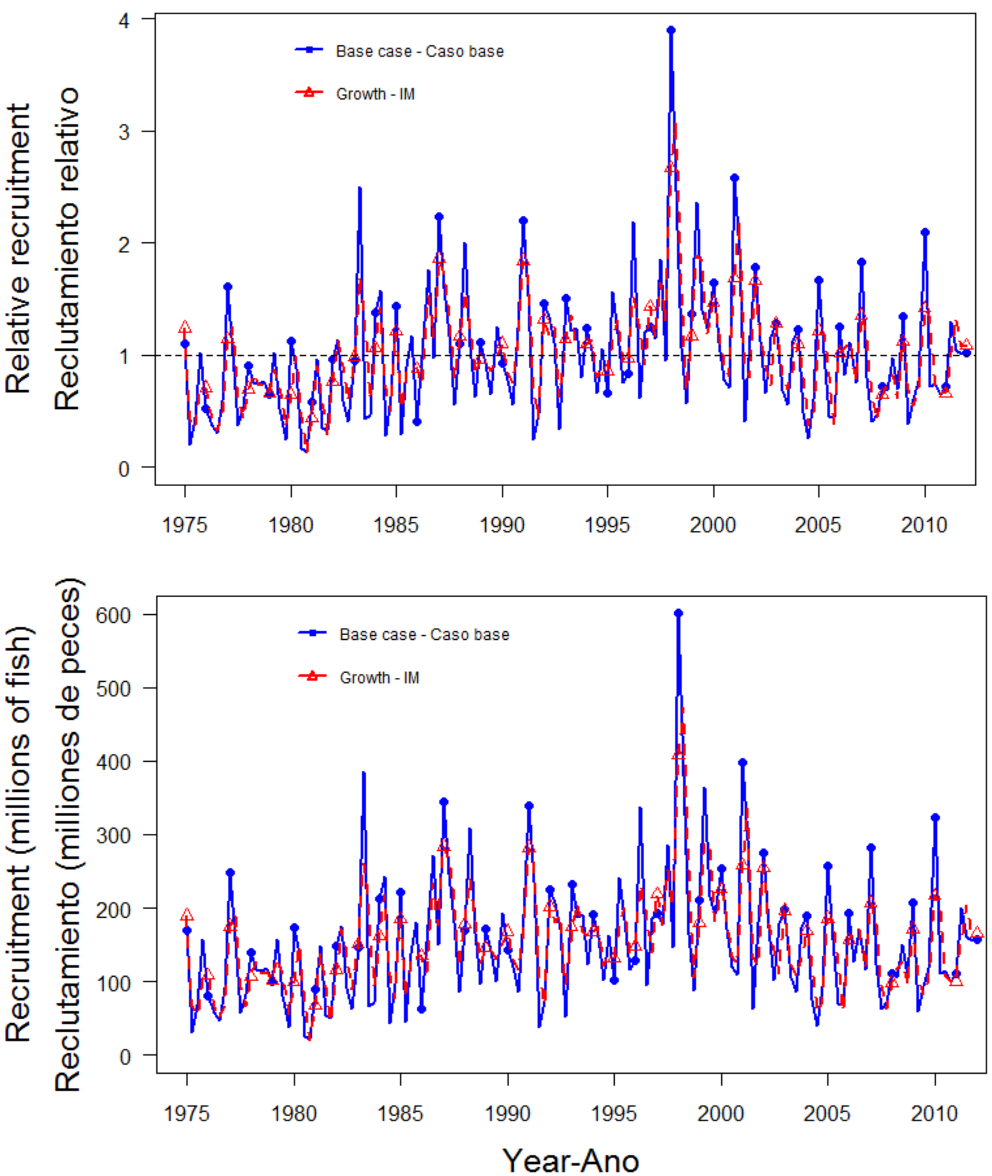


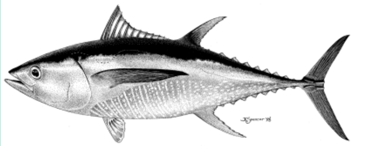
Model fit - likelihoods

	Base case	IM	
TOTAL	8289.5	8415.7	+126 units
Survey	-148.9	-155.5	
Length_comp	8443.8	8604.5	
Age_comp (NOT FIT)	139.1	215.4	+73 units
Recruitment	-5.4	-33.2	

