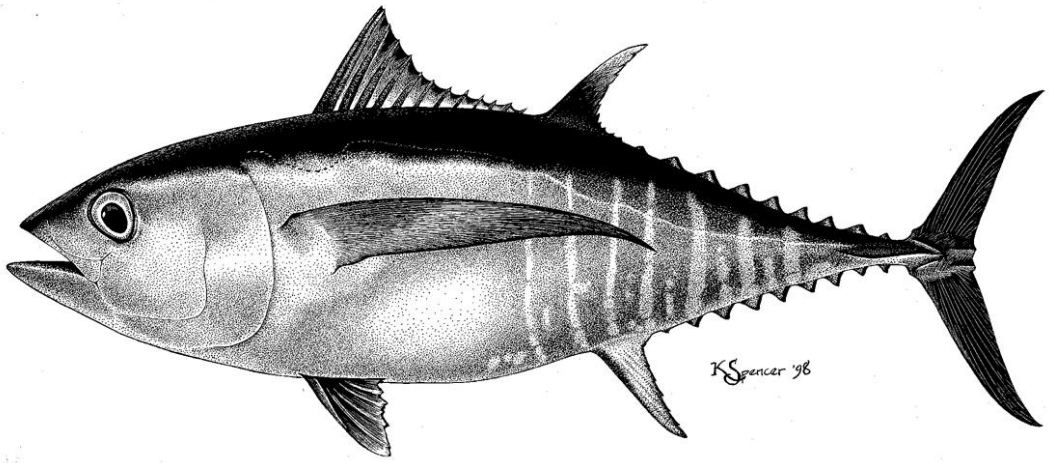
STATUS OF BIGEYE TUNA IN THE EASTERN PACIFIC OCEAN IN 2009

Alexandre Aires-da-Silva and Mark N. Maunder

January 1975 – December 2009



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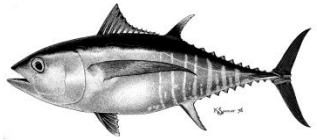
Outline

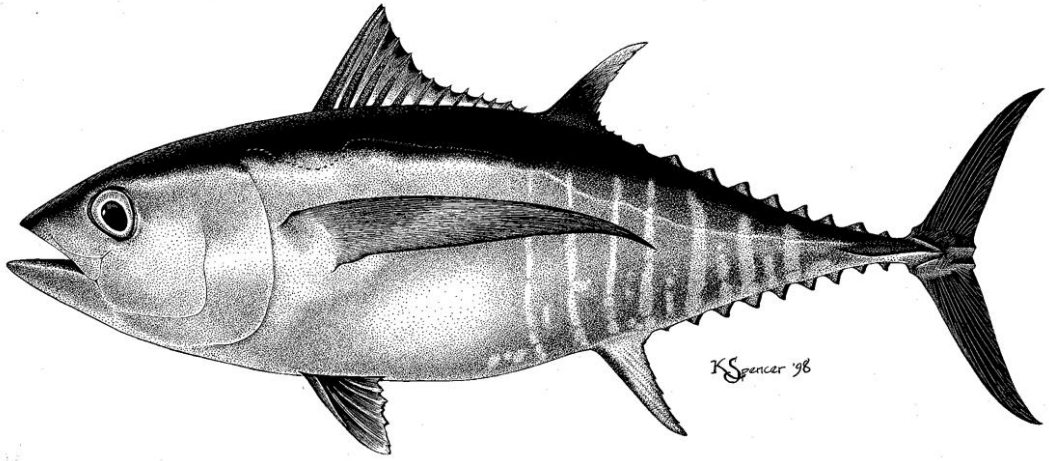


- Stock assessment (base case model)
  - Fishery data
  - Model assumptions (changes after May External Review)
  - Results (fishing mortality, recruitment, biomasses, others)
  - Stock status (base case)
  - Simulations (effect of resolutions, *status quo* and F_{MSY})
  - Retrospective analysis
  - Comparison to previous assessment (doc SAC-01-08b)
- Details on transition from SAR10 to SAC1

  (doc SCA-01-08b)
- Sensitivity analyses
- Summary conclusions

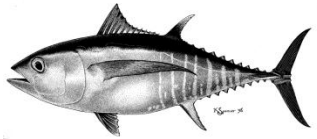
Overview of assessment model

- Age-structured, statistical, catch-at- length model (Stock Synthesis – Version 3)
- Integrated analysis
- Same type of model as MULTIFAN-CL, A-SCALA and CASAL



Fishery data

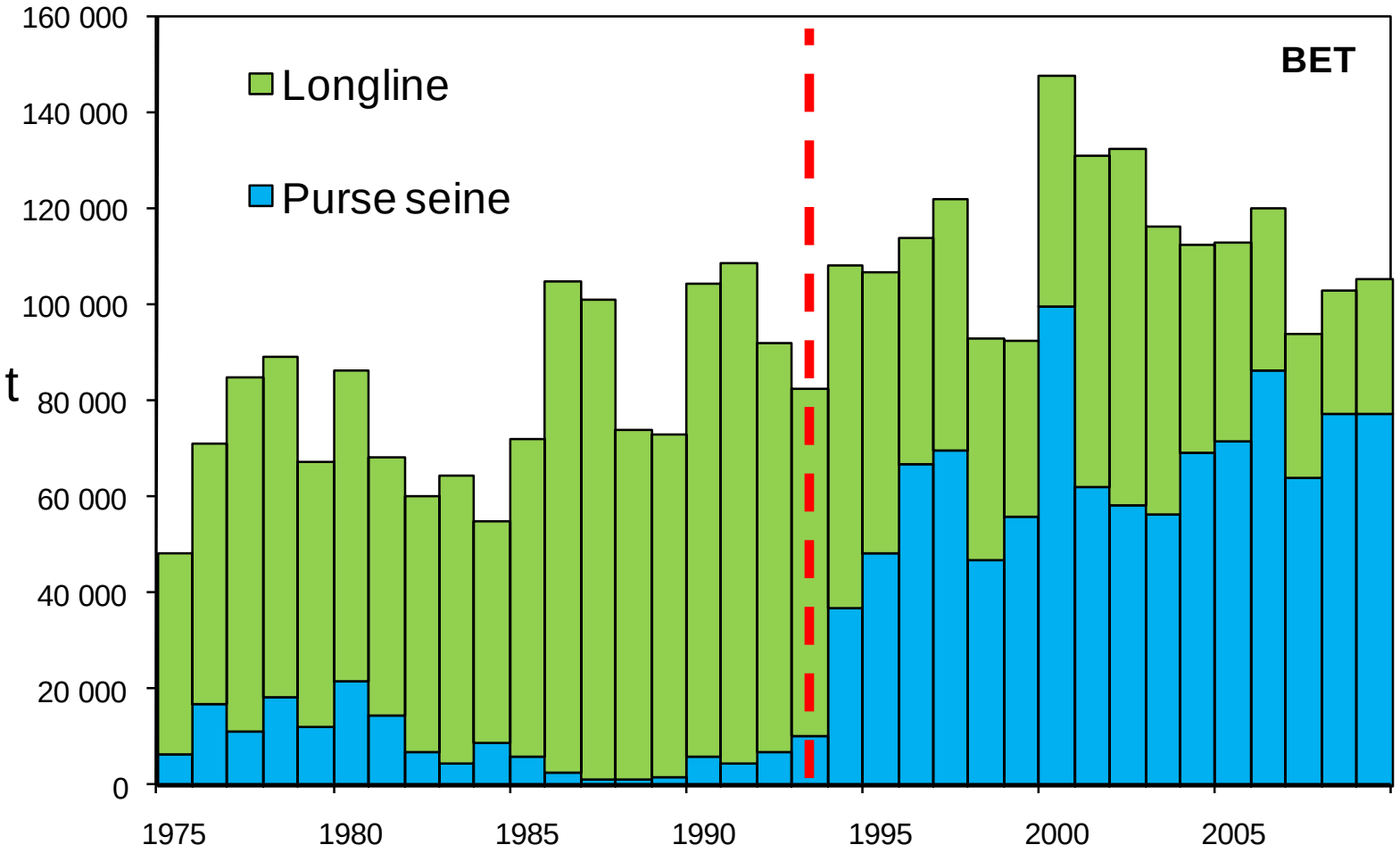
- Catches
- Fishery definitions
- Discards
- Fishing effort
- Catch-per-unit-effort (CPUE)
- Size compositions



New or updated data

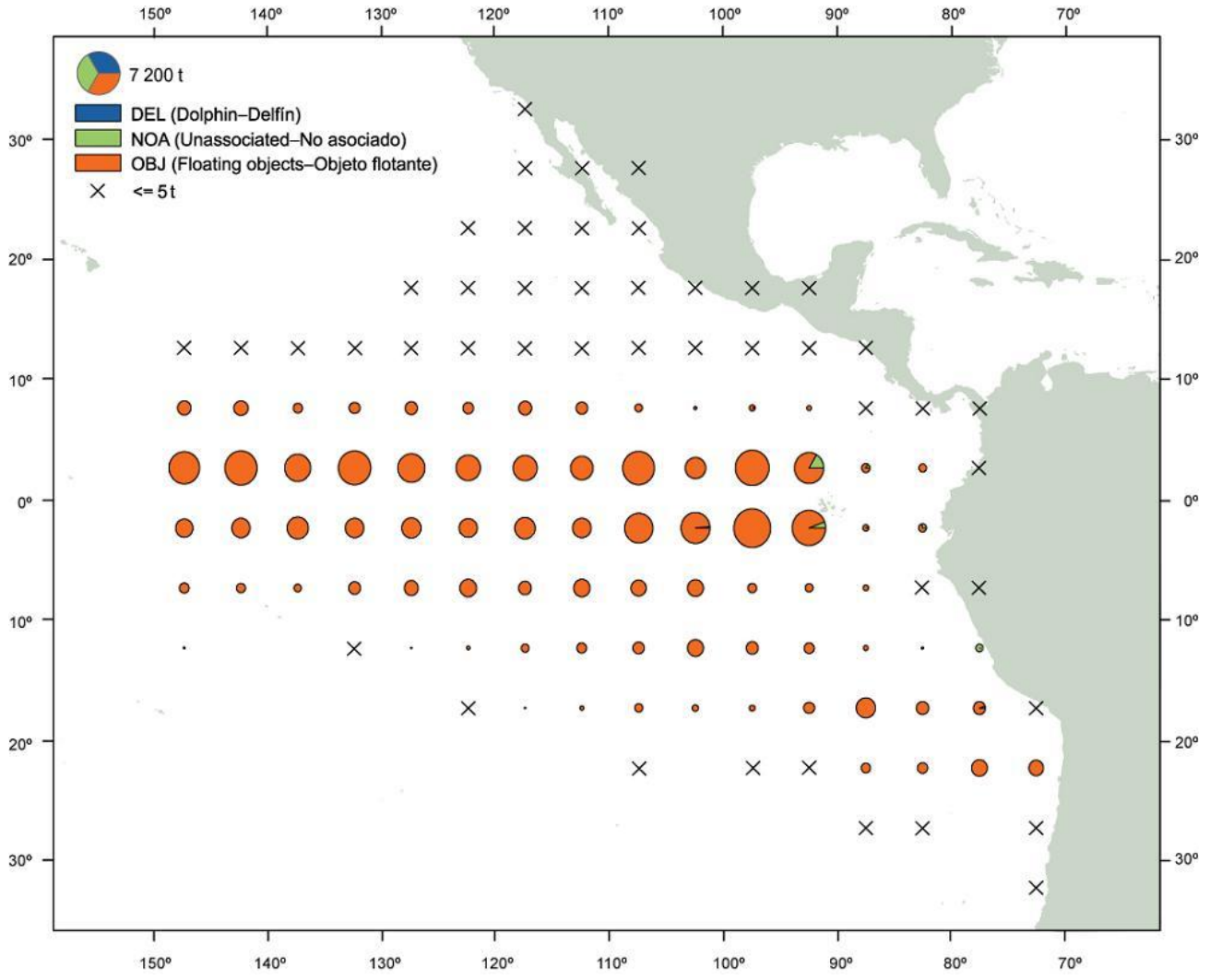
- Surface fisheries
  - Catch, CPUE and size-frequency data updated to include new data for 2009 and revised data for earlier years
- Longline fisheries
  - New or updated longline catch data: China (2008), Chinese Taipei (2006-2009), French Polynesia (2008), Japan (2006-2009), Korea (2008) and USA (2007-2008)
  - 2009 longline catch data available from monthly reports: China, French Polynesia, Korea, USA, Vanuatu
  - New or updated longline size-frequency data available for Japan (2006-2008)

Total catches



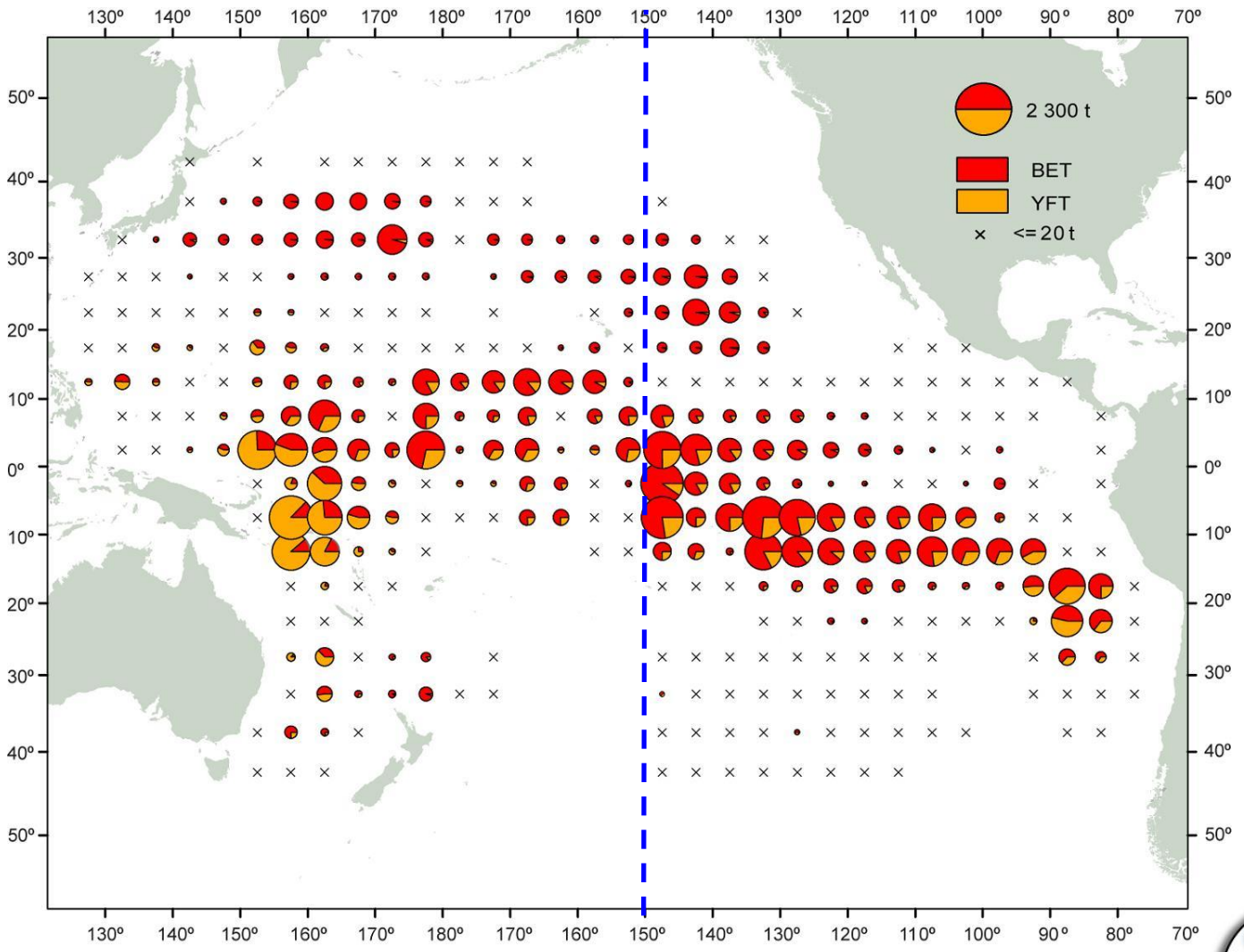
Expansion of FAD fishery

Spatial distribution of PS catches



Annual distribution of BET PS catches, 2009

Spatial distribution of LL catches



Average annual LL catch, 2004-2008

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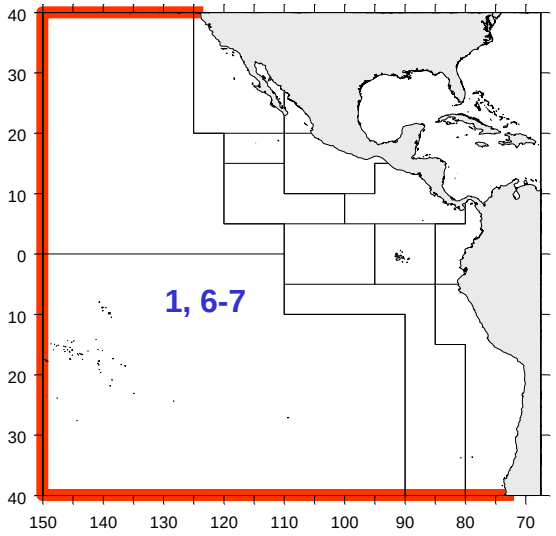
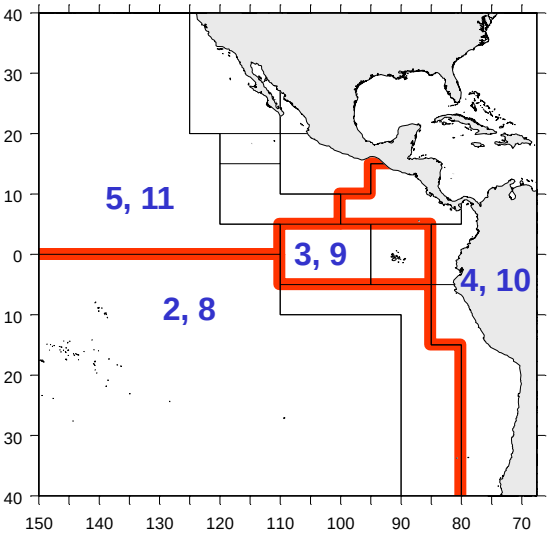
BET fishery definitions

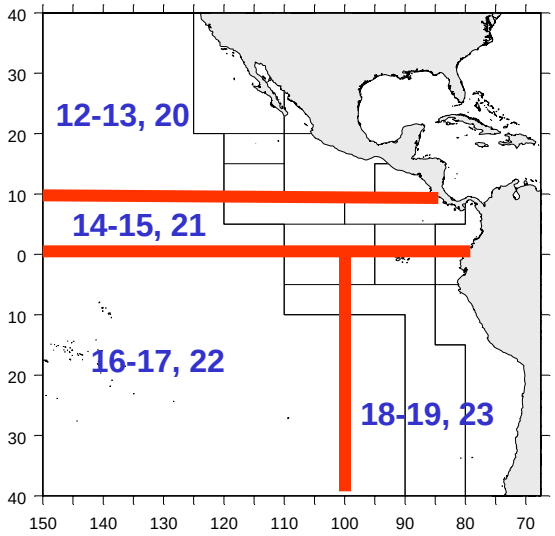
Early OBJ (1)
Early & Late DEL&NOA (6, 7)



Recent OBJ (2-5)
Discards (8-11)



Early/Late LL N (12-13, 20)
Early/Late LL C (14-15, 21)
Early/Late LL S (16-17, 22)
Early/Late LL I (18-19, 23)



GEAR TYPE: PS, LP, LL

PS set type (OBJ, NOA and DOL)

Time period

The IATTC sampling areas

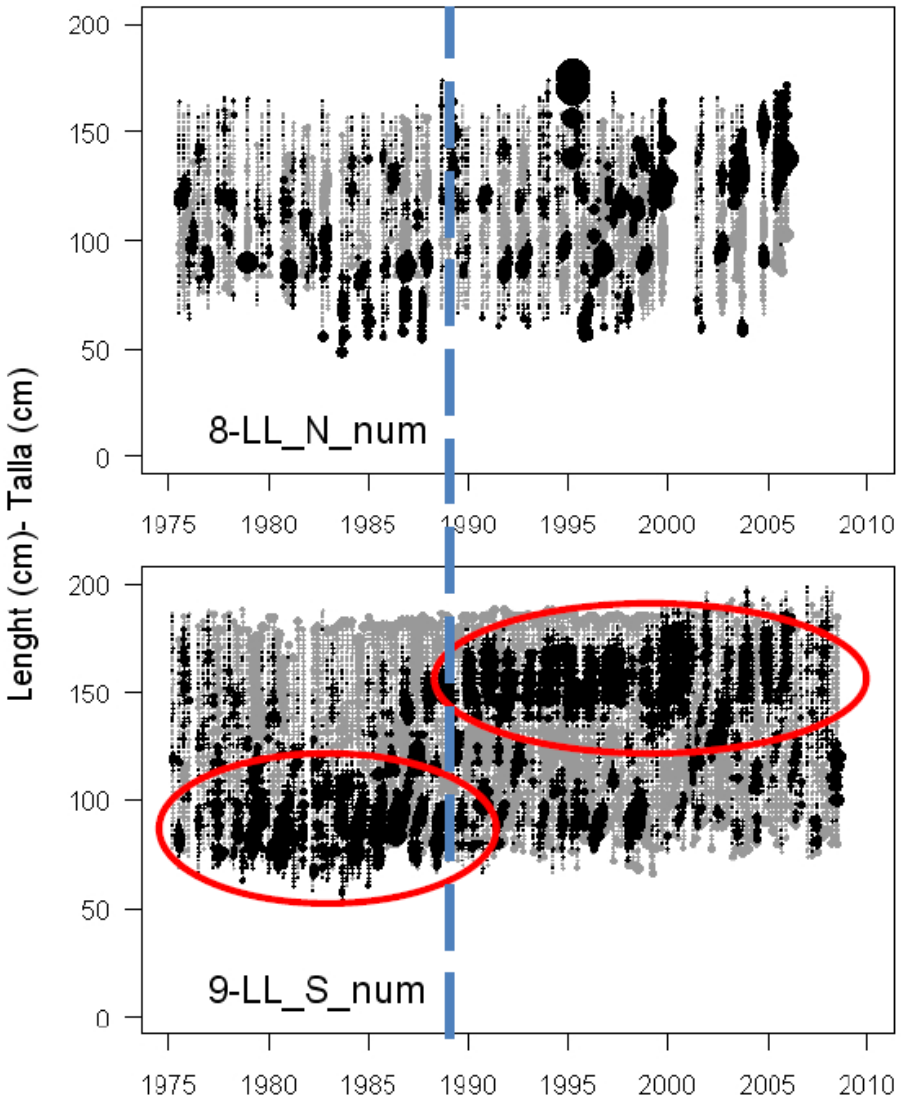
DEL – sets on dolphins

NOA – sets on unassociated fish

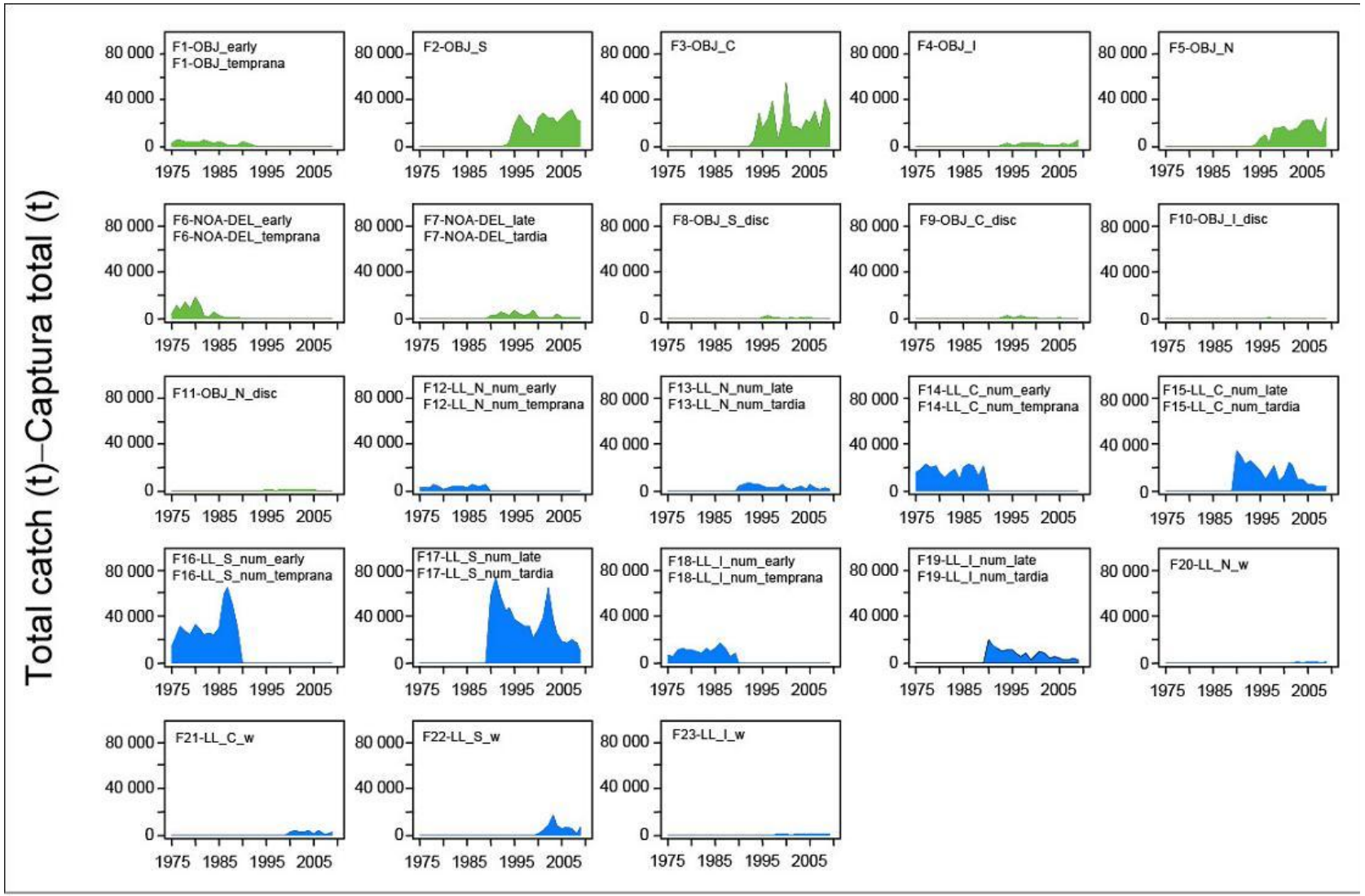
OBJ – sets on floating objects

LL – longline sets

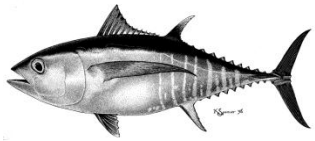
Two time blocks for LL?

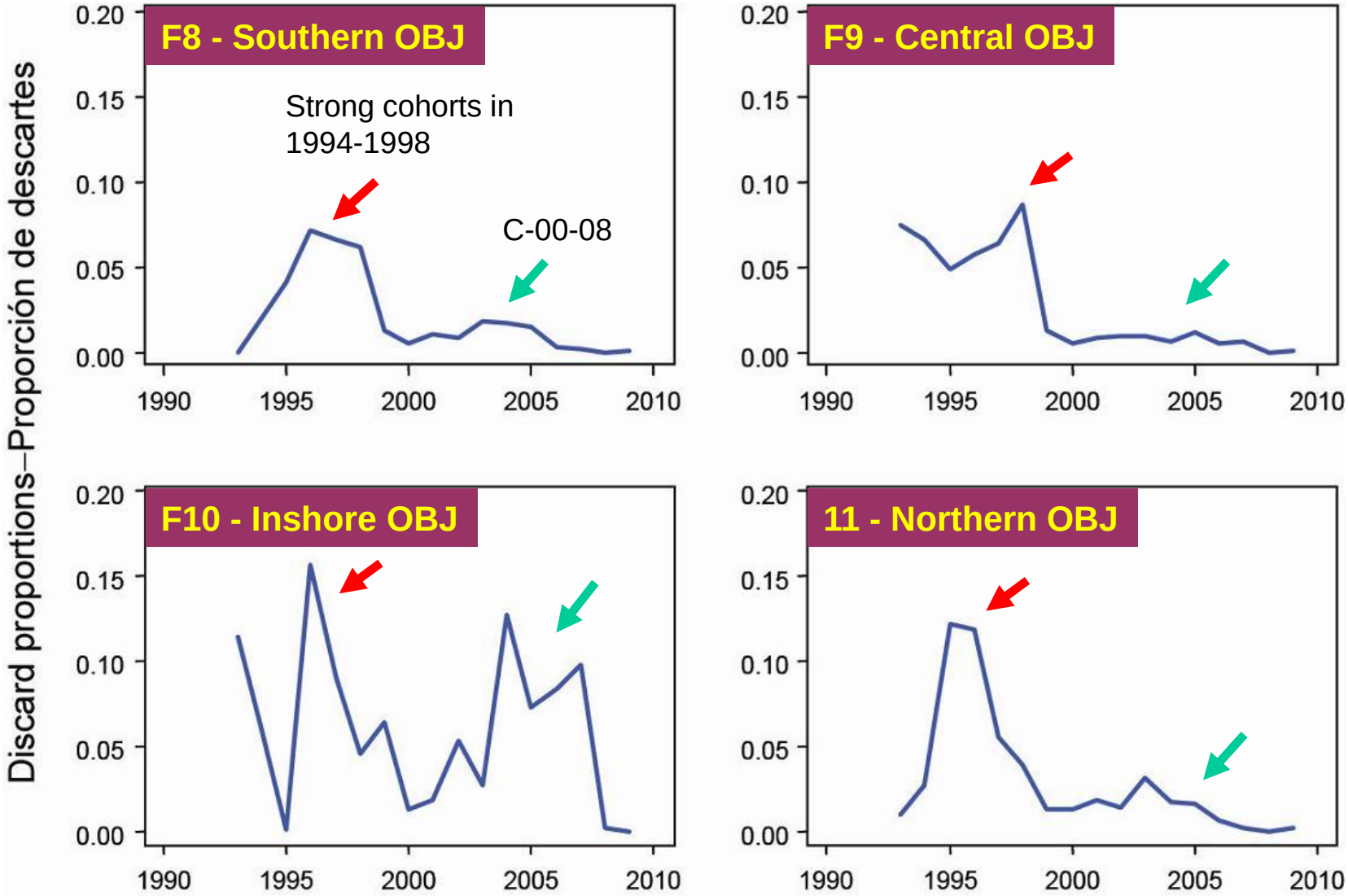


Annual catches by fishery

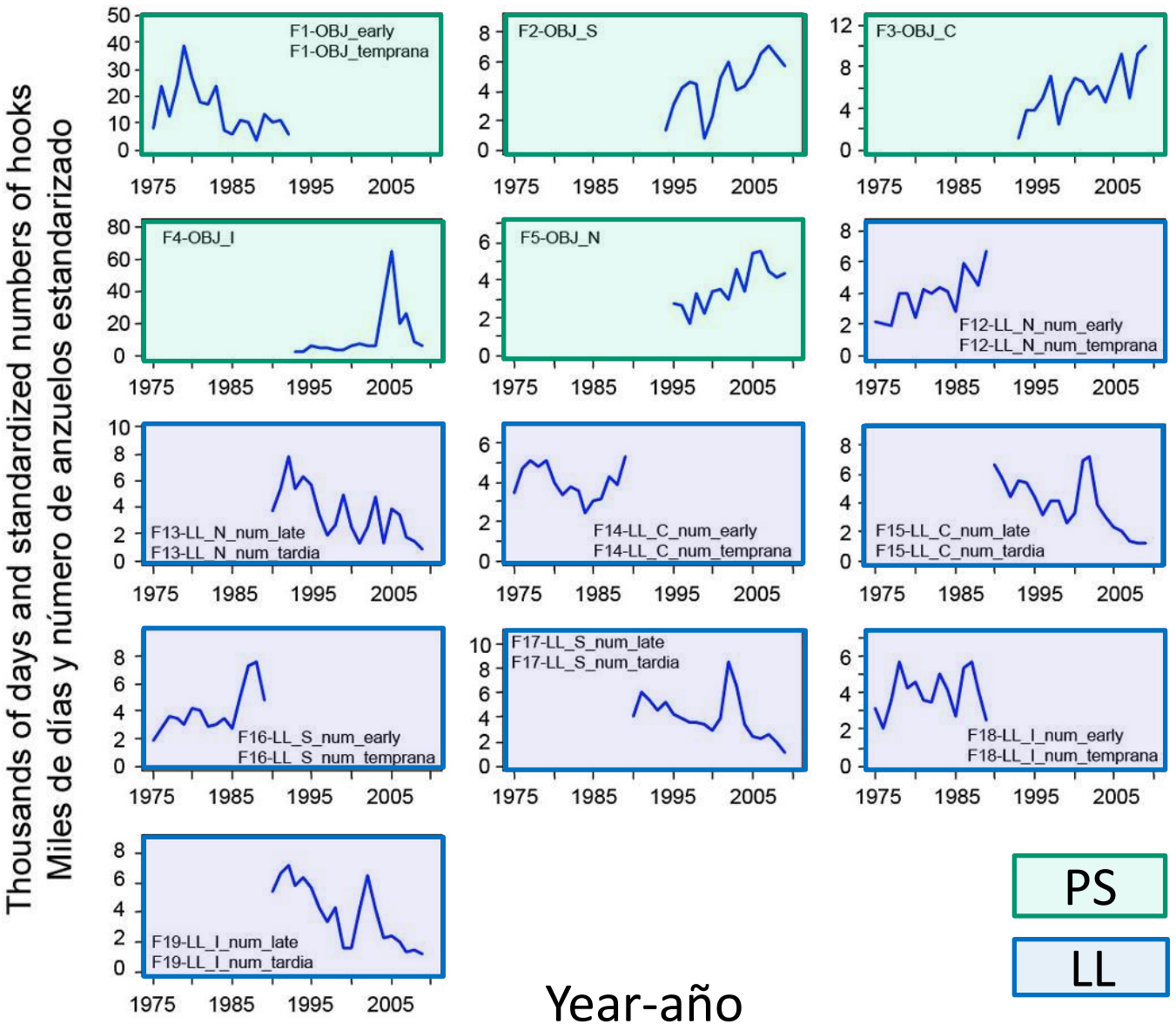


Discards




F8 - Southern OBJ
Strong cohorts in 1994-1998
C-00-08
F9 - Central OBJ
F10 - Inshore OBJ
11 - Northern OBJ
Discard proportions–Proporción de descartes
Year-año
0.20
0.15
0.10
0.05
0.00
1990
1995
2000
2005
2010

Fishing effort



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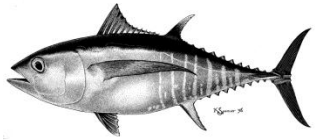
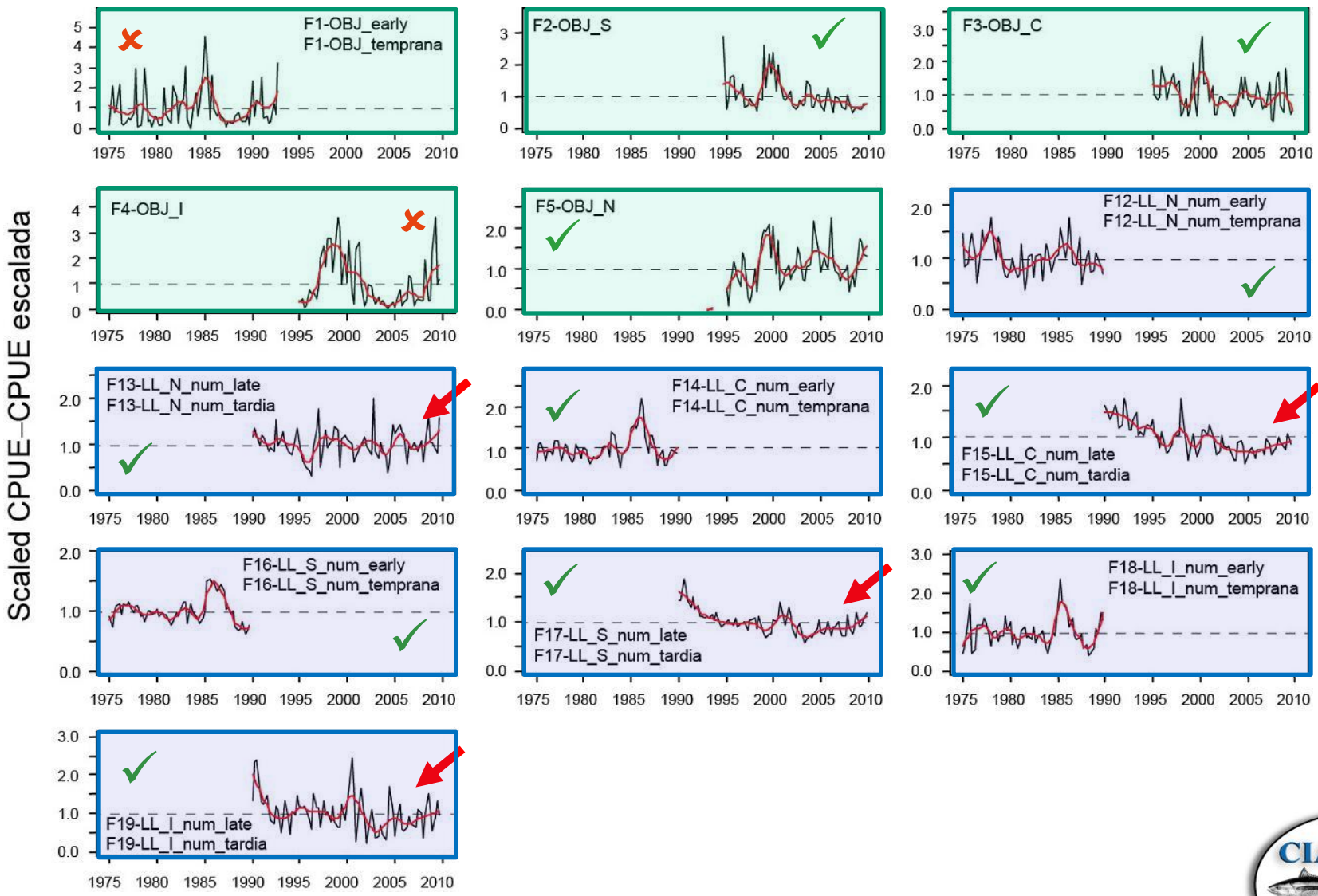
Catch-per-unit effort (CPUE)





Year-año

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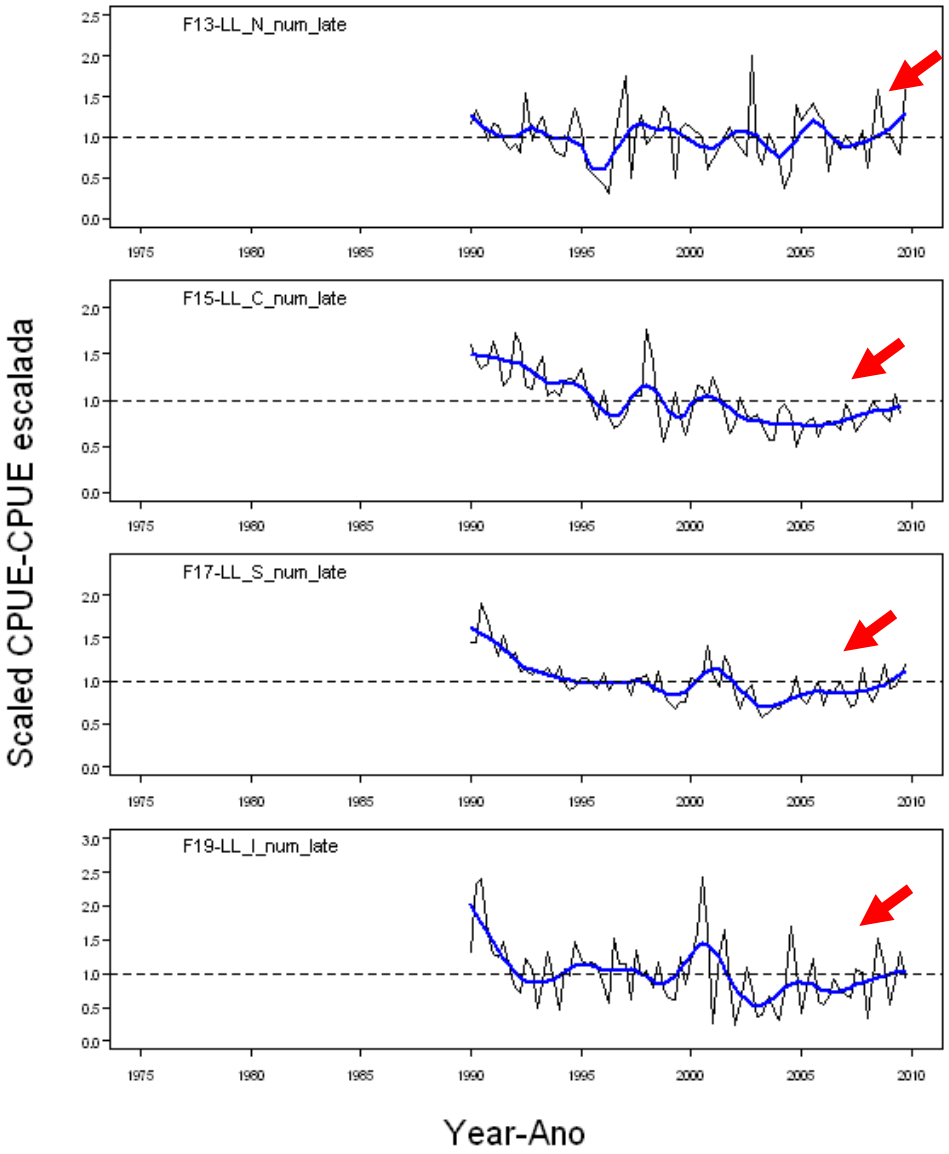
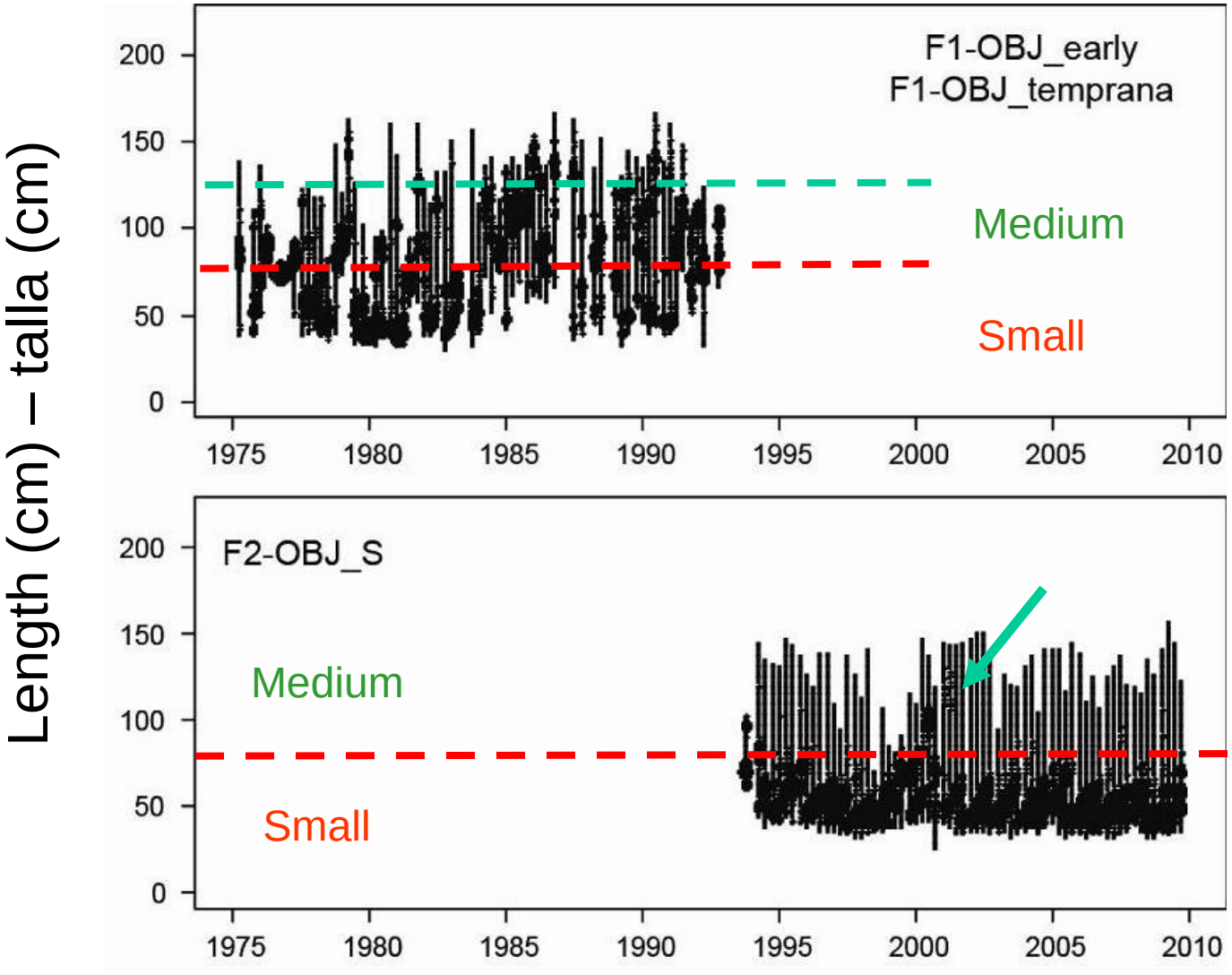
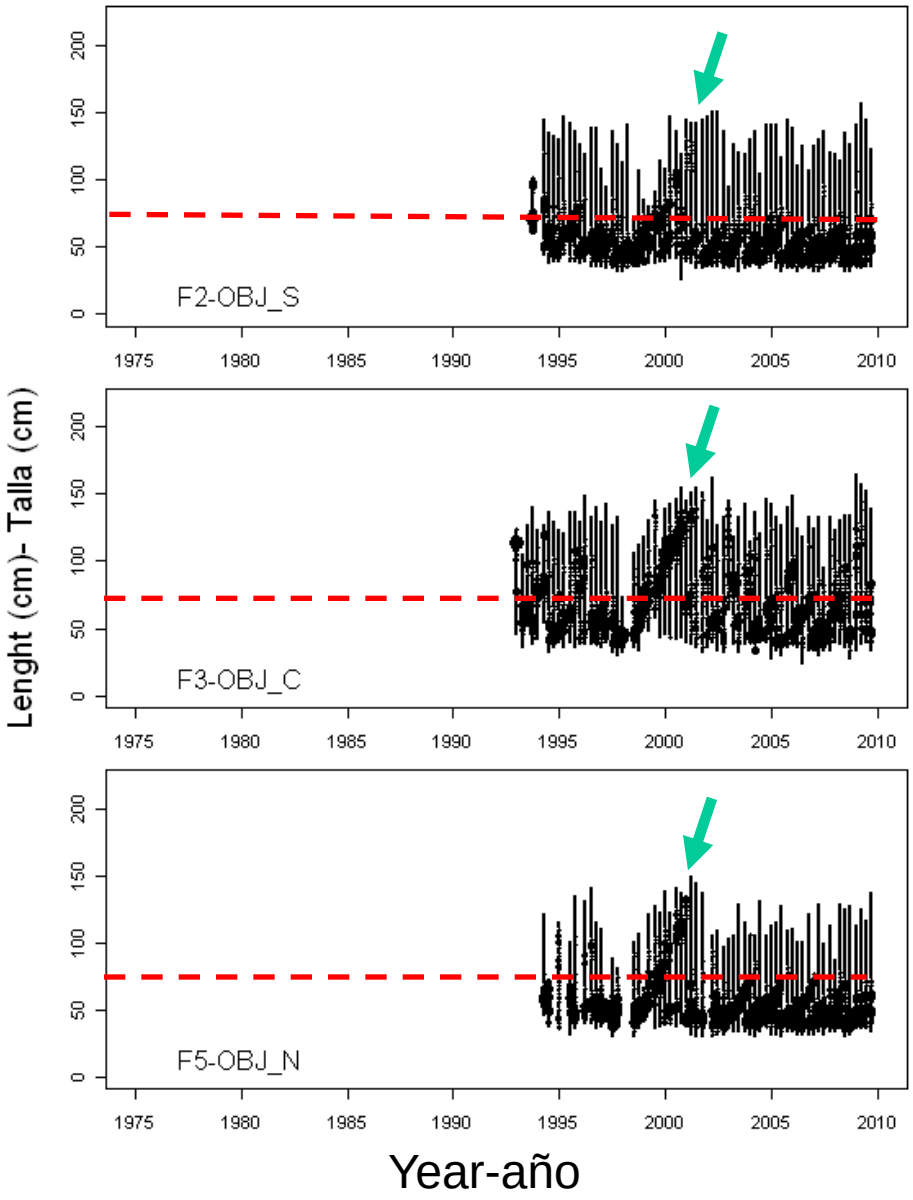
Longline CPUE trends