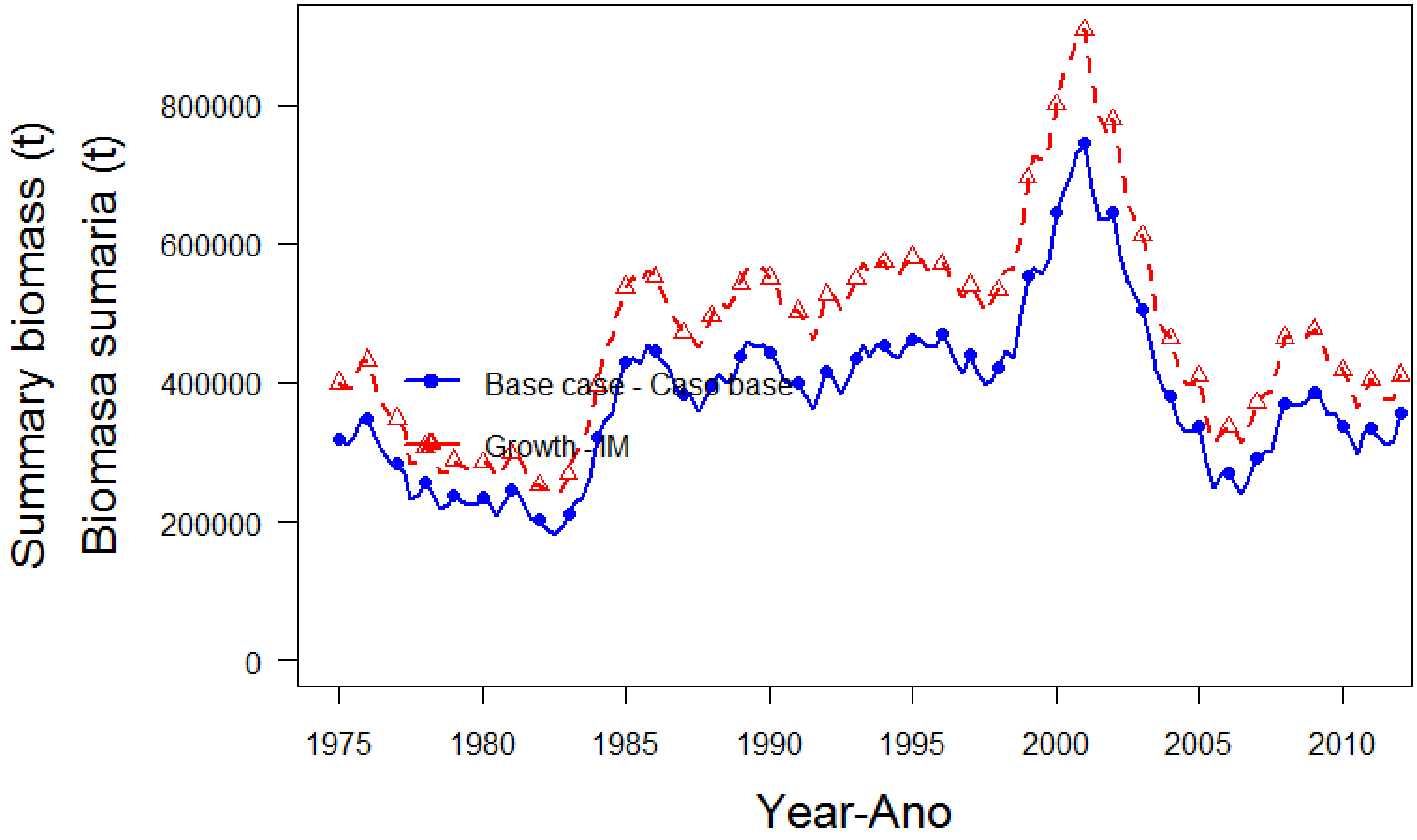
Recrutiments



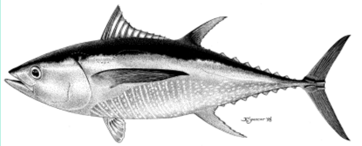


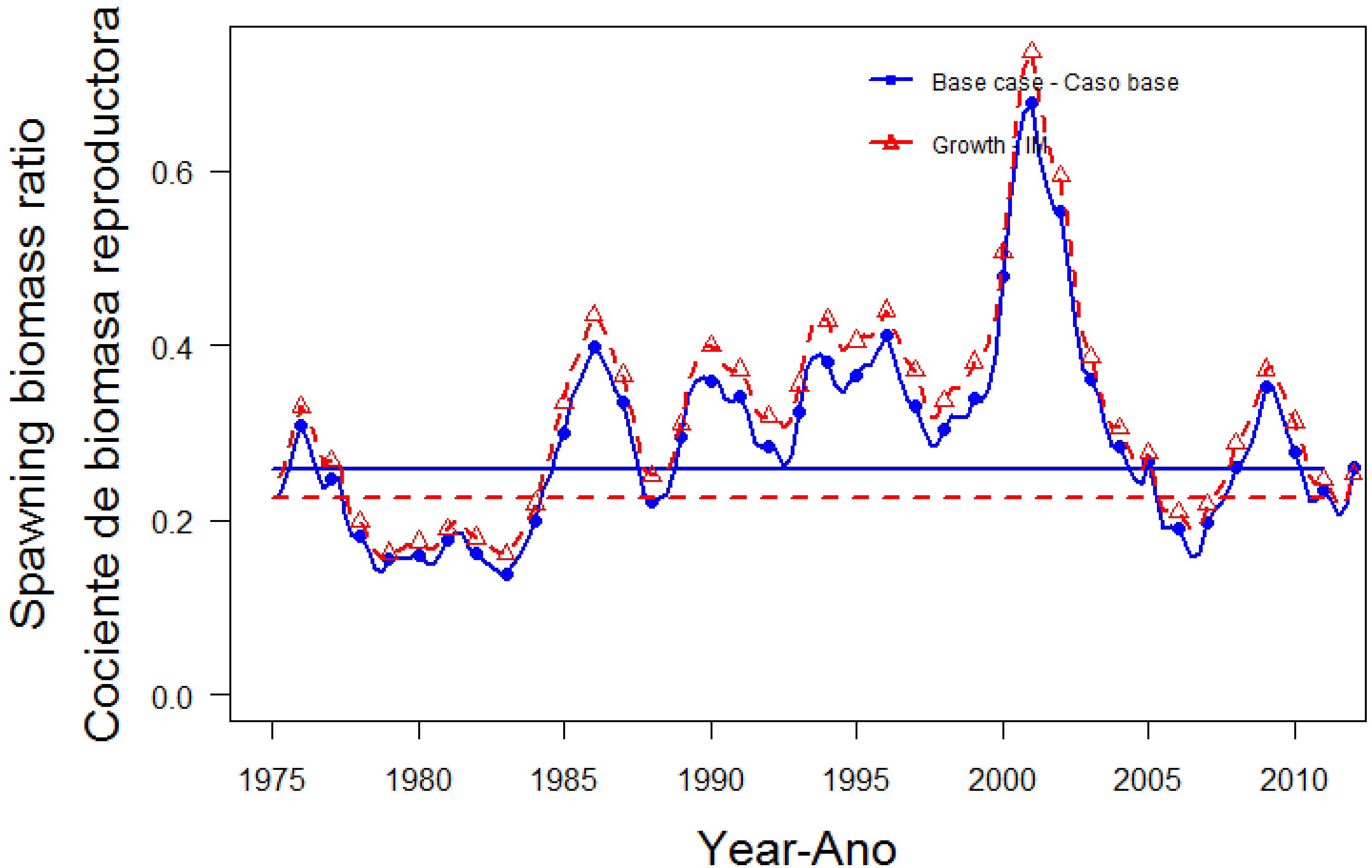


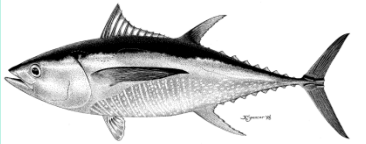
Biomasses


Summary biomass (t)
Biomasa sumaria (t)
800000
600000
400000
200000
0
Base case - Caso base
Growth - M
1975
1980
1985
1990
1995
2000
2005
2010
Year-Ano

SBR