Size compositions – OBJ transition



Size compositions – OBJ fisheries

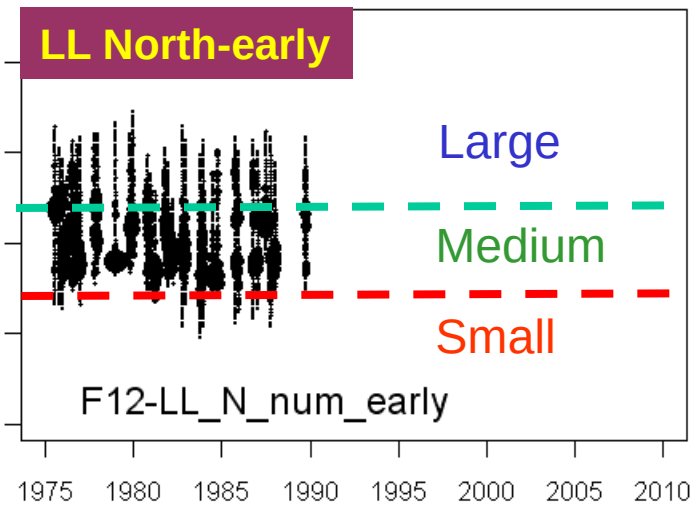


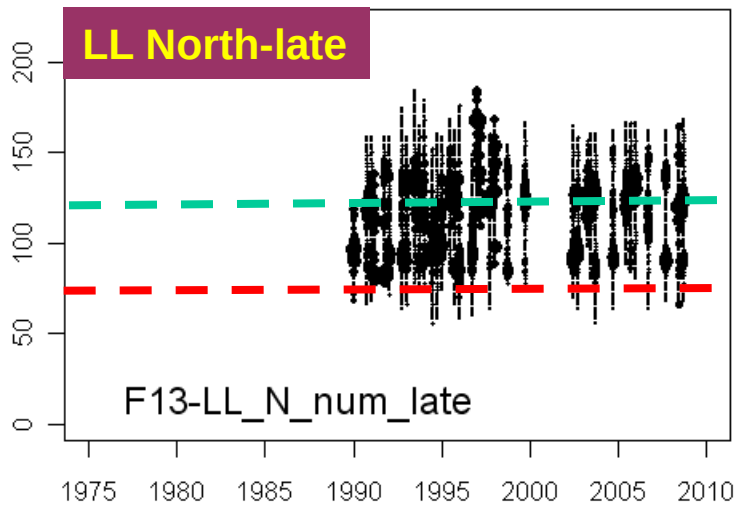
Medium

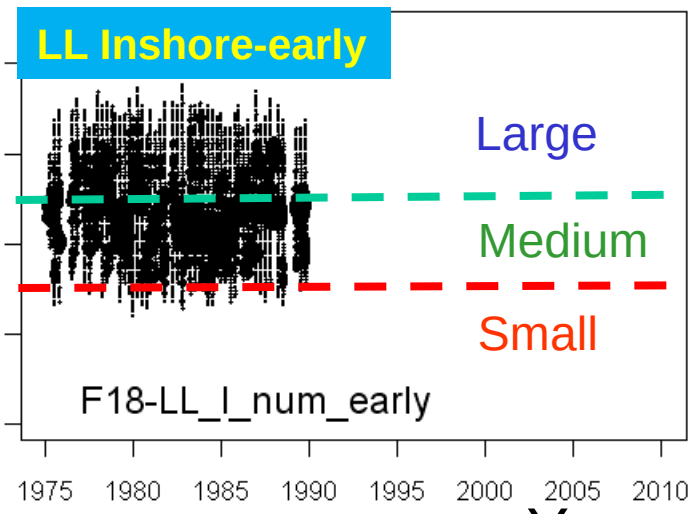
Small

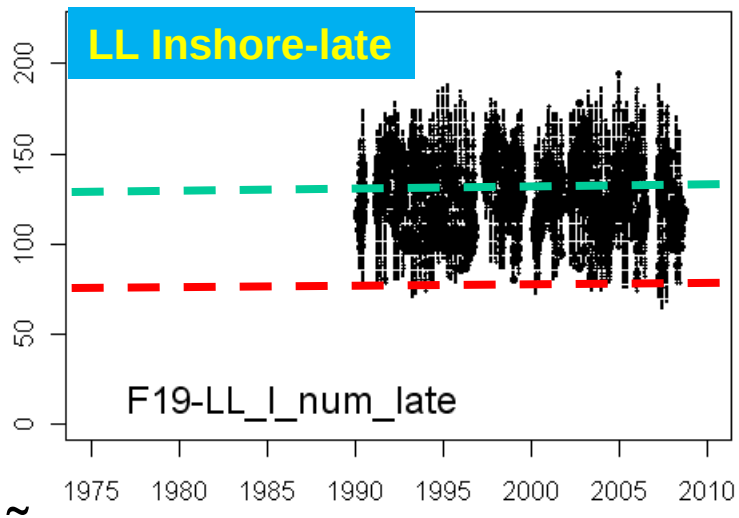
Fishery data

Size compositions – LL



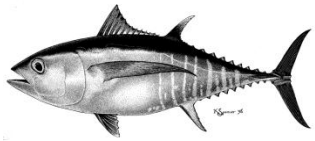


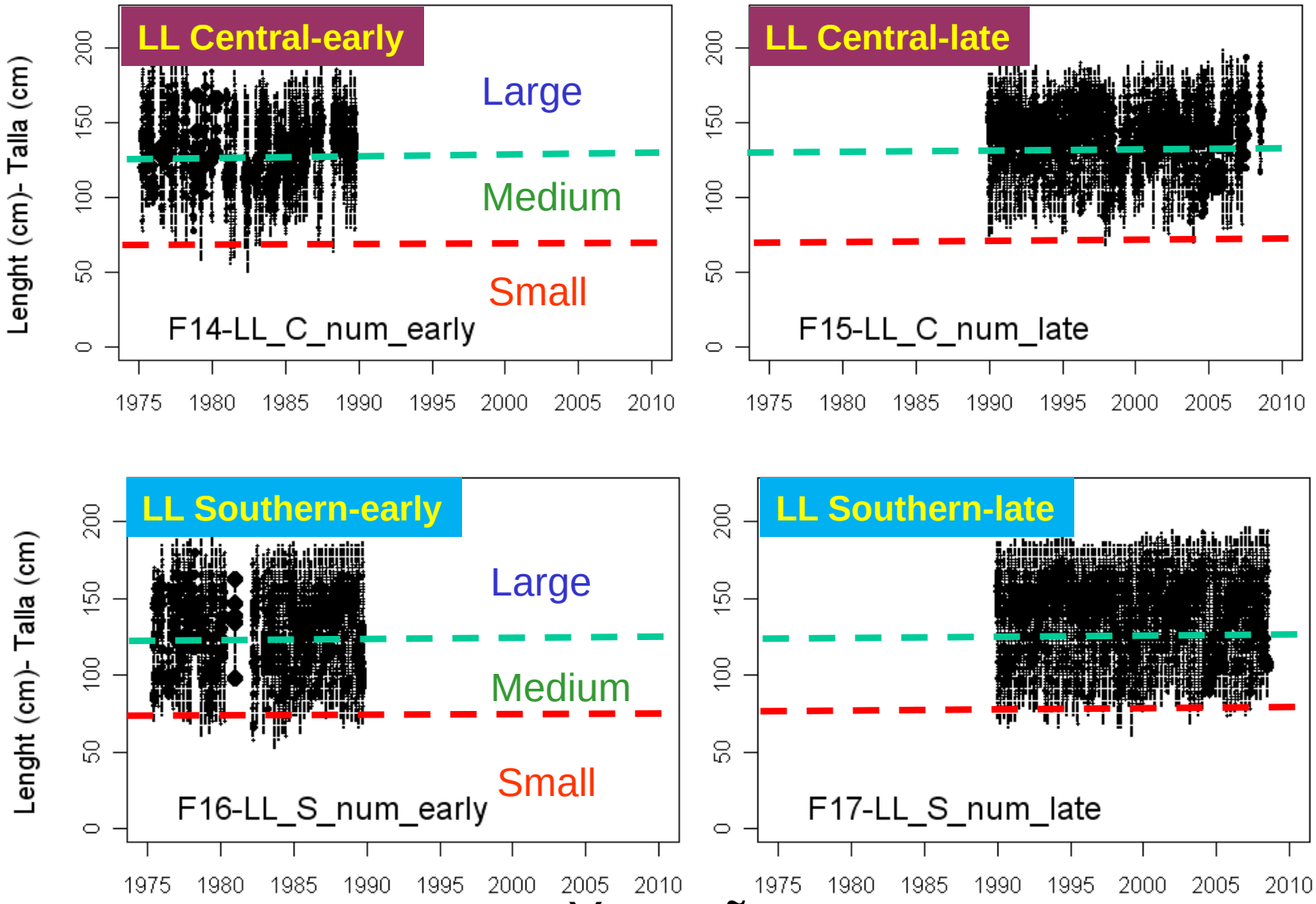


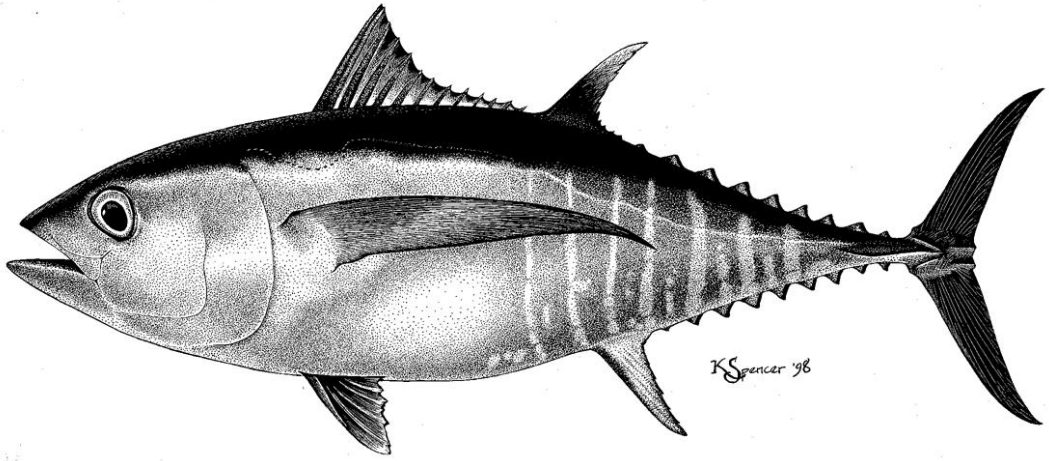


Year-año

Size compositions – LL (cont.)

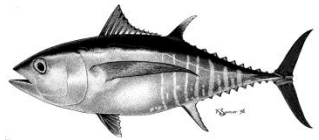






Model assumptions (base case)

- Changes after BET External Review, May 2010
- Movement and stock structure
- Biology (growth, natural mortality and maturity)
- Stock-recruitment relationship (S-R)



Changes after May External Review

- Fishery definitions: New spatial definitions of logline fisheries (4 fisheries)
- Data weighting: the CV of the southern LL fishery was fixed (0.15) rather than estimated
- Growth modeling: Richards curve, with variance of length-at-age estimated rather than fixed
- Modeling of catchability and selectivity:
  - Two time blocks for all LL fisheries
  - Early dome, late asymptotic selectivities

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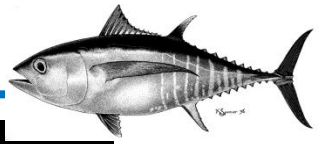
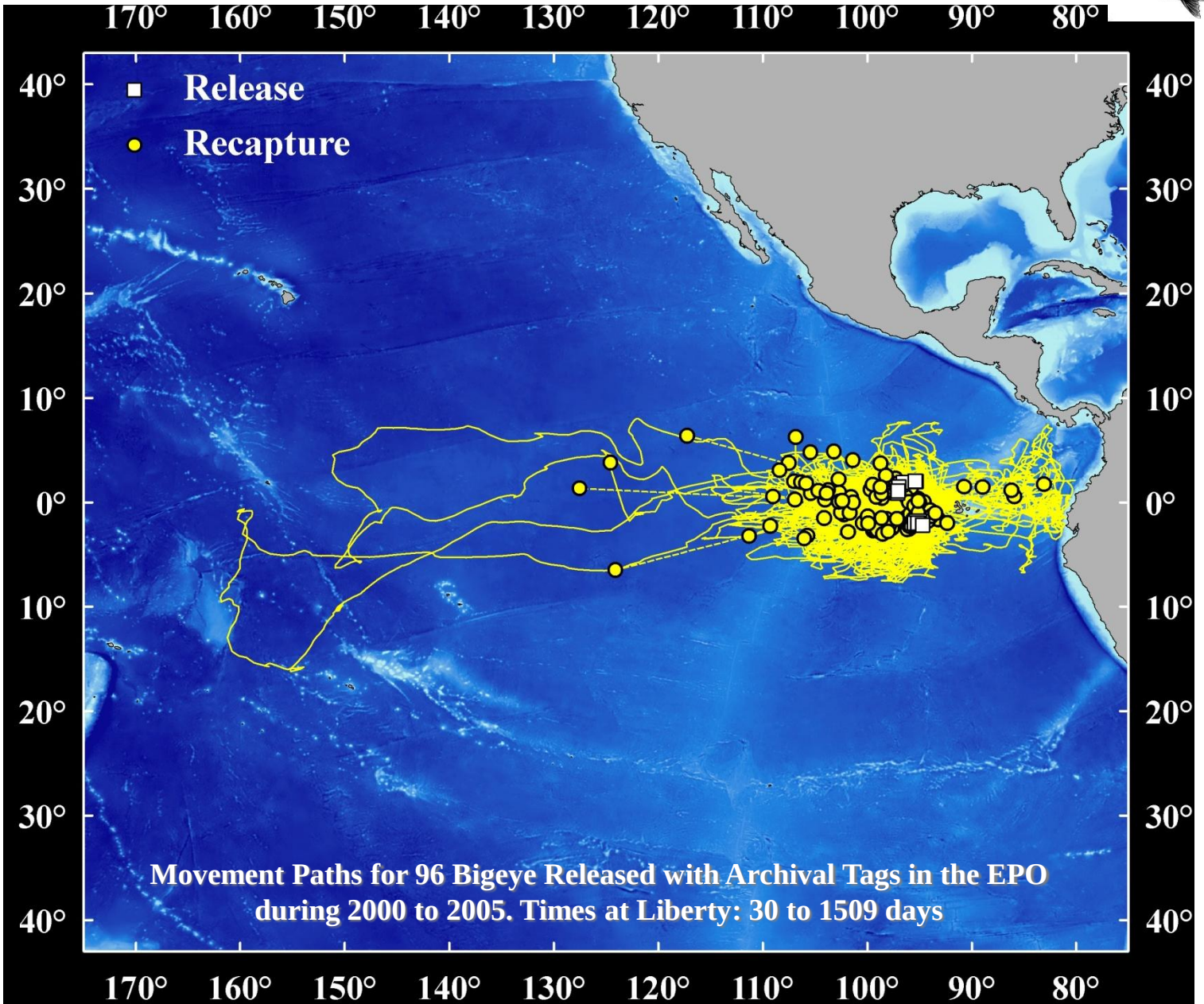
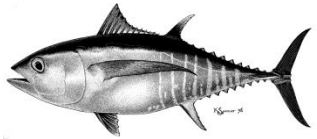
BET movement



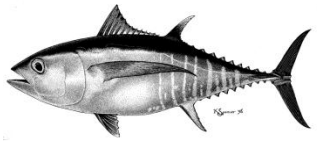


BET stock structure

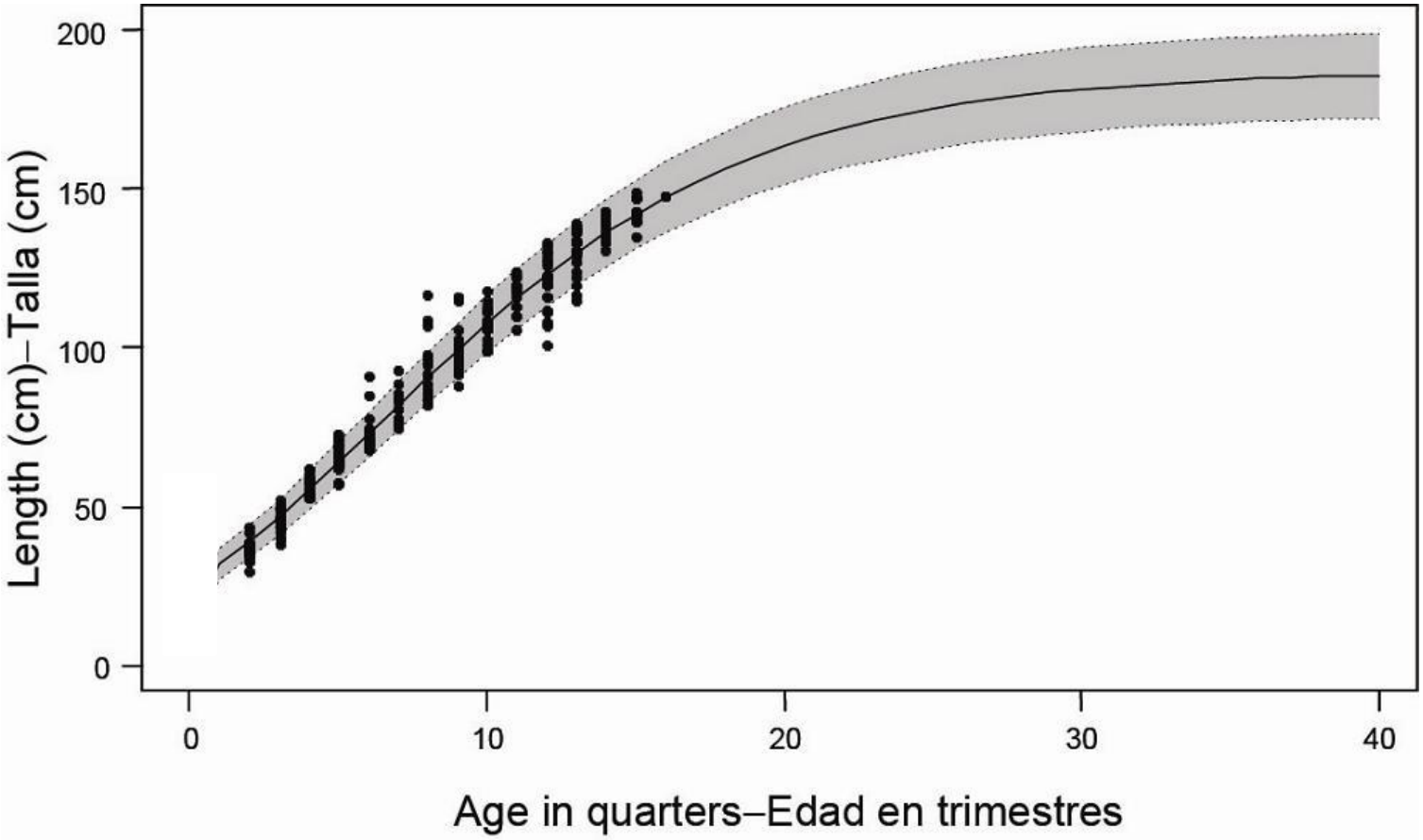


- Minimal net movement of fish between the EPO and WCPO
- Single stock of bigeye in EPO

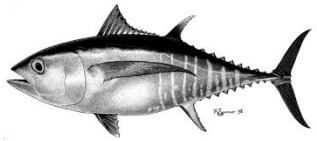
Age and growth



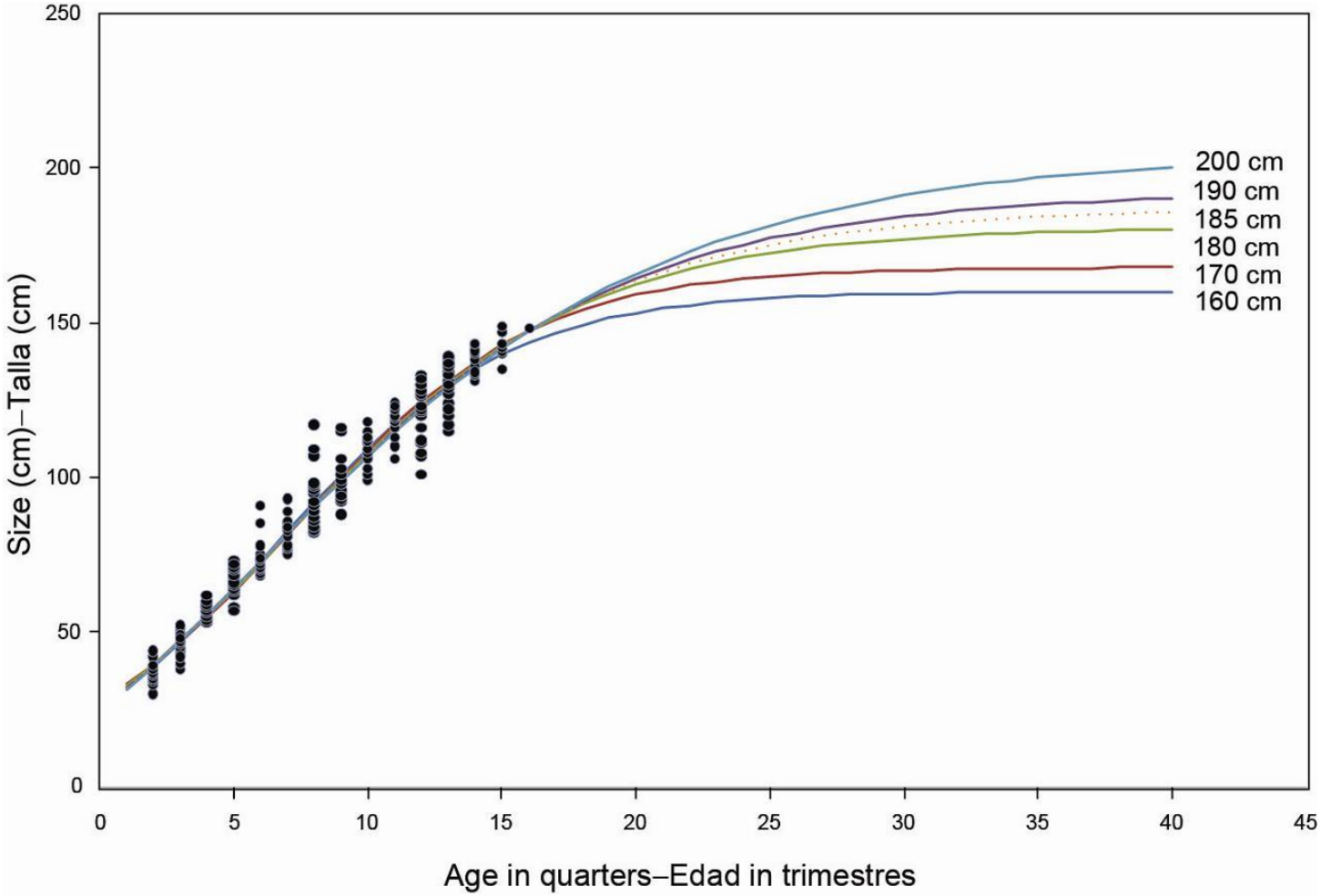
- Richards growth curve
  - L_2 fixed (185.5 cm)
  - Variability of length-at-age (LSD) estimated



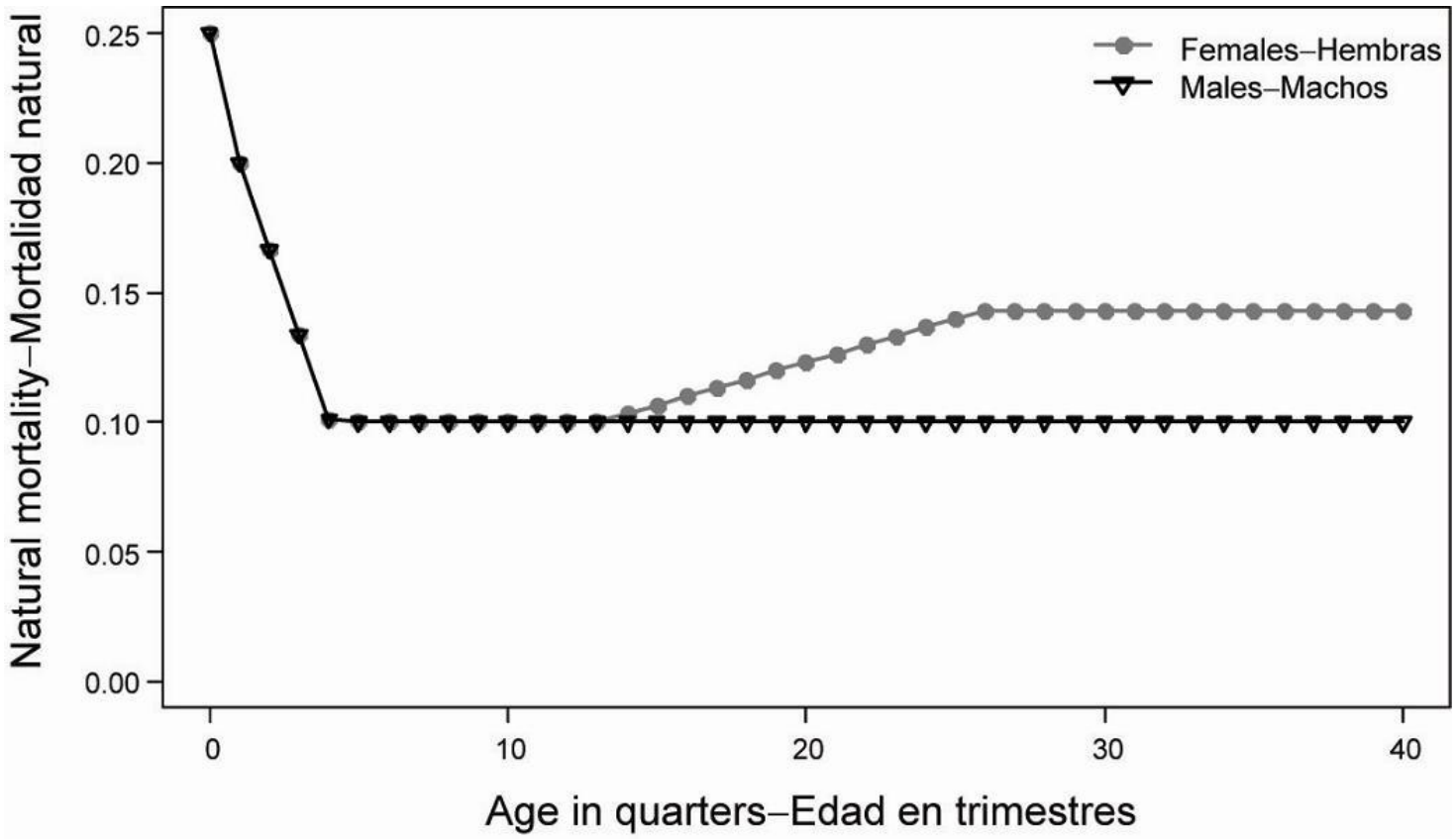
Age and growth - sensitivity



- Sensitivity analysis to fixed value of L_2 (Appendix B)
- Likelihood profile for L_2 (Appendix B)



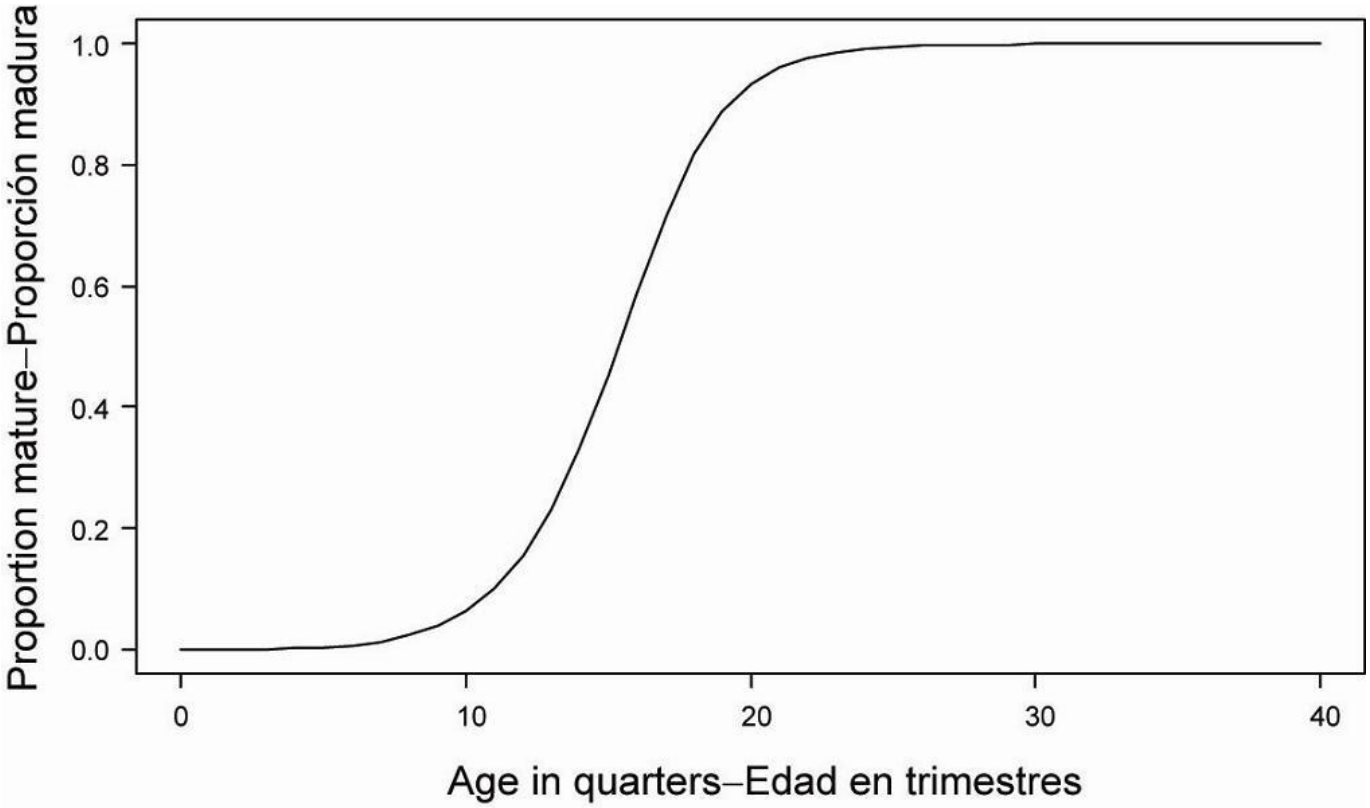
Natural mortality



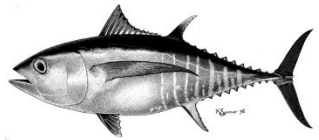
- Sensitivity analysis
  - Juvenile *M* (SARM-9-INF-B)
  - Adult *M* (Appendix C)

Maturity schedule

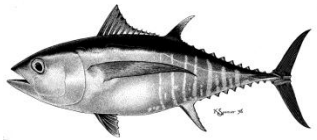
- Age-specific maturity (Schaefer and Fuller, 2006)



Stock-recruitment relationship

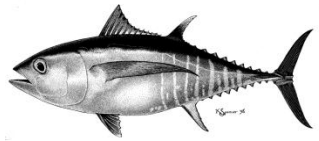


- Beverton-Holt relationship
- No S-R relationship (steepness = 1)
- Sensitivity analysis
  - Steepness = 0.75
  - Likelihood profile on steepness (0.5, 0.6, 0.7, 0.8, 0.9, 1.0)



Fixed parameters

- Average size of older fish (L_2 at 185 cm)
- Sex and age-specific mortality-rates (M)
- Age-specific maturity schedule
- CV of LL-S CPUE (0.15)
- Selectivity curves for discard fisheries
- Steepness of stock-recruitment relationship (h=1)