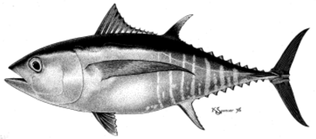

Base case - Caso base
Growth - IM
Spawning biomass ratio
Cociente de biomasa reproductora
0.0
0.2
0.4
0.6
1975
1980
1985
1990
1995
2000
2005
2010
Year-Ano



Management quantities

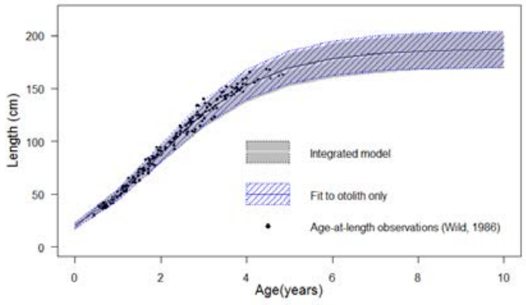
quant	Base case	Growth IM
msy	262,642	286,750
Bmsy	356,682	396,187
Smsy	3,334	3,052
Bmsy/Bzero	0.31	0.31
Smsy/Szero	0.26	0.22
Crecent/msy	0.79	0.72
Brecent/Bmsy	1.0	1.04
Srecent/Smsy	1.0	1.13
Fmultiplier	1.15	1.46

Methods

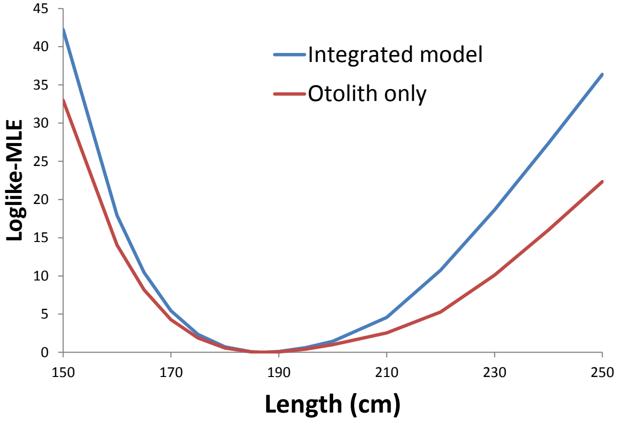


Lessons from YFT analysis

- Growth parameters from IM are very similar to those produce by fitting to otolith data only:
  - Average size of the older fish (L_2)
  - Variability of the length-at-age (L_{SD})