Estimated parameters

- Recruitment in every quarter from 1975 to 2009 (average recruitment and temporal recruitment anomalies)
- Catchability coefficients for the 11 CPUE time series (OBJ F2,3 and 5, and LL F12-19)
- CV for 9 CPUE indices (all OBJ and all LL except LL-S)
- Selectivity curves for late Central and Southern LL fisheries are assumed to be logistic (catch larger fish)
- Selectivities for all other fisheries (except discards) are assumed to be dome-shaped (double normal)
- Initial population age-structure

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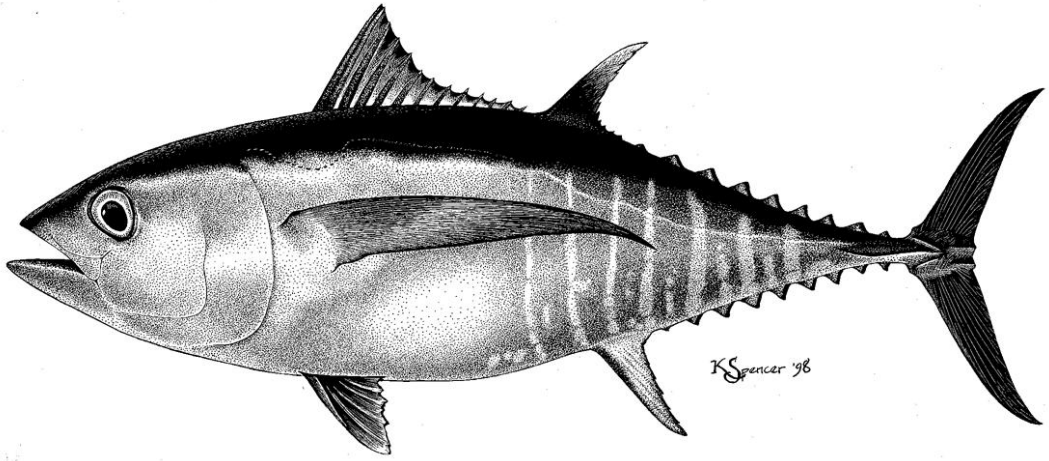
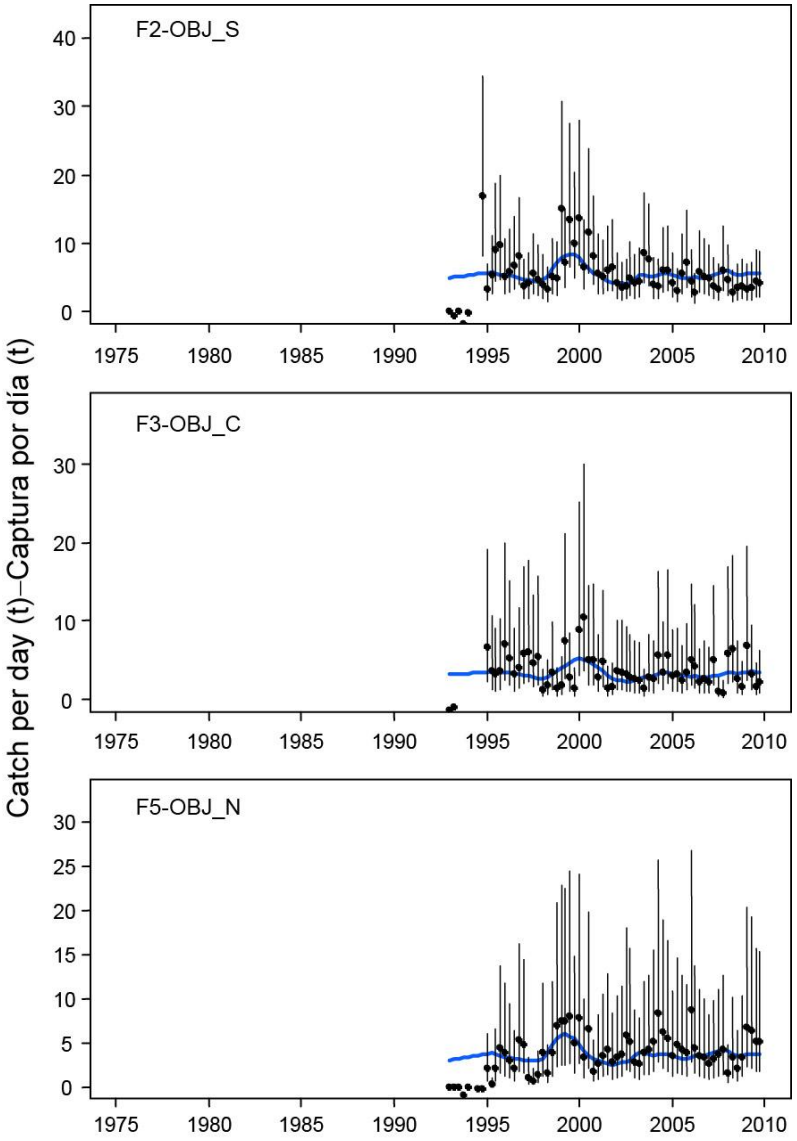


Results (base case)

- Model fits (CPUE and size compositions)
- Fishing mortality
- Selectivity
- Recruitment
- Biomass

Fit to CPUE – OBJ fisheries

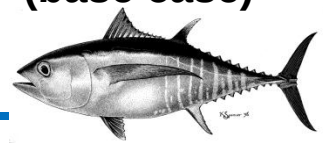
Results (base case)

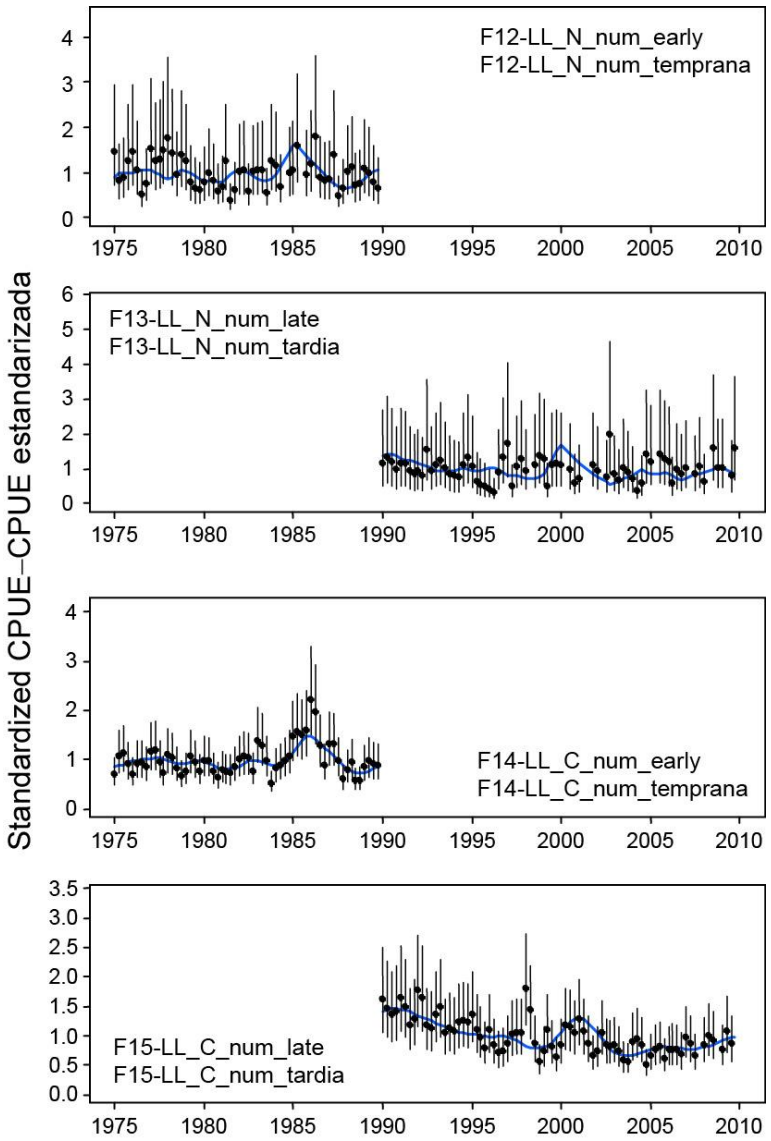


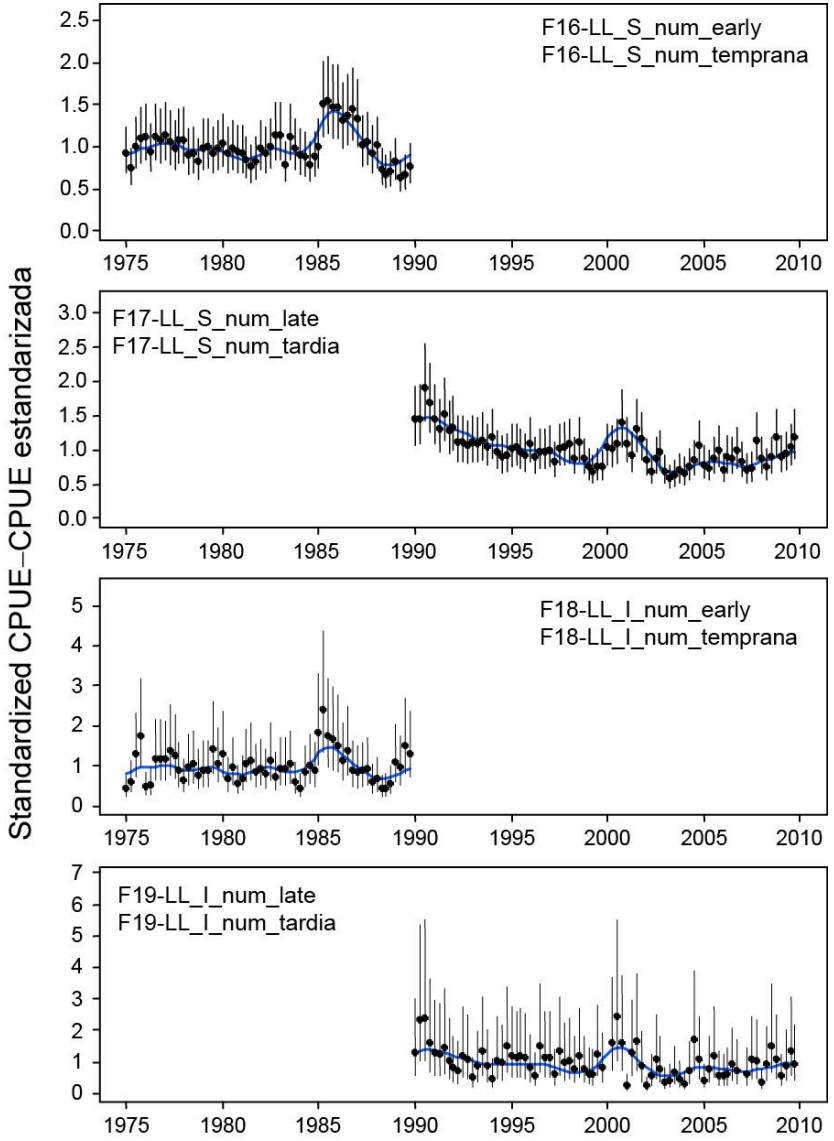
Fishery	CV
F2-OBJ_S	0.36
F3-OBJ_C	0.54
F5-OBJ_N	0.57
F12-LL_N_num_early	0.36
F13-LL_N_num_late	0.43
F14-LL_C_num_early	0.20
F15-LL_C_num_late	0.22
F16-LL_S_num_early	0.15
F17-LL_S_num_late	0.15
F18-LL_I_num_early	0.30
F19-LL_I_num_late	0.42

Fit to CPUE – LL fisheries

Results (base case)

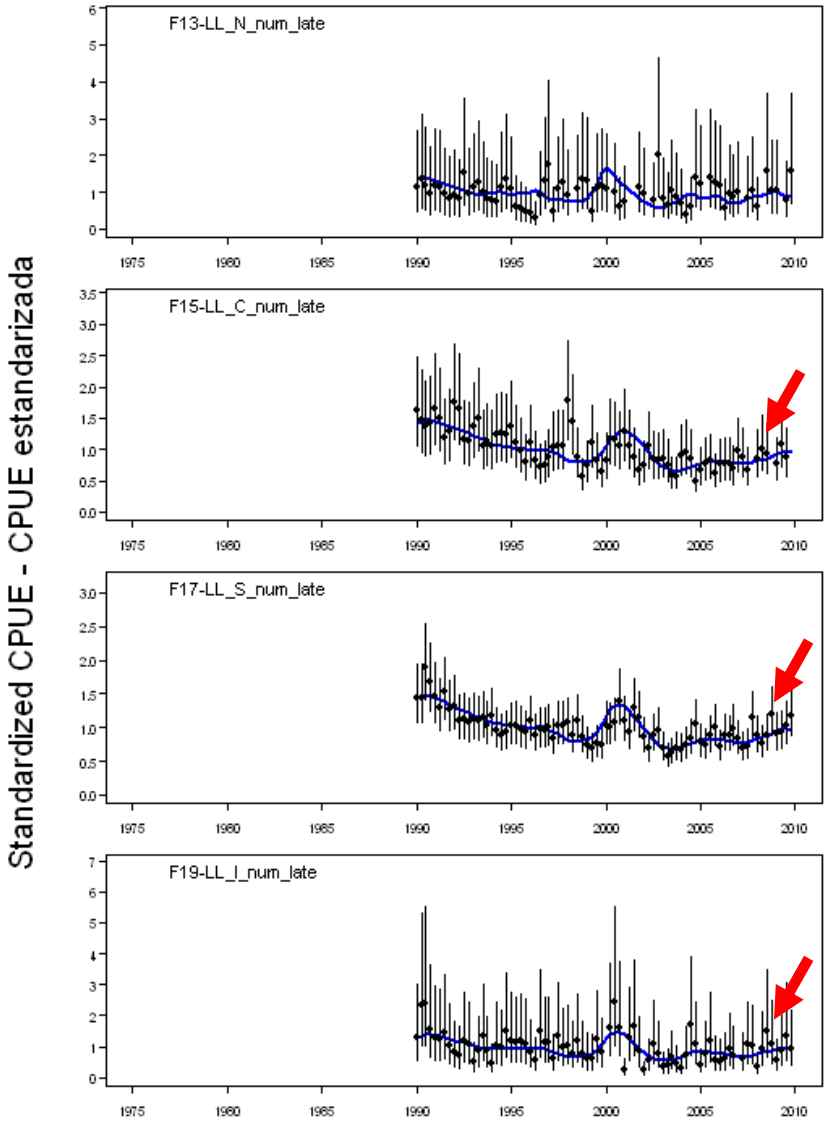




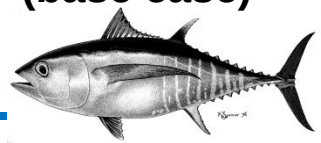


Fit to CPUE – Late LL fisheries

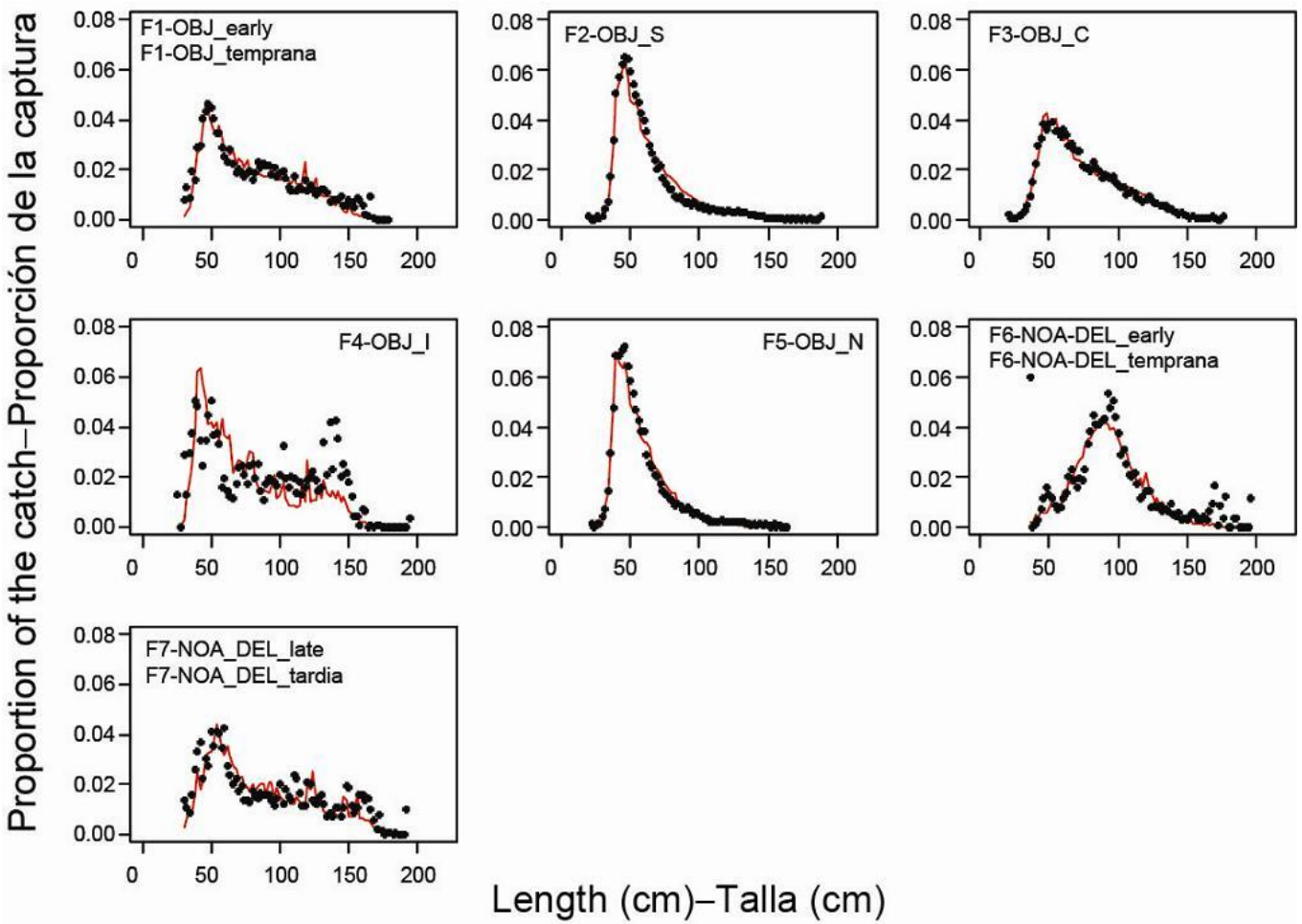
Results (base case)



Average fits to size comps.

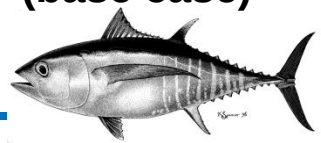


Surface fisheries

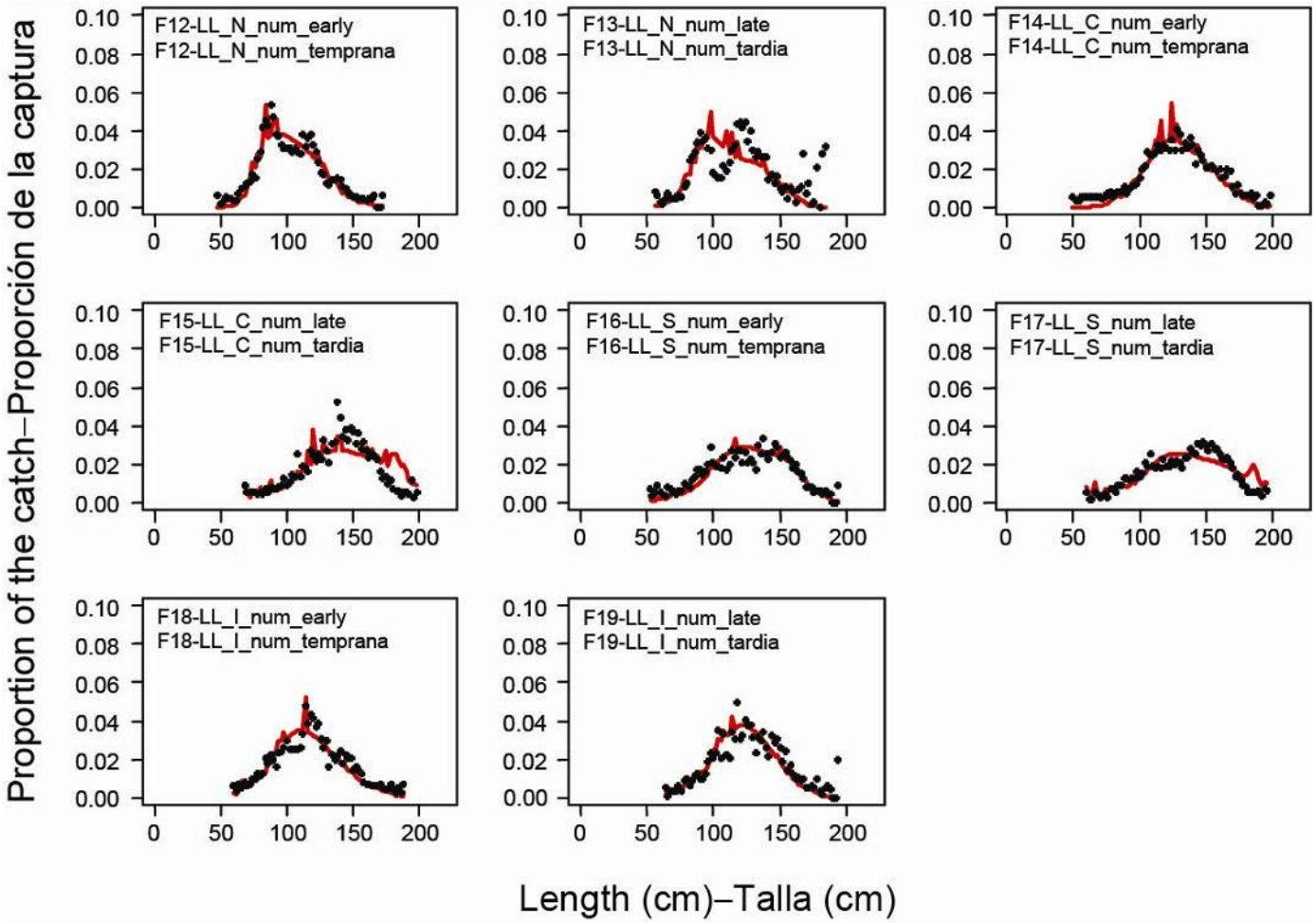


Average fits to size comps.

Results (base case)

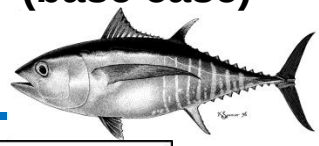


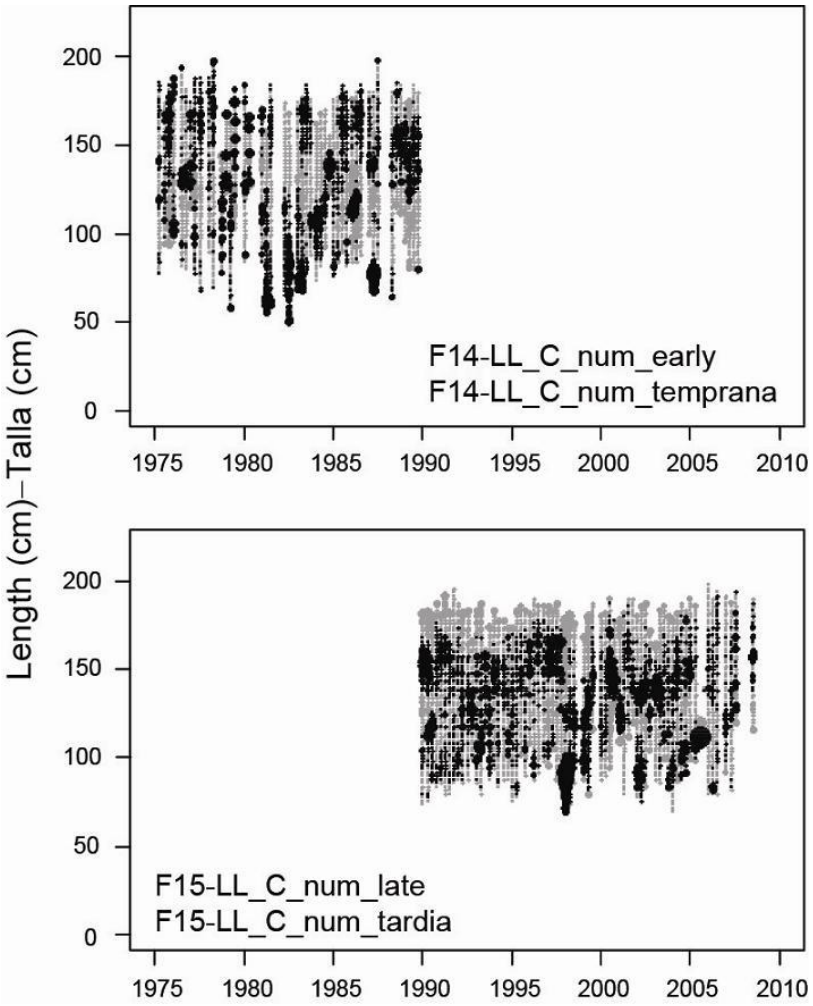
Longline fisheries

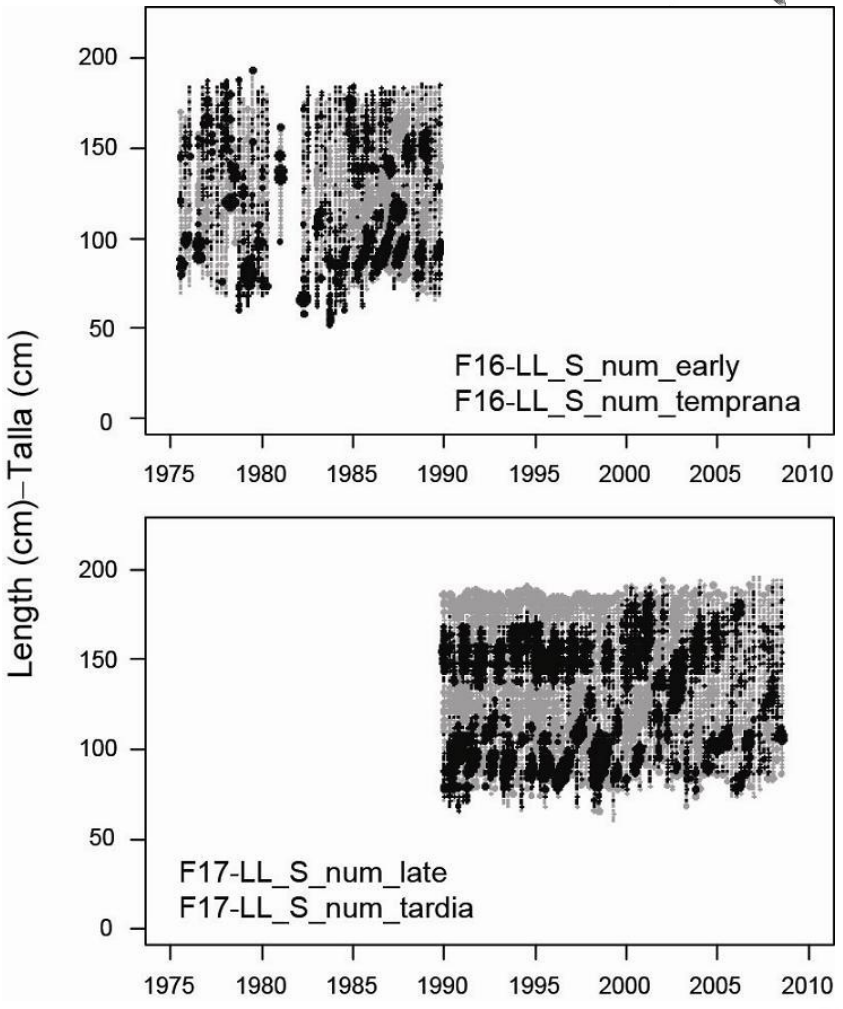


LL Size comp. residual pattern

Results
(base case)