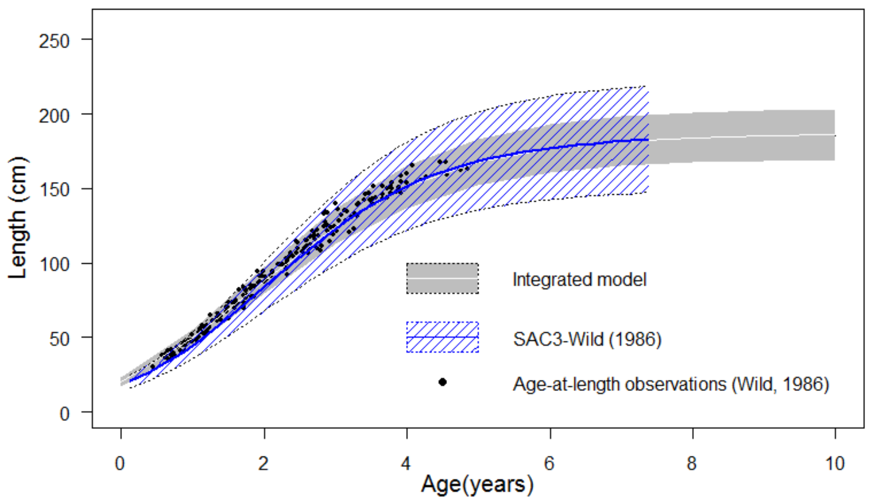


- Uncertainty of L_2 was slightly reduced with IM

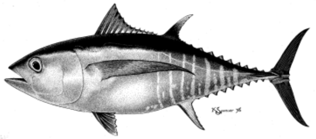


Lessons from YFT analysis (cont.)

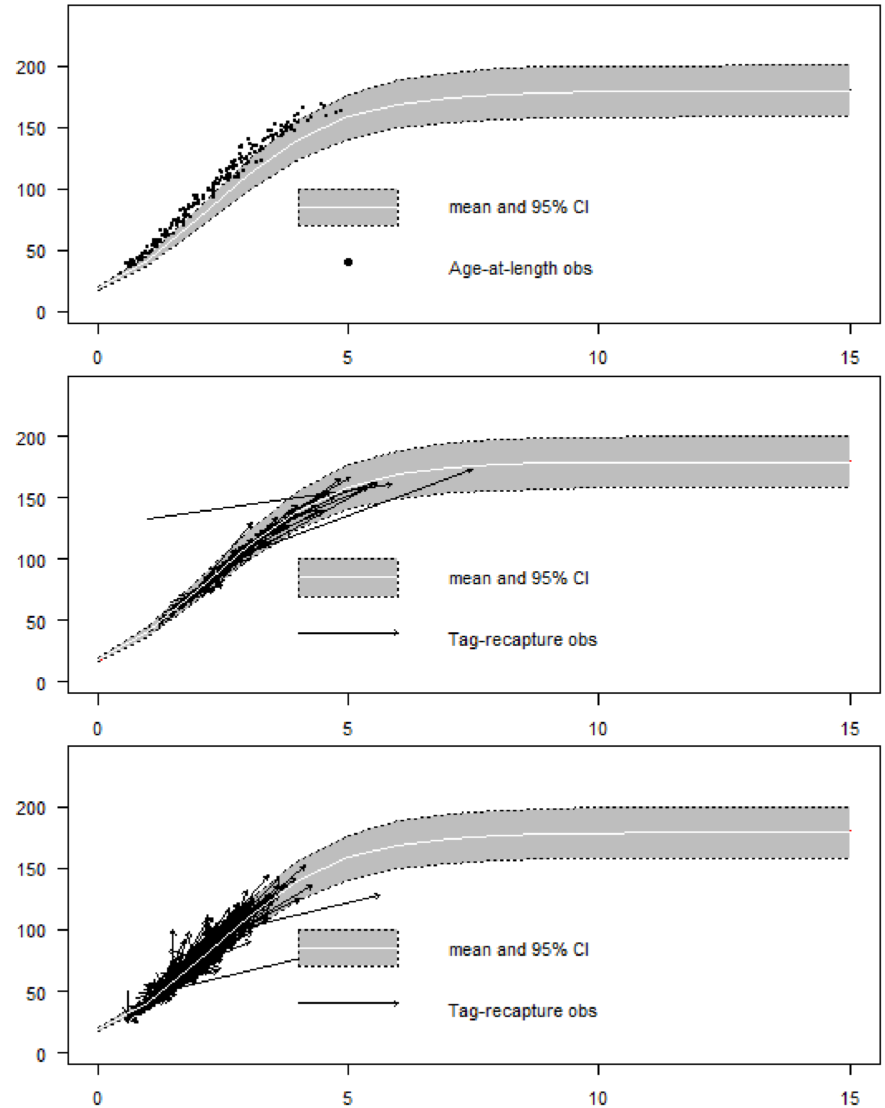
- Estimates of variability of L@A by IM are lower than base case, but used relationships differ:
  - Base case: CV=F(A)
  - Integrated model: SD=F(LAA)



Lessons from YFT analysis (cont.)

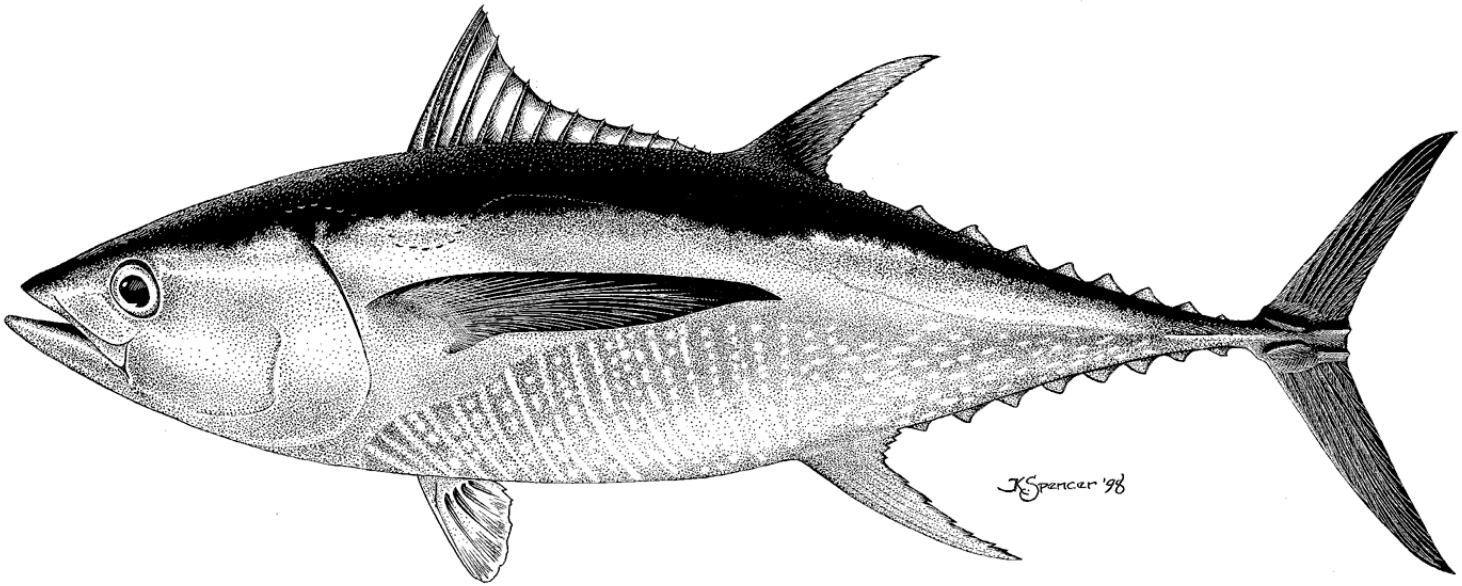


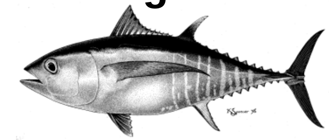
- More optimistic assessment results with IM growth estimates:
  - Fmultiplier increases
  - Srecent/Smsy increases



200
150
100
50
0
0
5
10
15
mean and 95% CI
Age-at-length obs
mean and 95% CI
Tag-recapture obs
mean and 95% CI
Tag-recapture obs

Questions?