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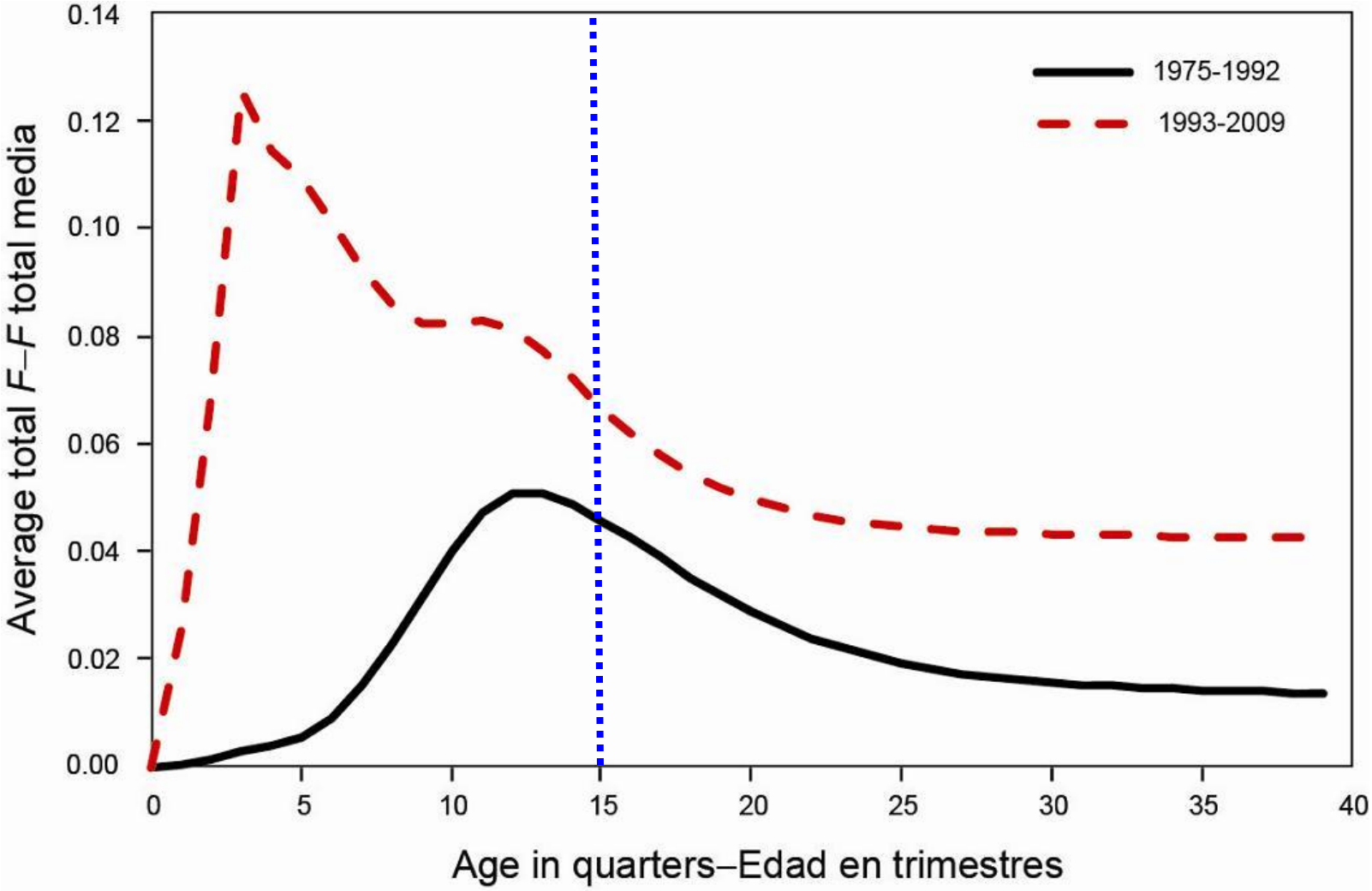
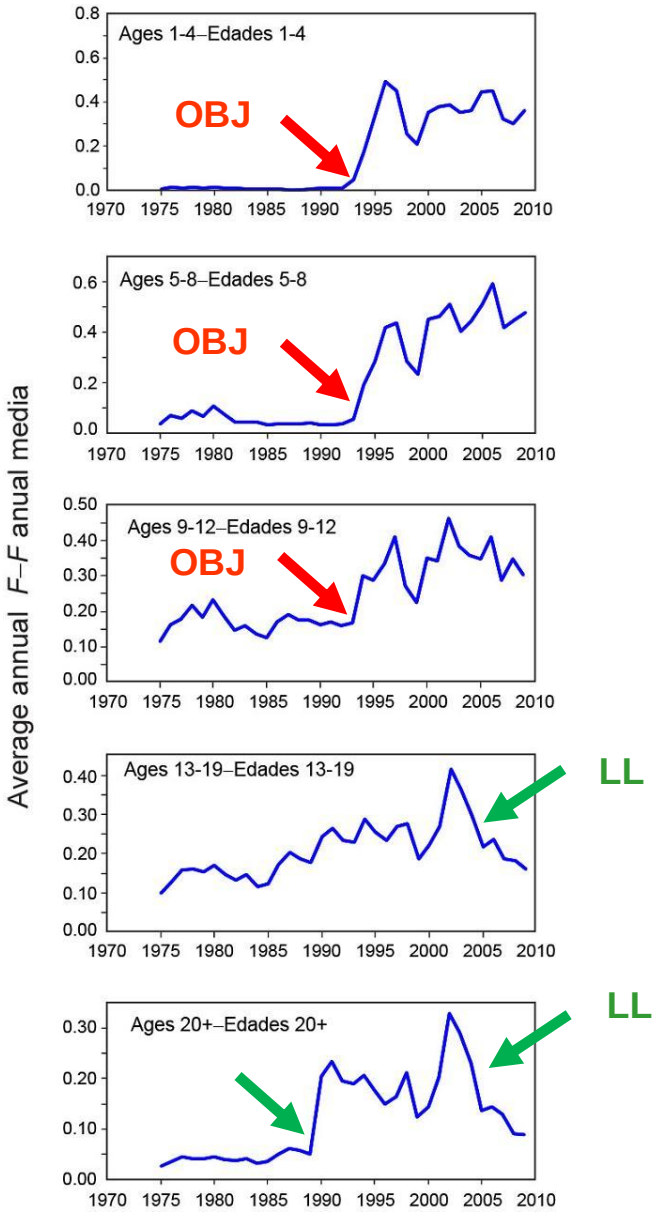
Age-specific fishing mortality

Results
(base case)



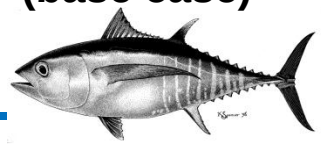
Fishing mortality

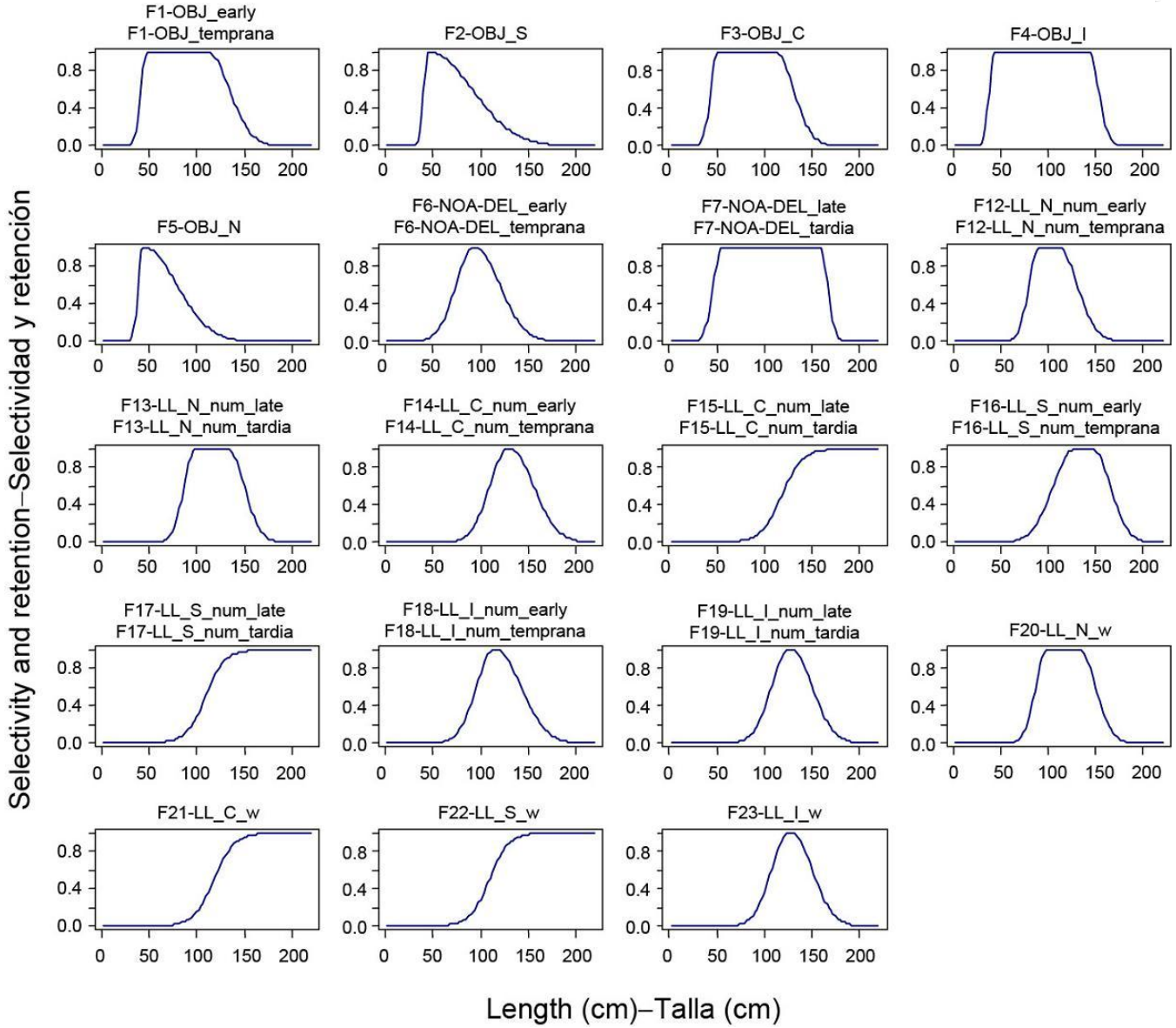
Results
(base case)



Size selectivity

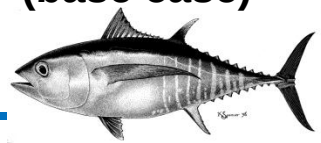
Results (base case)

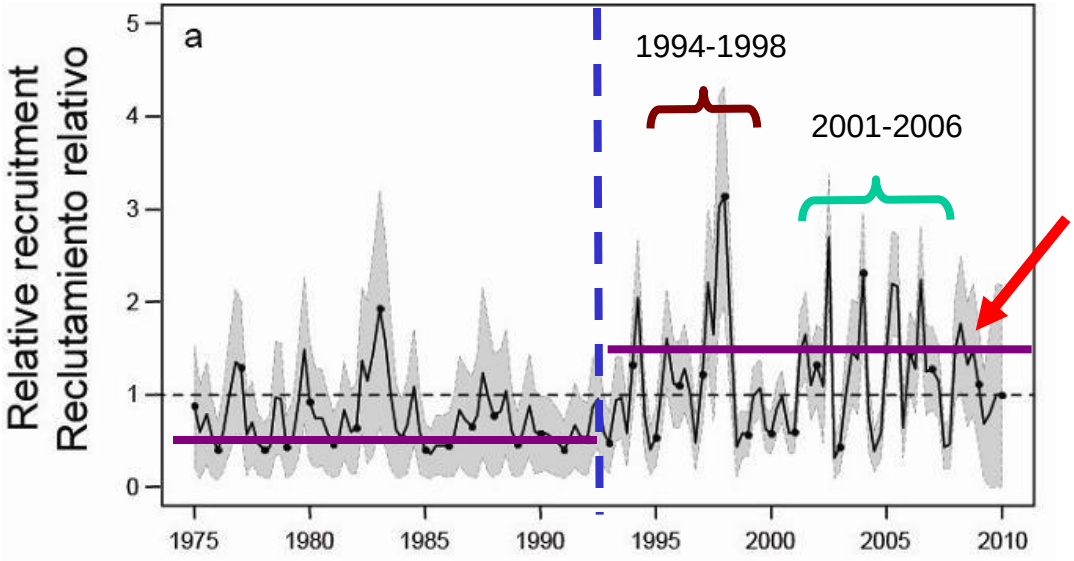


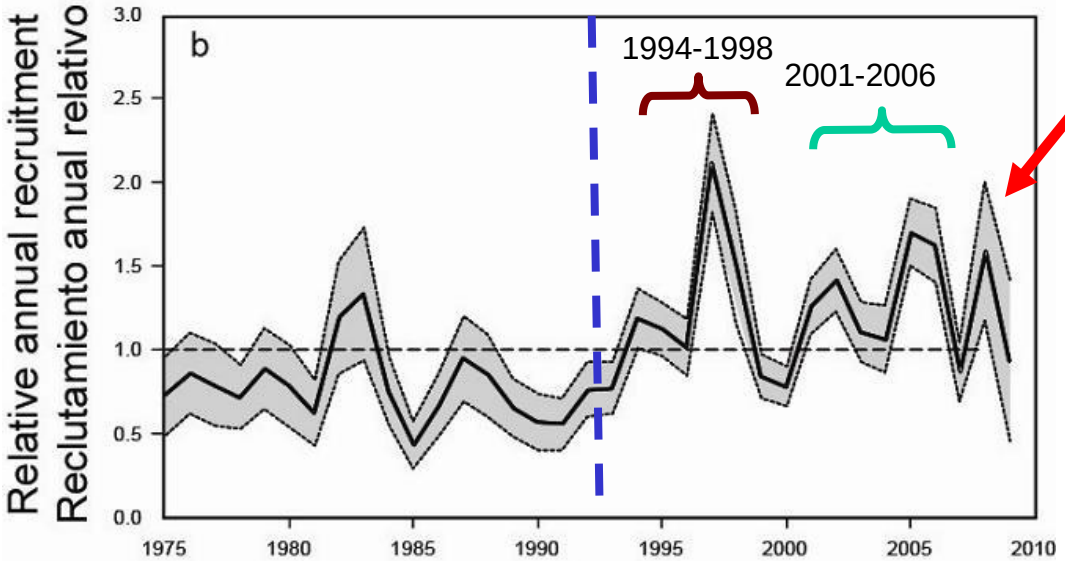


Recruitment

Results (base case)







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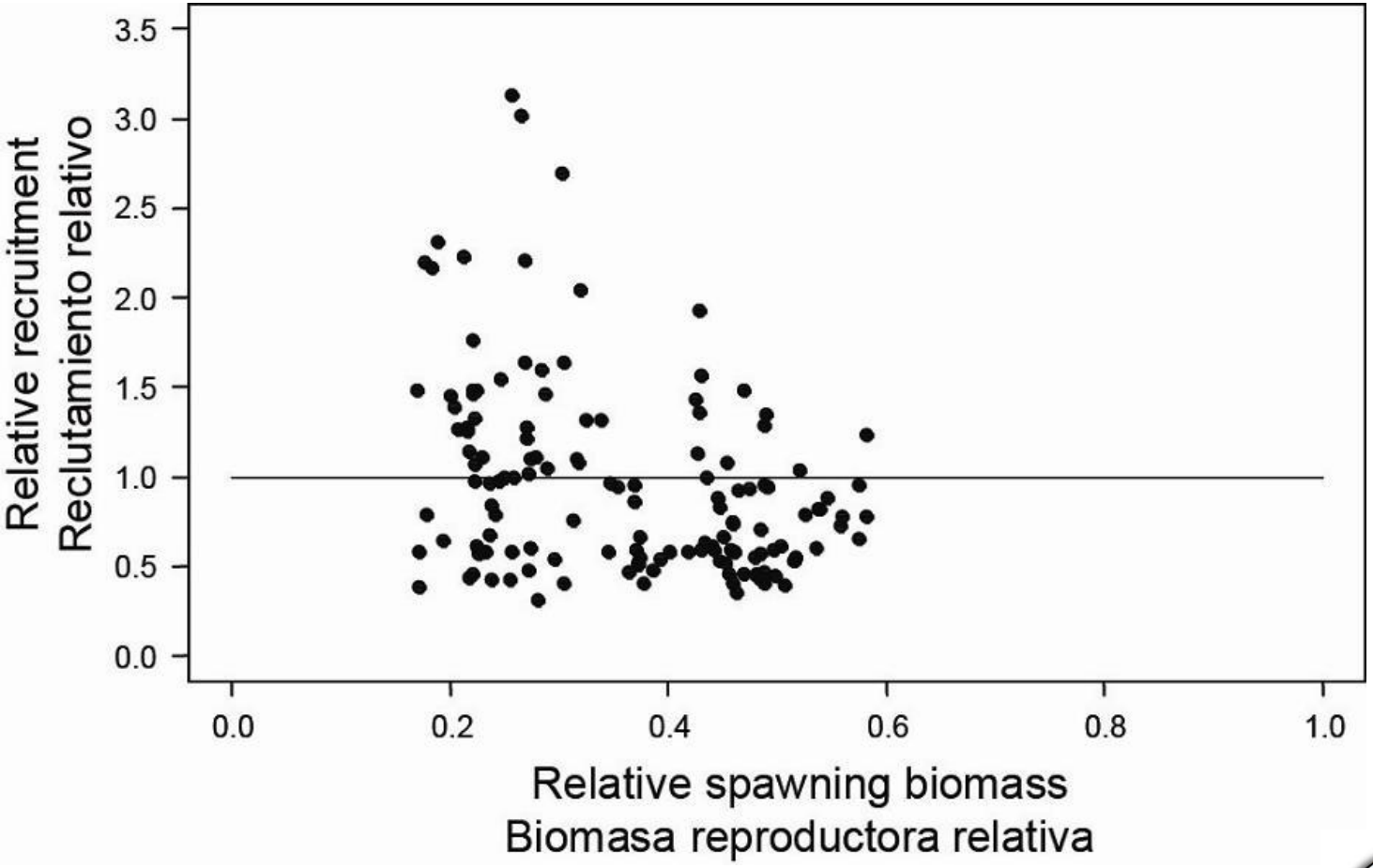
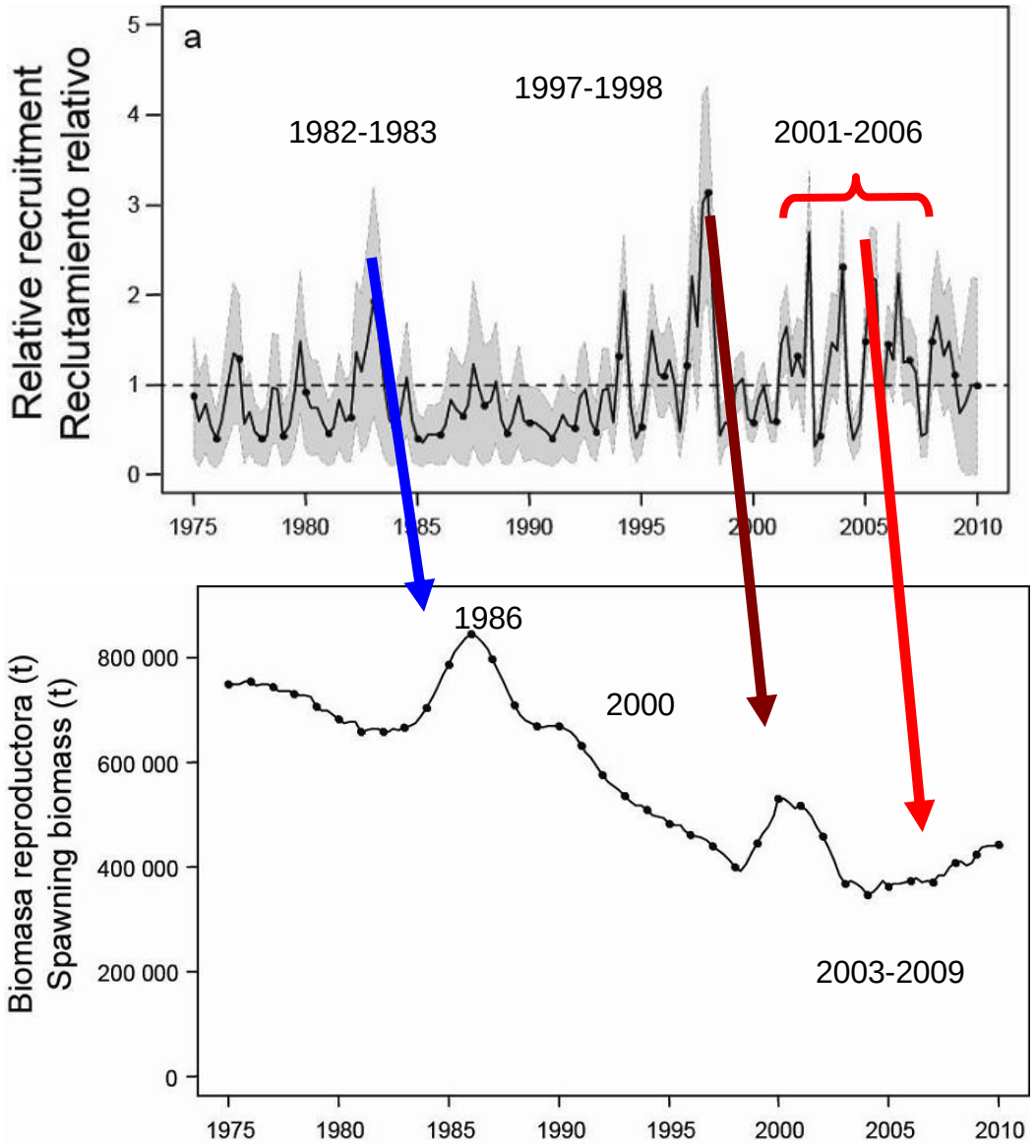
Stock-recruitment

Results (base case)



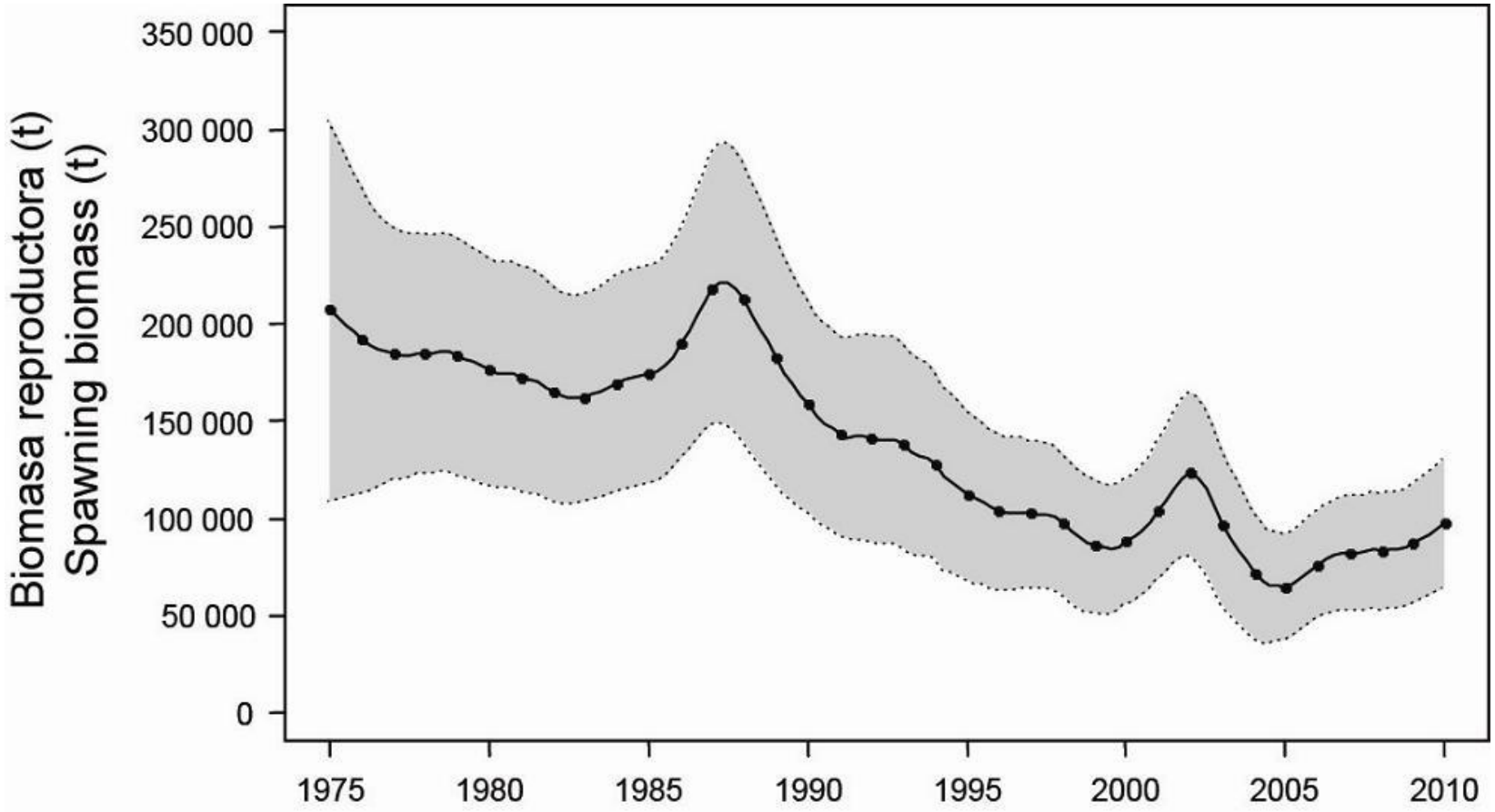
Summary biomass

Results (base case)



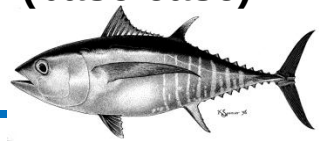
Spawning biomass

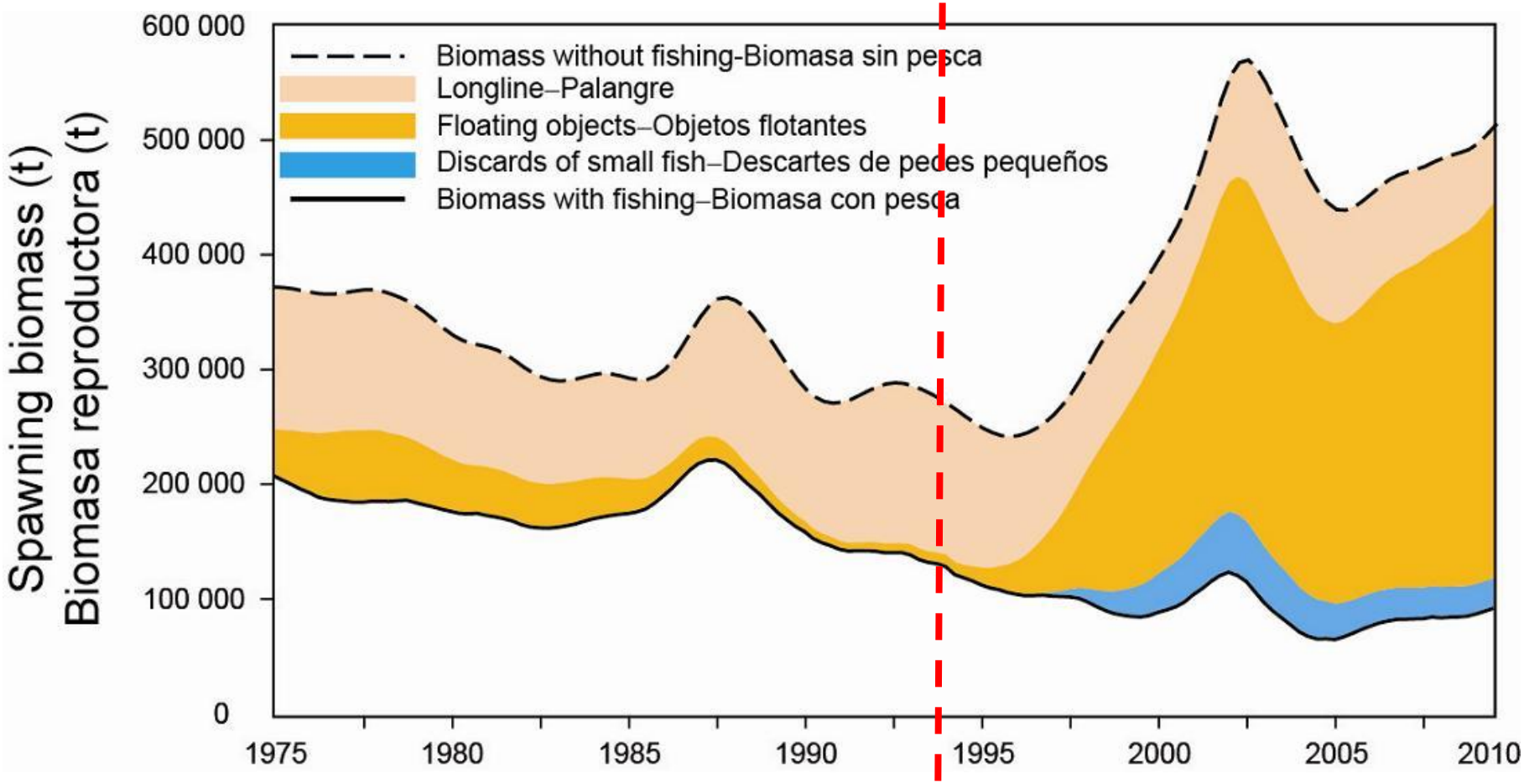
Results
(base case)



Fishery impact

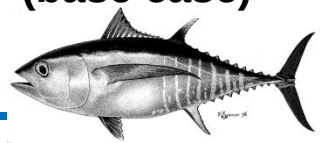
Results
(base case)

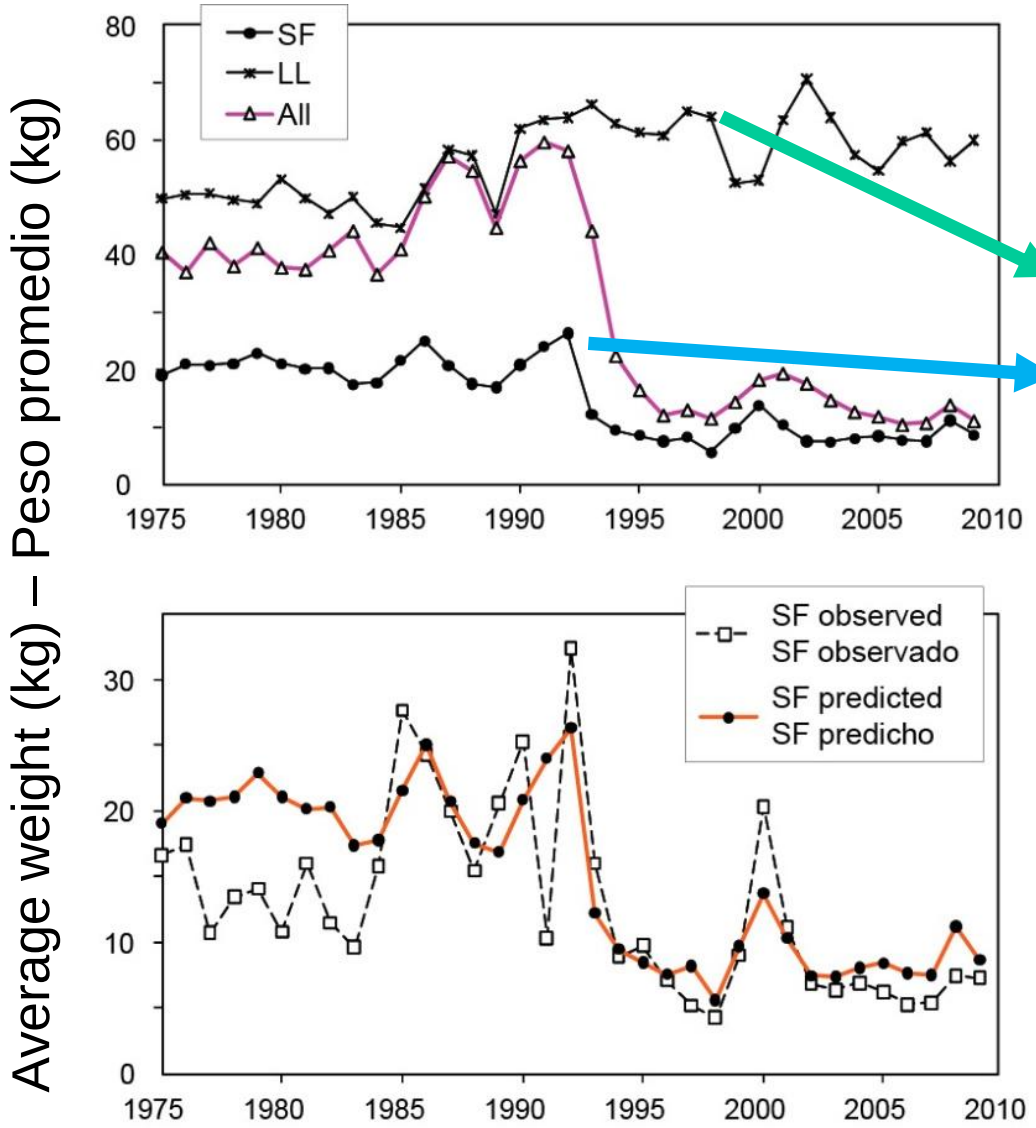




BET average weight

Results (base case)



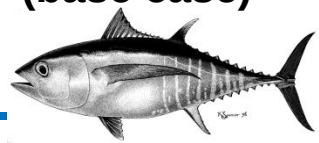


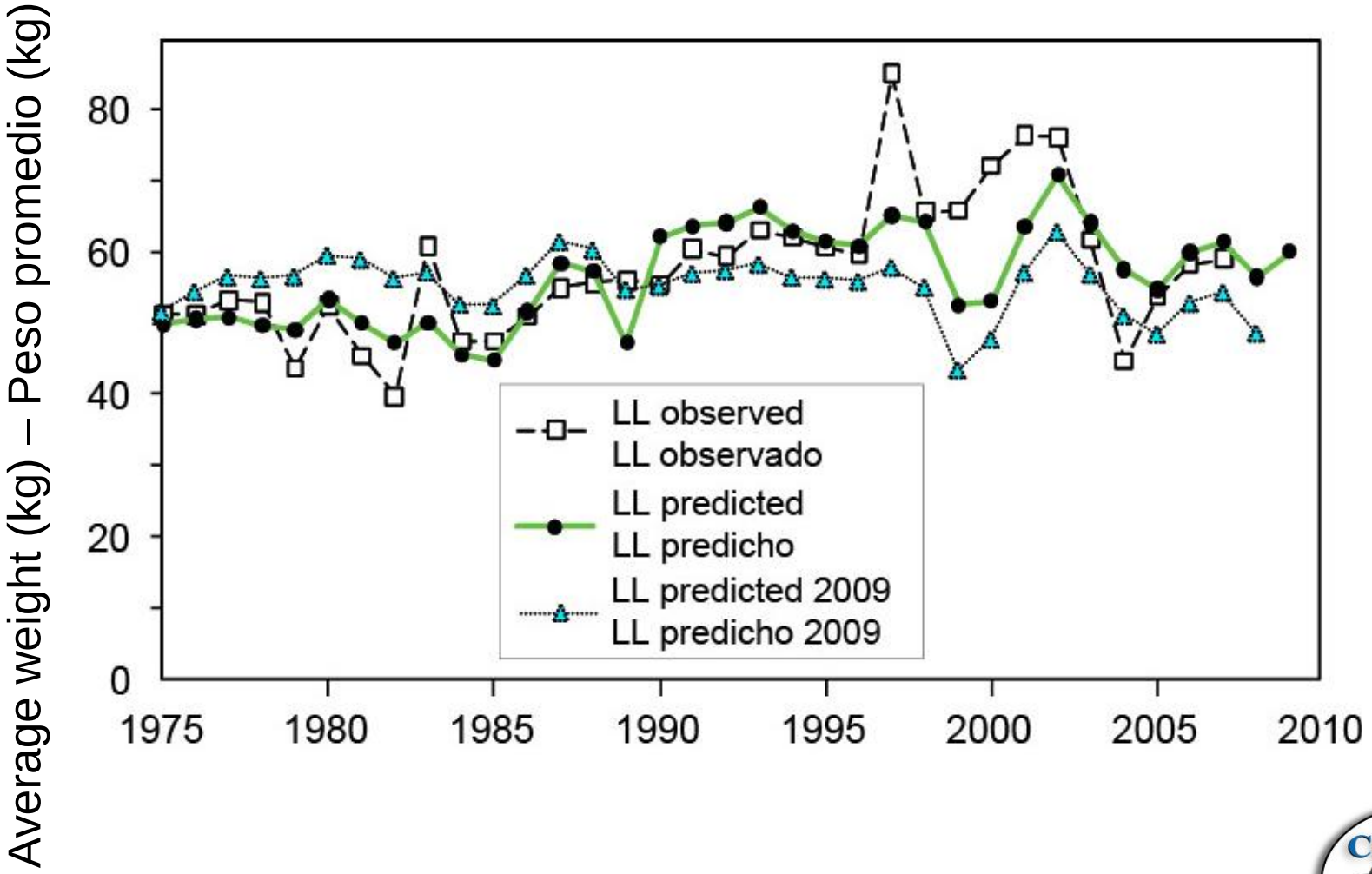
Strong cohort in 1997-1998

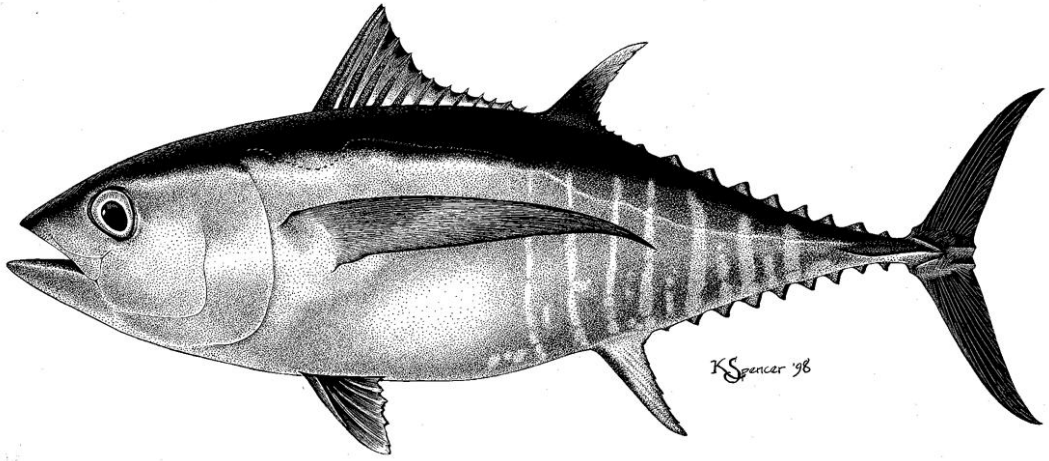
OBJ expansion (1993)

BET average weight - LL

Results
(base case)



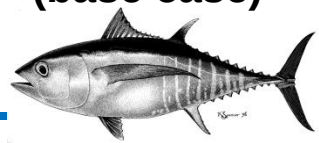


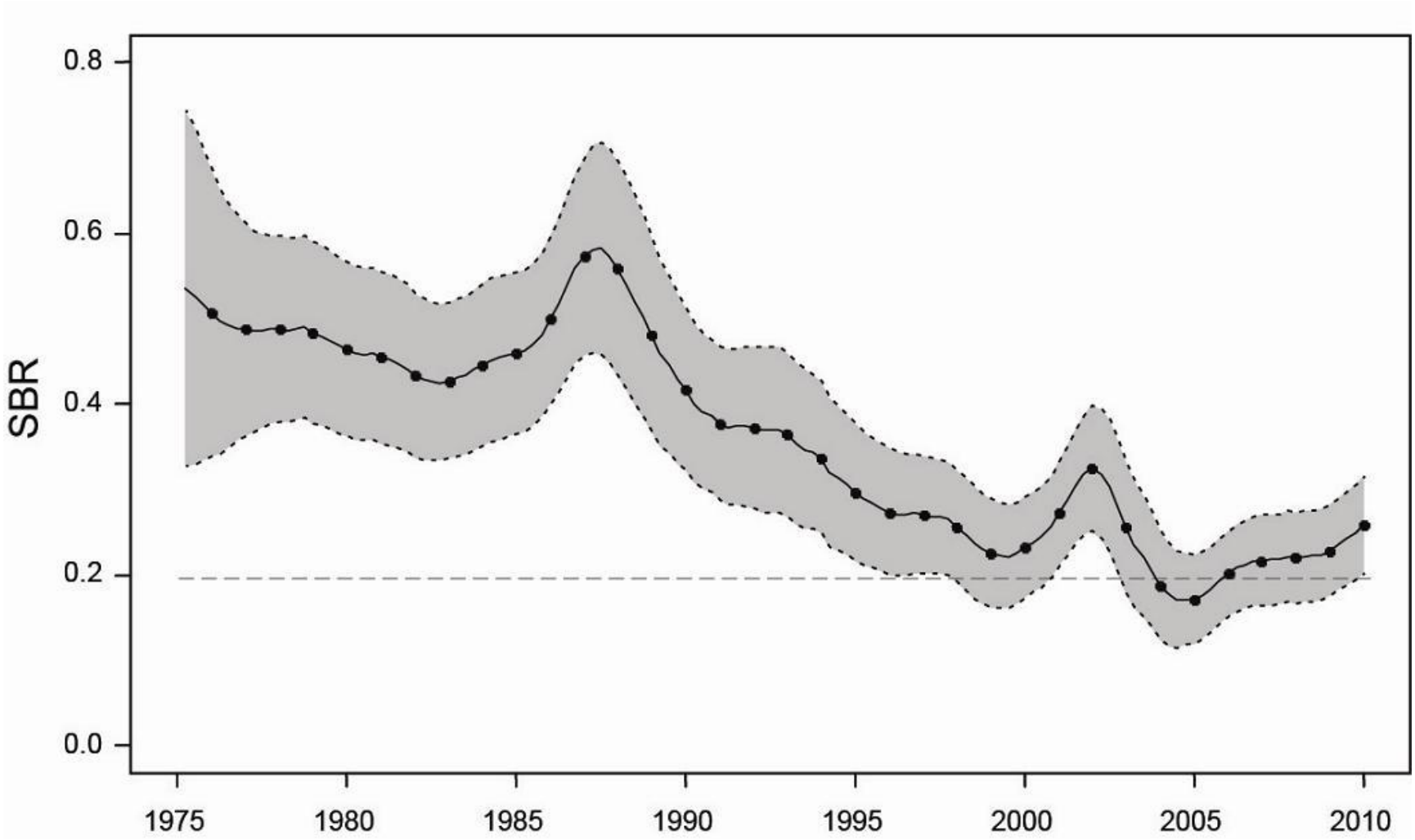


Stock status (base case)

- Spawning Biomass Ratio (SBR)
- Maximum Sustainable Yield (MSY)

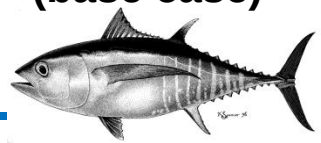
Spawning Biomass Ratio (SBR)





Management quantities

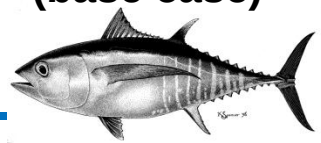
Stock status (base case)

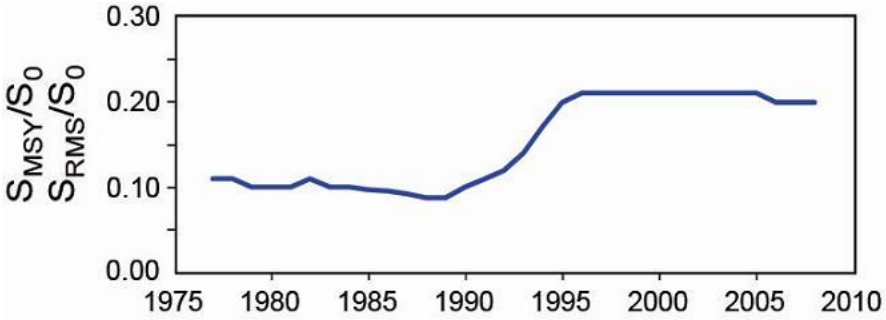


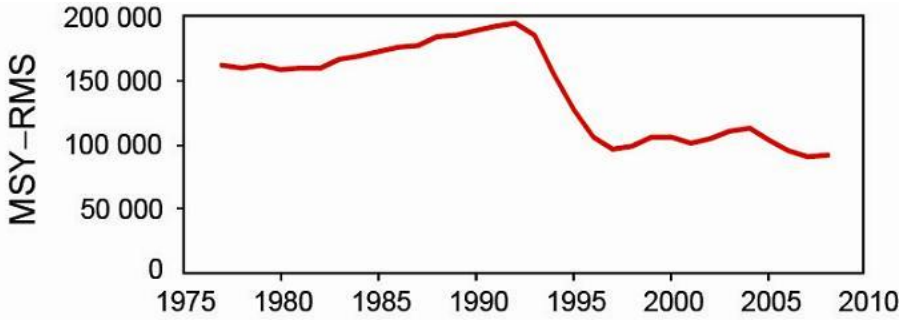
	F's 2007-2009 Base case	F's 2007-2008
MSY	90,538	93,412
Bmsy	332,331	335,584
Smsy	73,690	73,661
Bmsy/B0	0.25	0.25
Smsy/S0	0.19	0.19
Crecent/MSY	1.17	1.13
Brecent/Bmsy	1.33	1.32
Srecent/Smsy	1.33	1.33
Fmultiplier	1.13	1.14

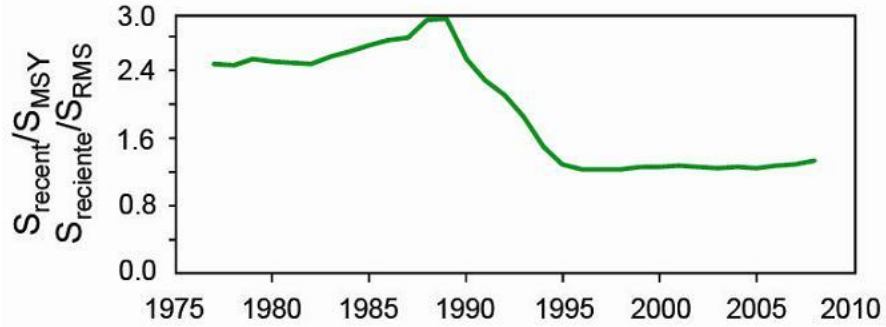
Time varying indicators

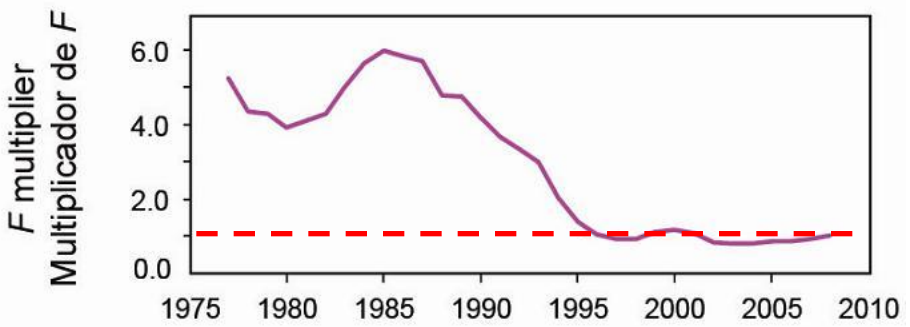
Stock status (base case)



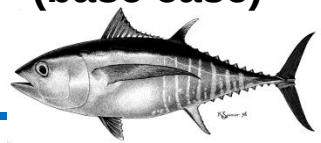








MSY-quantities by fishery



	Base case	Purse seine only	Longline Only
MSY	90,538	67,928	208,887
Bmsy	332,331	266,626	371,166
Smsy	73,690	62,008	40,302
Bmsy/B0	0.25	0.2	0.28
Smsy/S0	0.19	0.16	0.11
Crecent/MSY	1.17	1.56	0.51
Brecent/Bmsy	1.33	1.66	1.19
Srecent/Smsy	1.33	1.58	2.43
Fmultiplier	1.13	1.6	9.56

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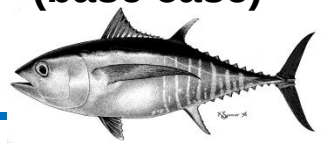
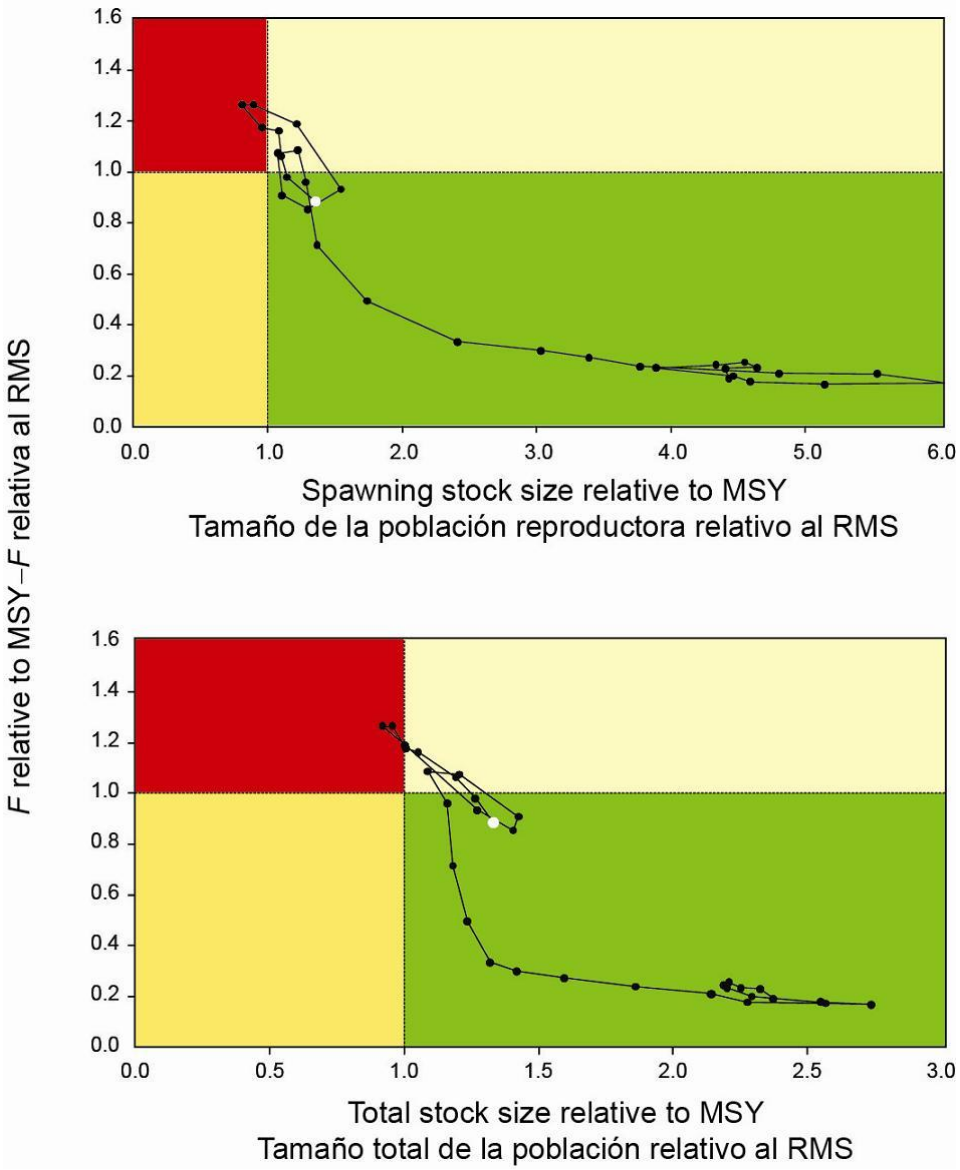
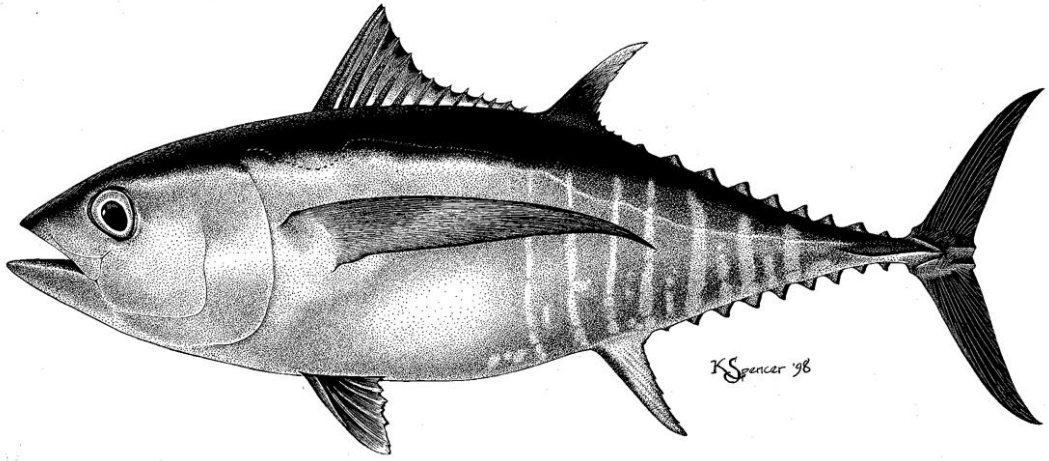
Phase plots