Longline expansion in EPO

- Length of the largest fish observed (close to virgin population)

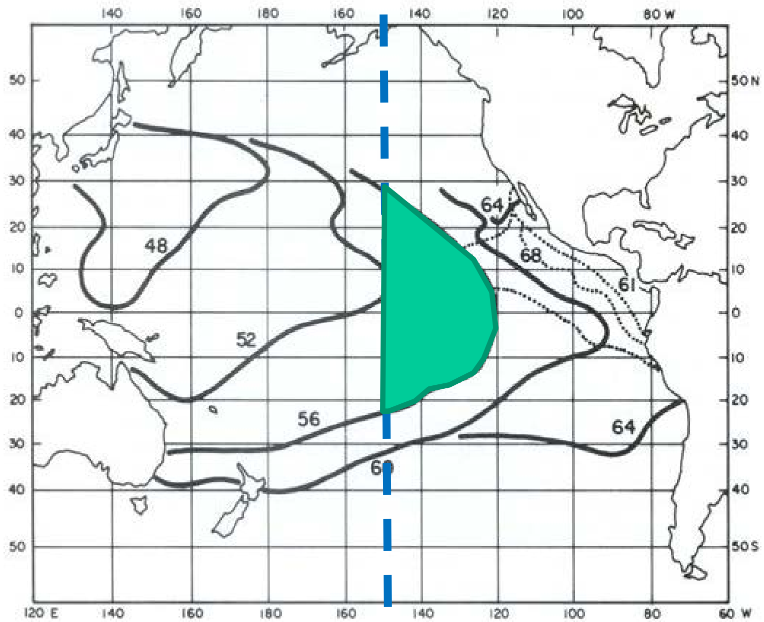


FIGURE 1. Geographical expansion of the Japanese longline fishery (solid curves) and the surface fishery in the eastern Pacific (dotted curves). Numerals denote calendar year.

Suzuki, Tomlinson and Honma (1978)

BIGEYE TUNA SIZE, GROWTH AND SEXUAL MATURITY 63

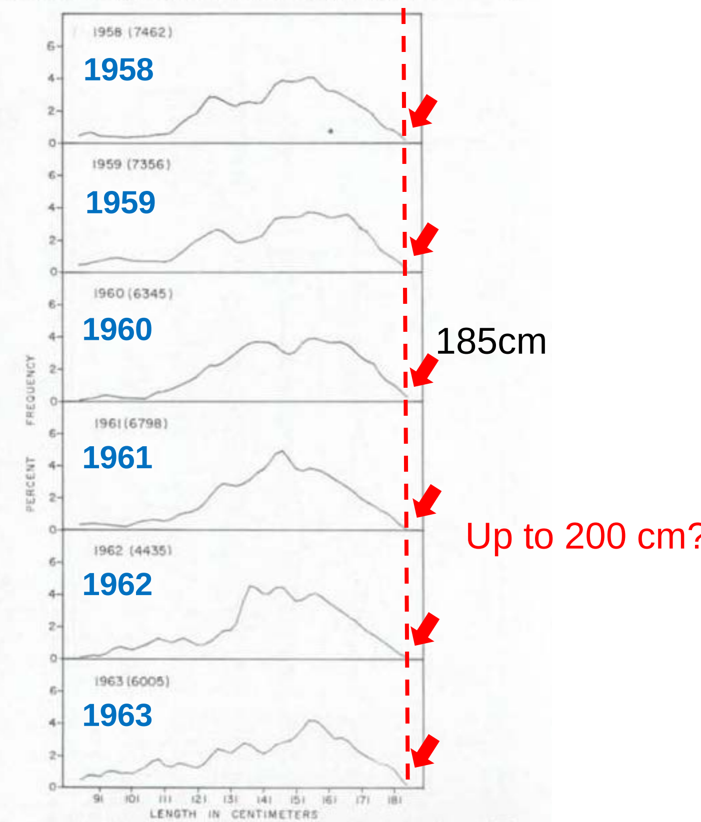


FIGURE 2. Annual length-frequency distribution of bigeye tuna caught by long-line in the southern area, during 1958-1963, expressed as a percentage. Year and number of individuals shown in upper left-hand corner of each panel.

Kume and Joseph (1966)