Stock status (base case)

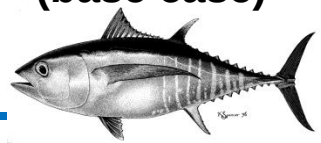






Projection simulations (base case)

- Effect of conservation resolutions
- Status quo fishing strategy
- MSY fishing strategy



Forward projections

- Projection period: 10 years (2010-2020)
- Evaluate:
  - Catches (surface and longline fisheries)
  - Spawning Biomass Ratio (SBR)
- Three exploitation scenarios:
  - Status quo (F_{cur}): 3-year F average (2007-2009)
  - No resolution
  - F_{MSY}

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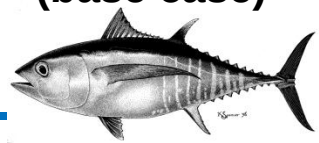
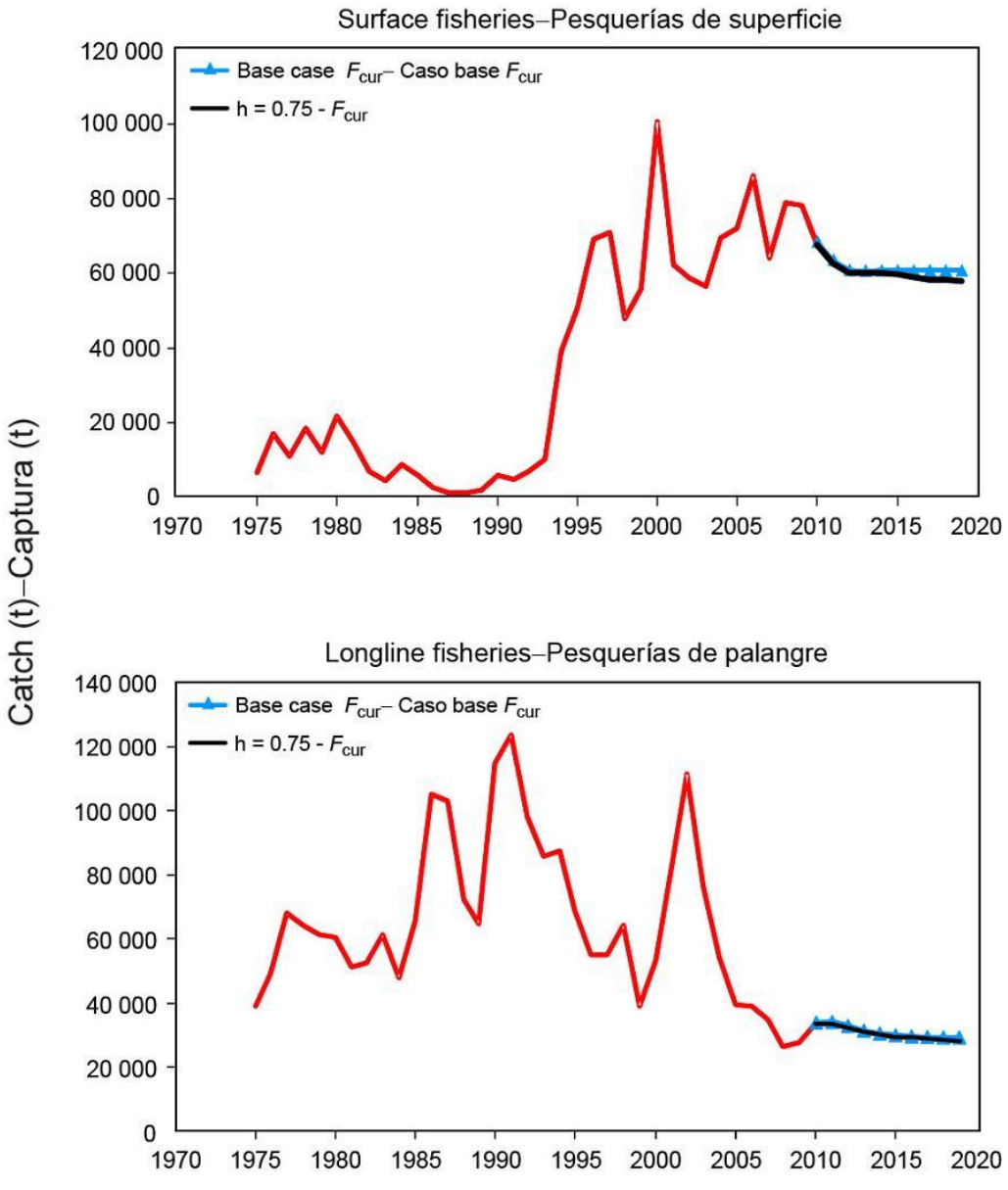
Projected catches – *Status quo* (F_{cur})

Projections (base case)





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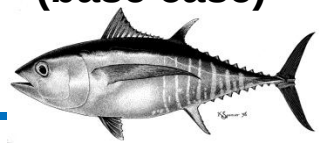
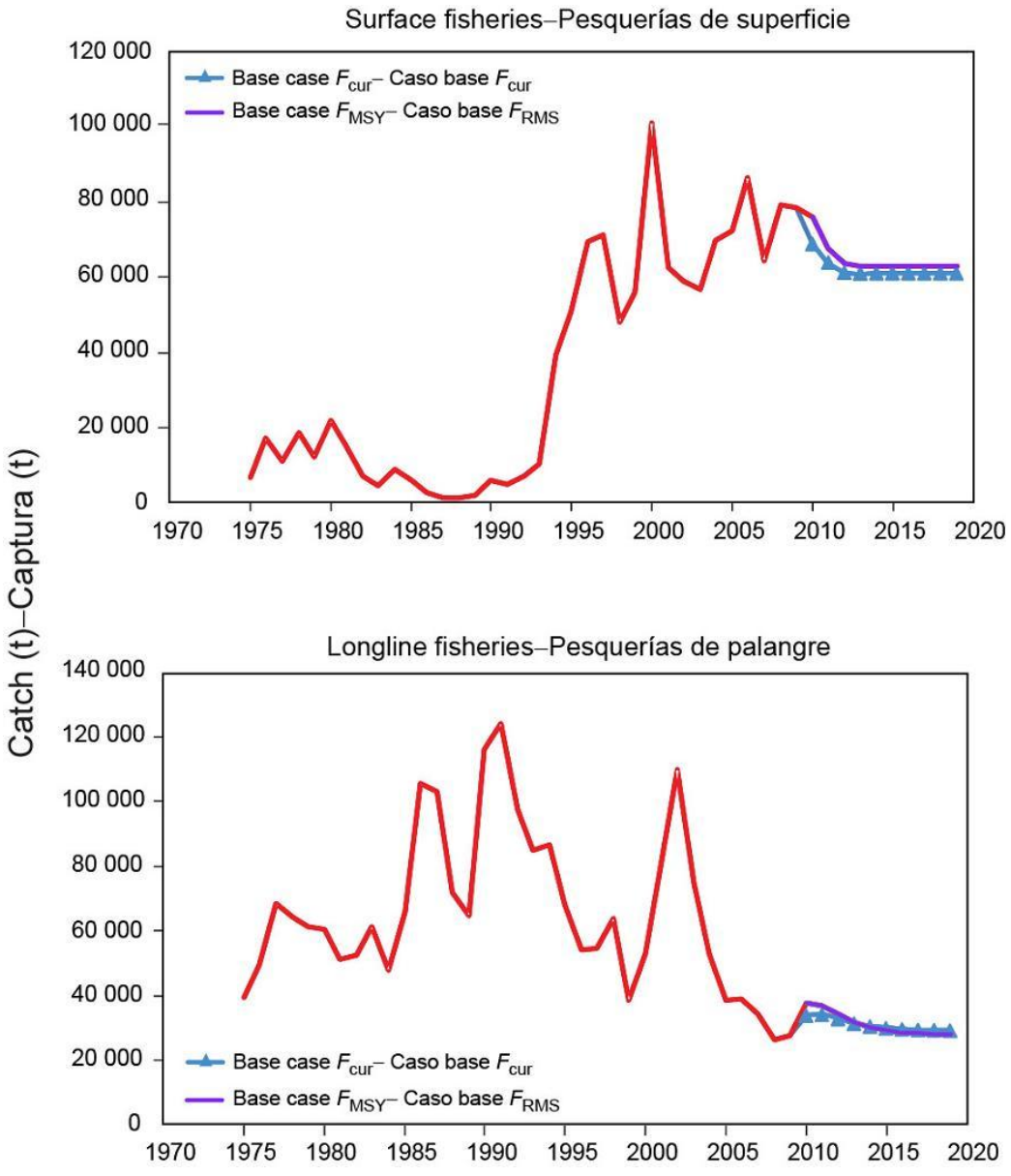
Projected catches – F_{cur} and F_{msy}

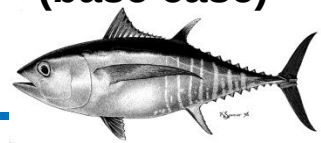
Projections (base case)

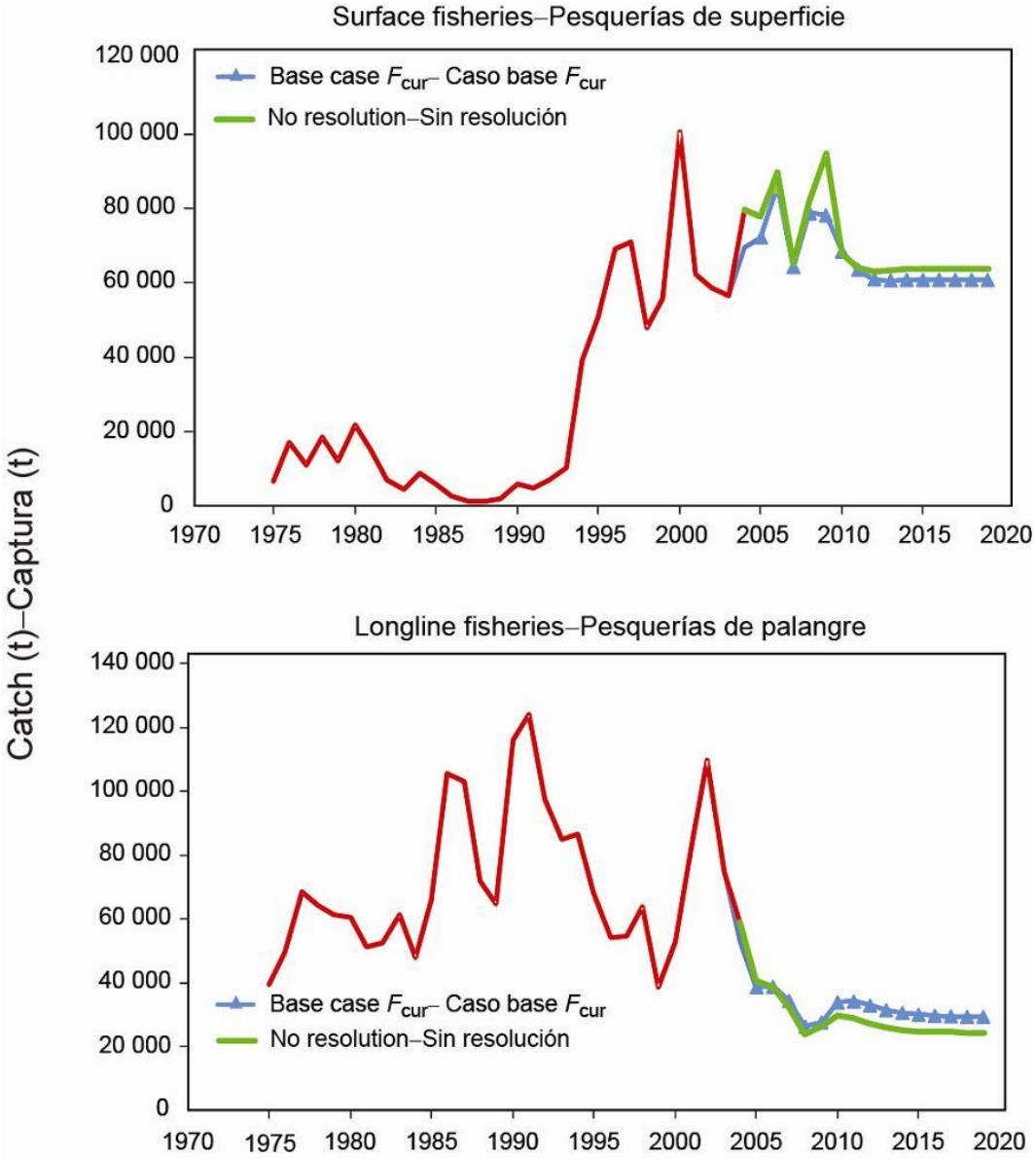




Projected catches – effect of resolutions

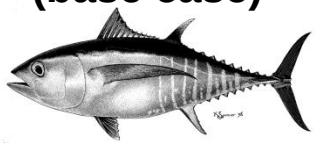
Projections (base case)

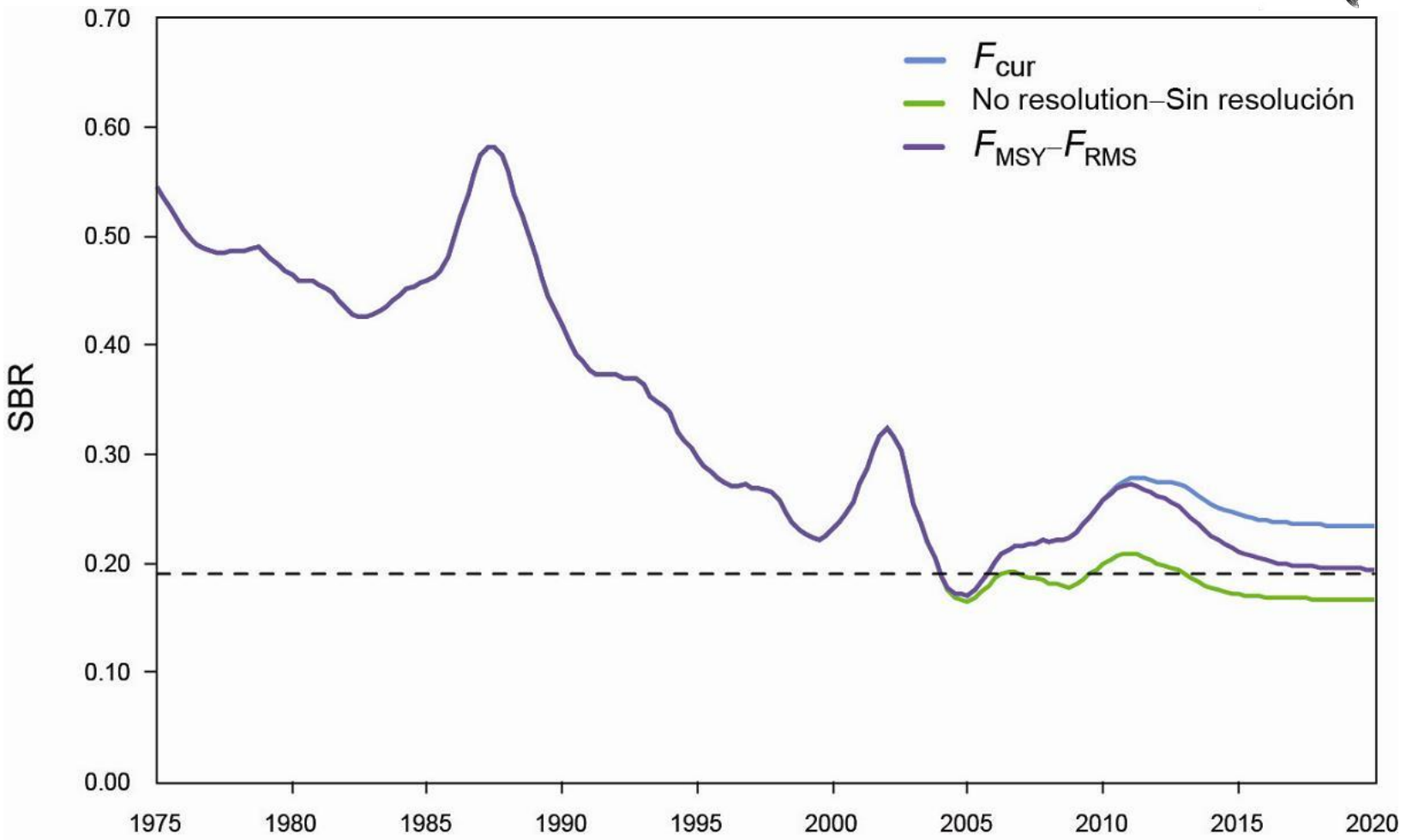


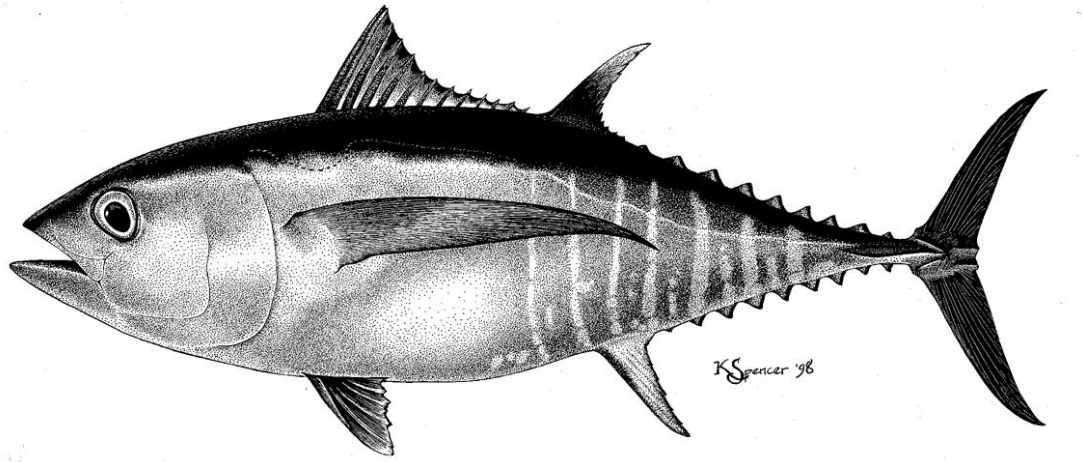


Spawning Biomass Ratio

Projections (base case)



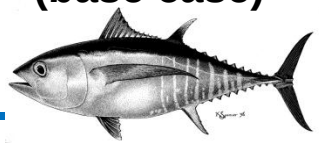


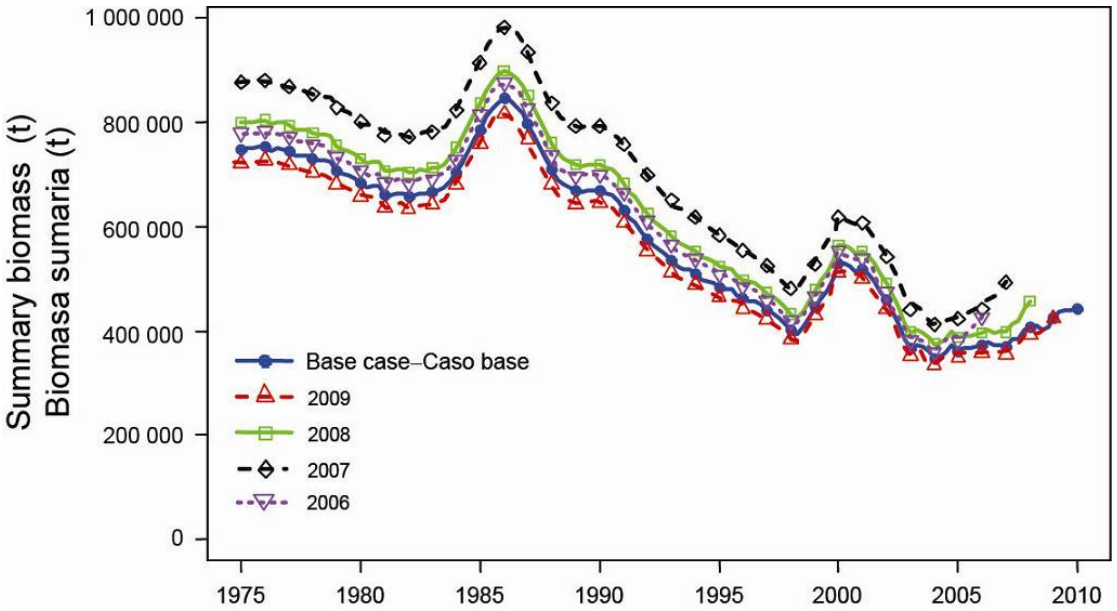


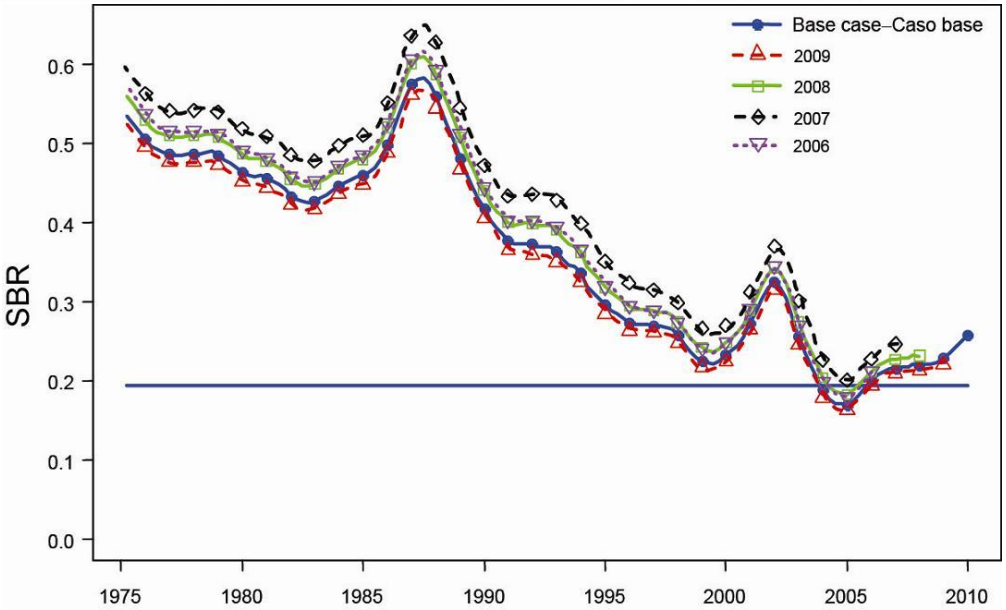
Retrospective analysis

Biomasses - retrospective

Retrospective (base case)

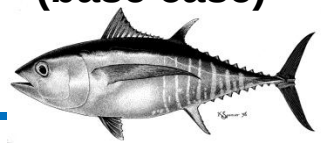


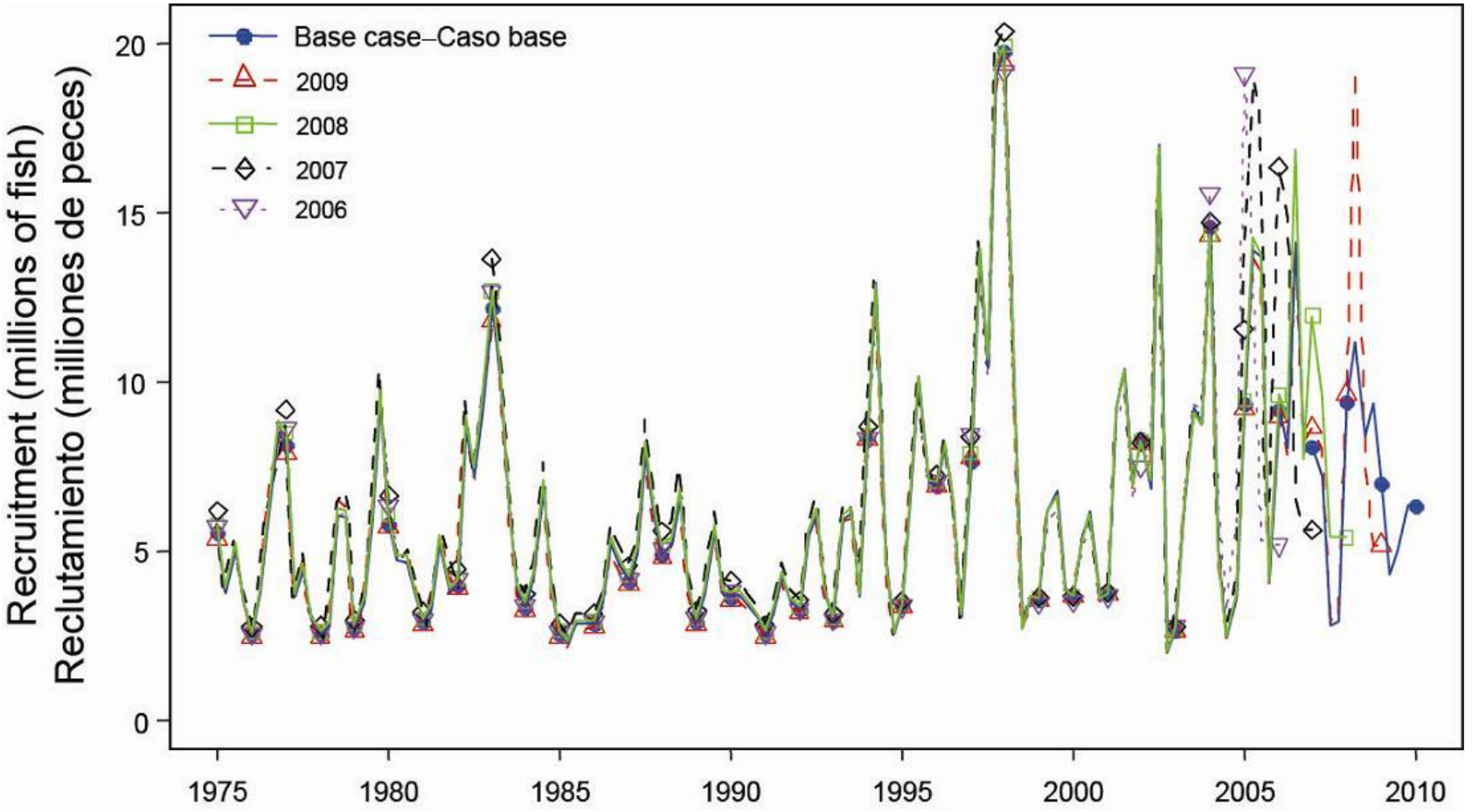




Recruitment - retrospective

Retrospective (base case)





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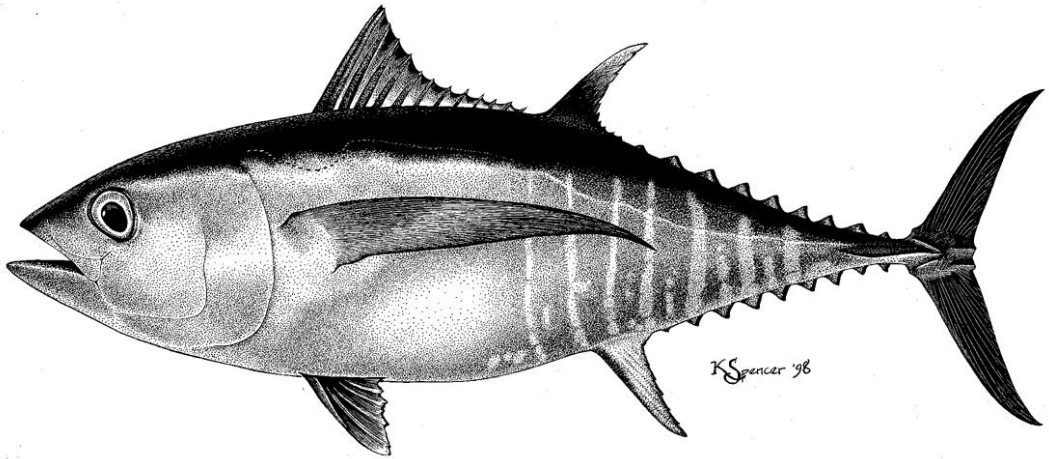
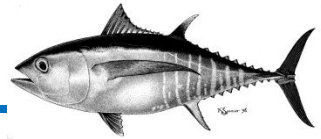


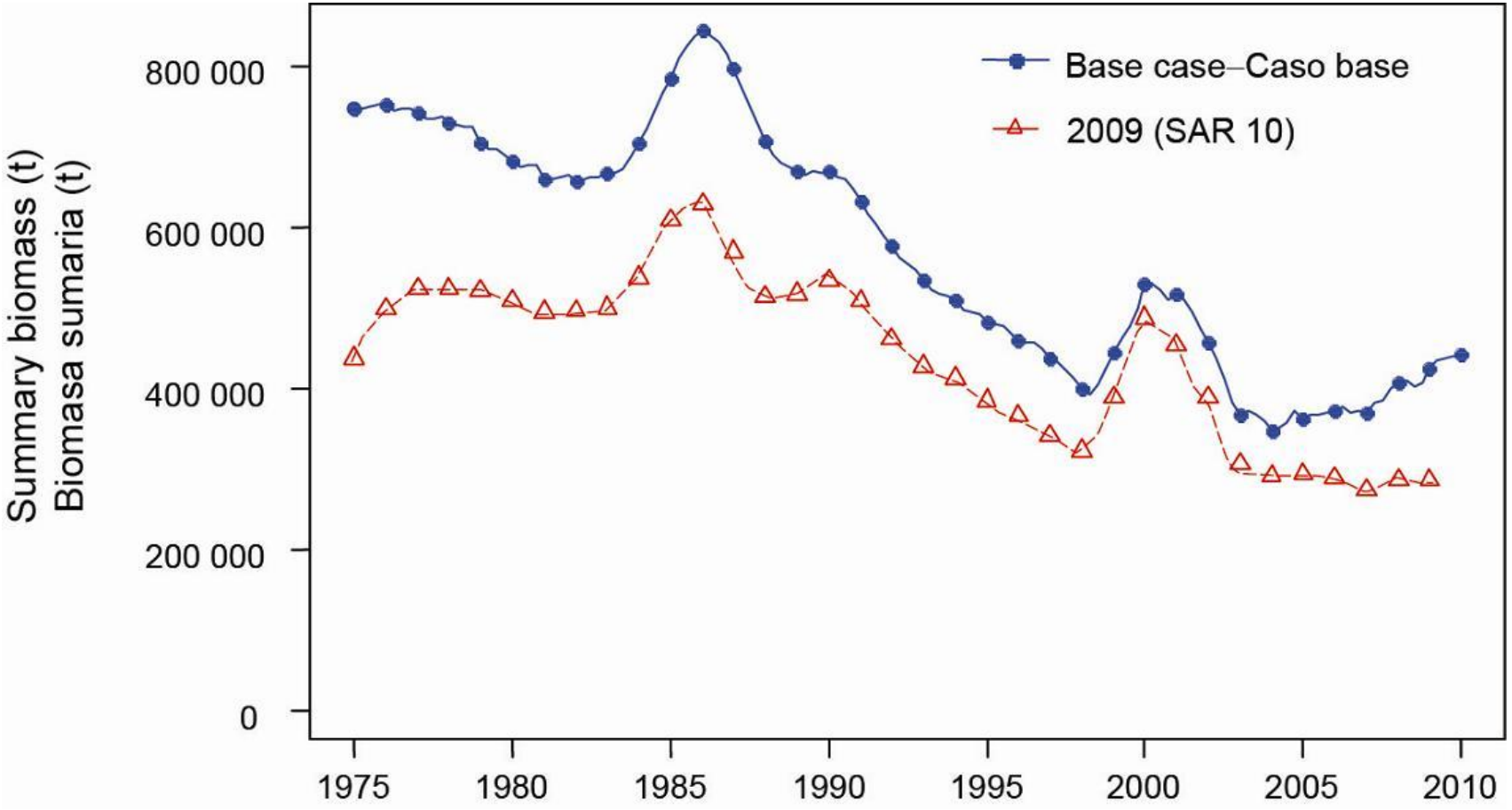
Comparison to previous assessment

(SAR 10 -2009)

Summary biomass

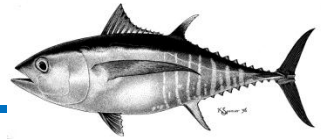
Comparison to SAR10

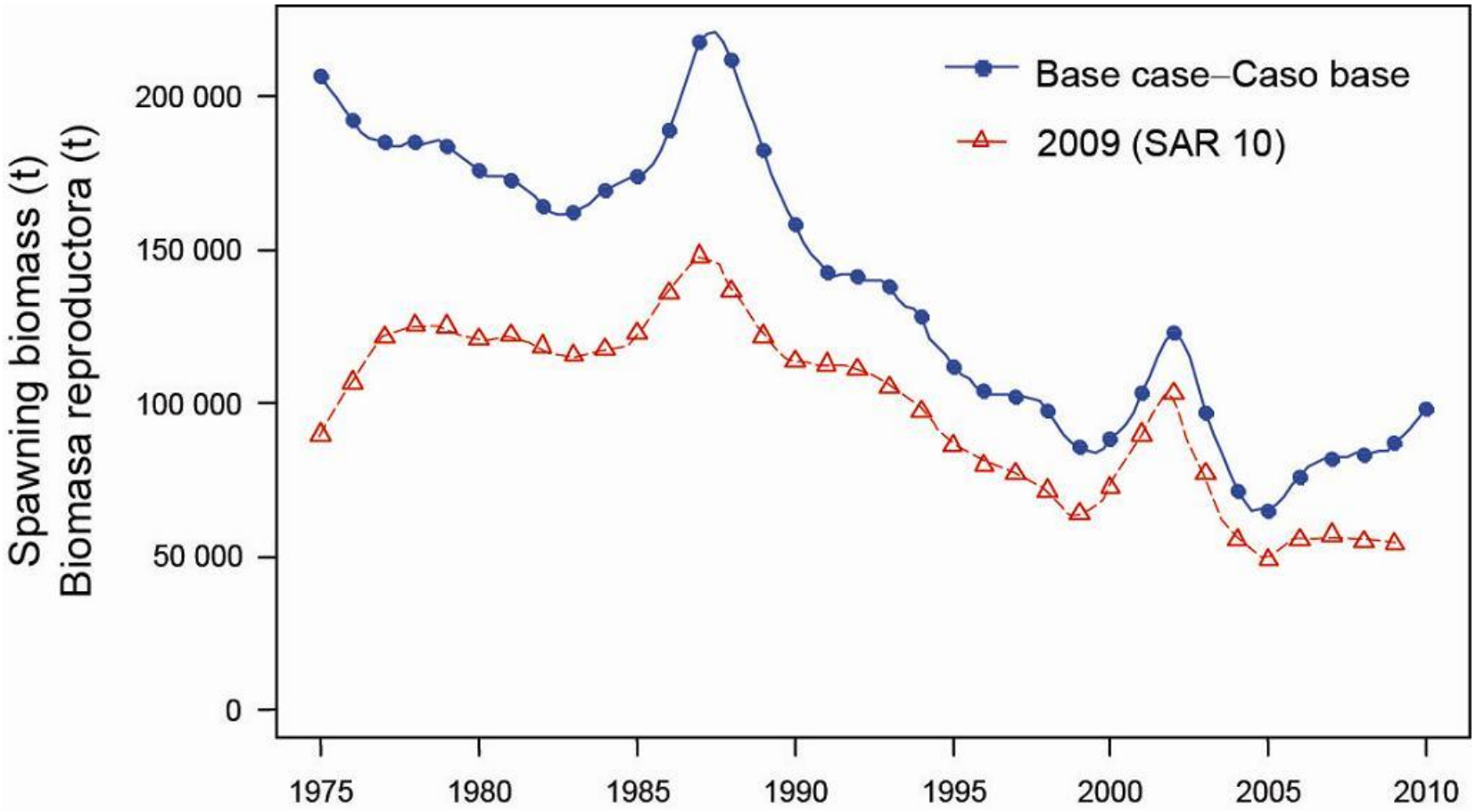




Spawning biomass

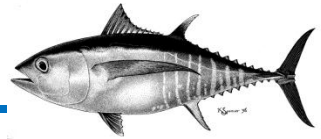
Comparison to SAR10

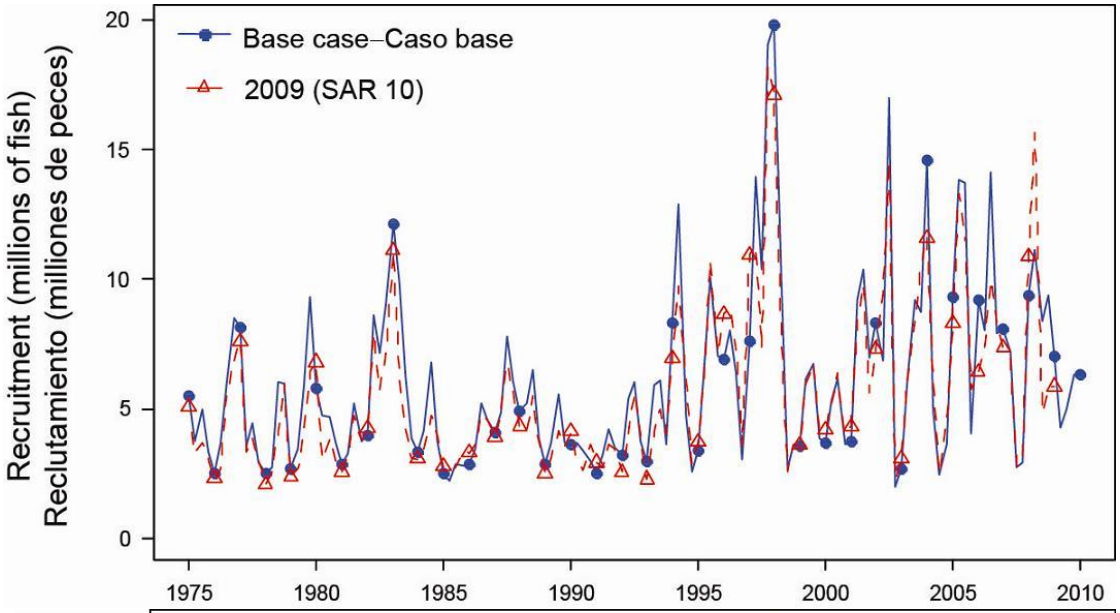


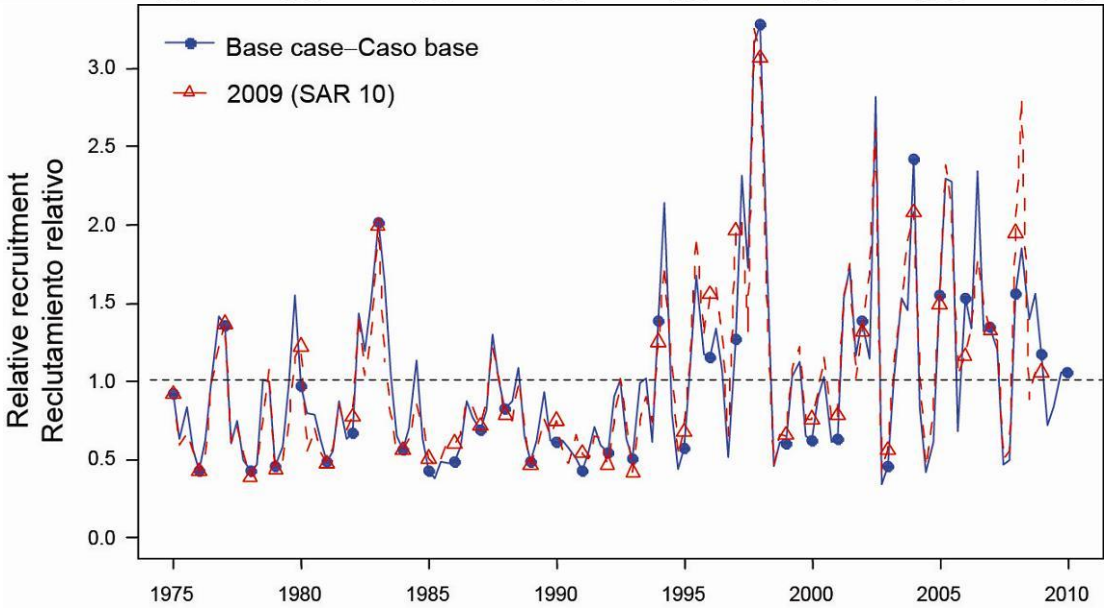


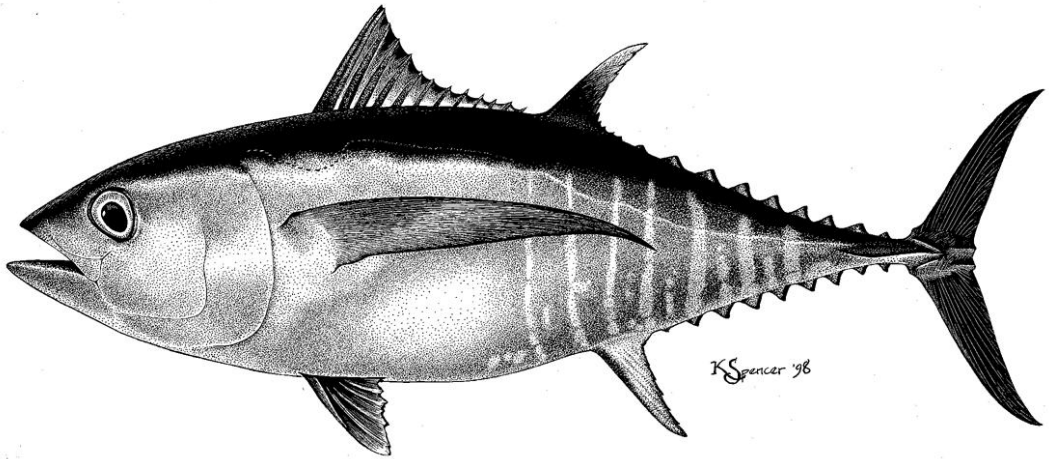
Recruitment

Comparison to SAR10







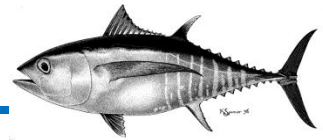


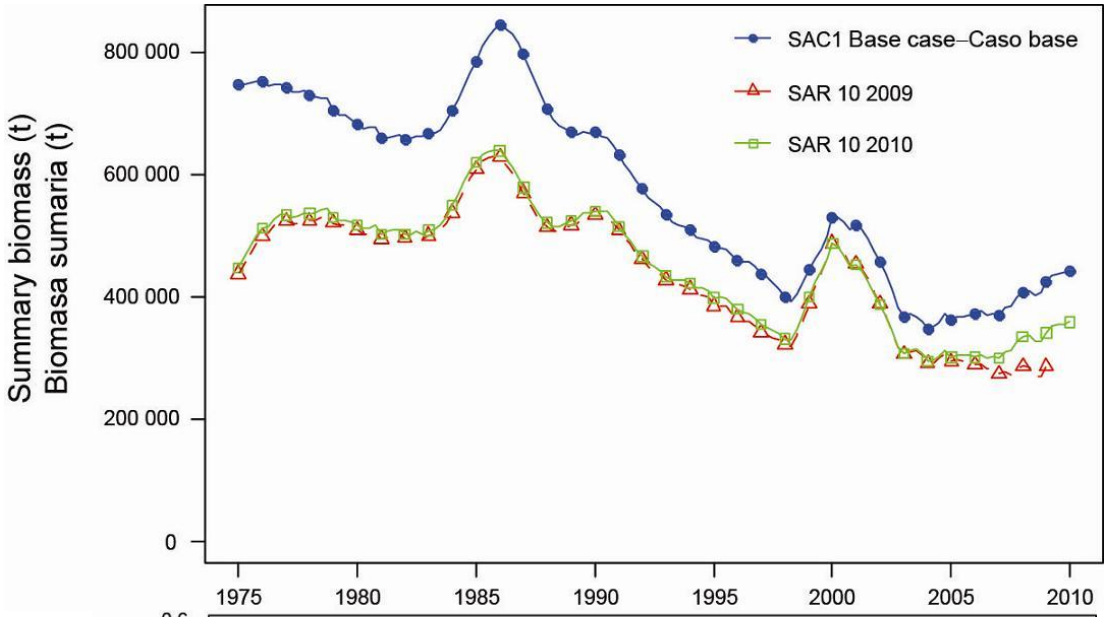
Transition from SAR 10 to current base case model (SAC1)

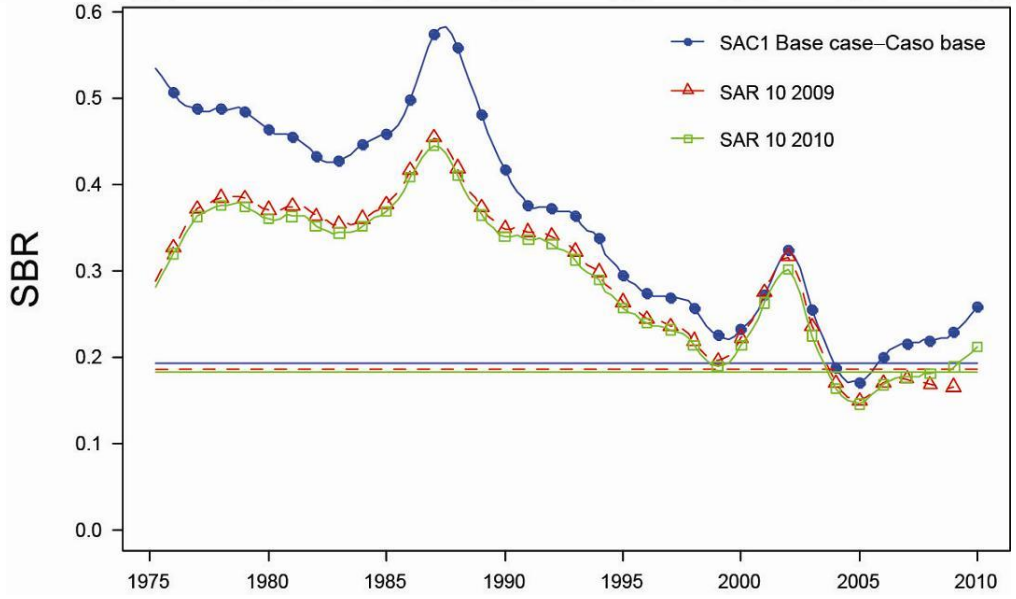
(see doc SAC-01-08b)

Update SAR 10 model

Transition from SAR10 to SAC1







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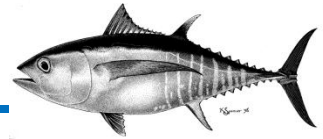
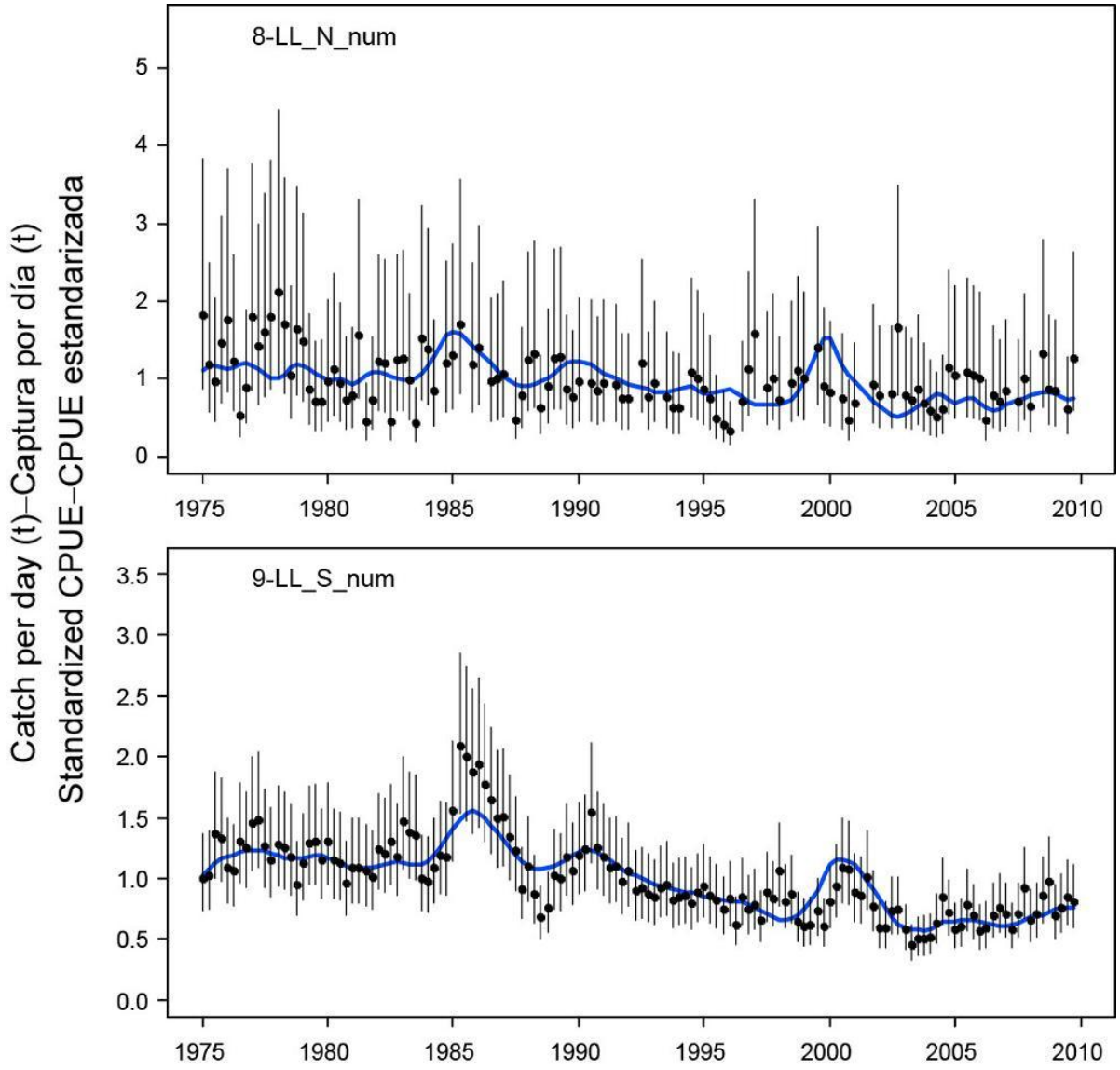
Update SAR 10 model

Transition from SAR10 to SAC1





Update SAR 10 model

Transition from SAR10 to SAC1

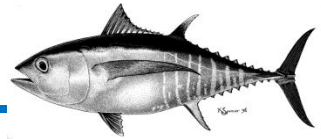
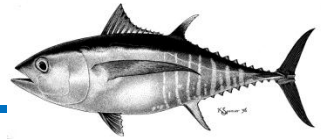


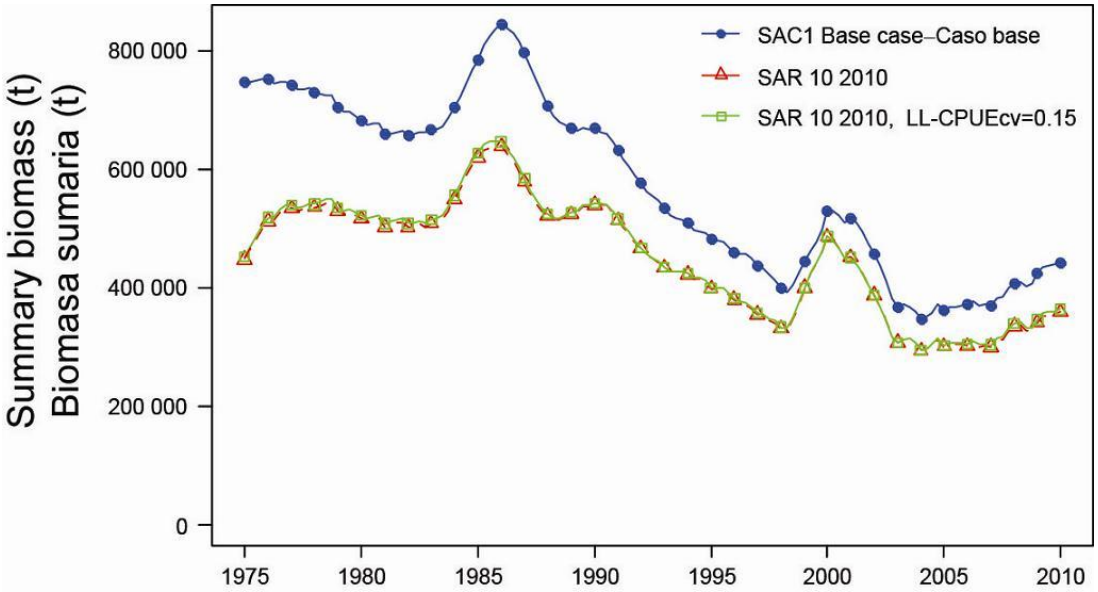
TABLE 1.1. Estimates of the MSY and its associated quantities for bigeye tuna for the base case assessment and the sensitivity analyses using an updated SAR10 (Aires-da-Silva and Maunder 2010) configuration model.

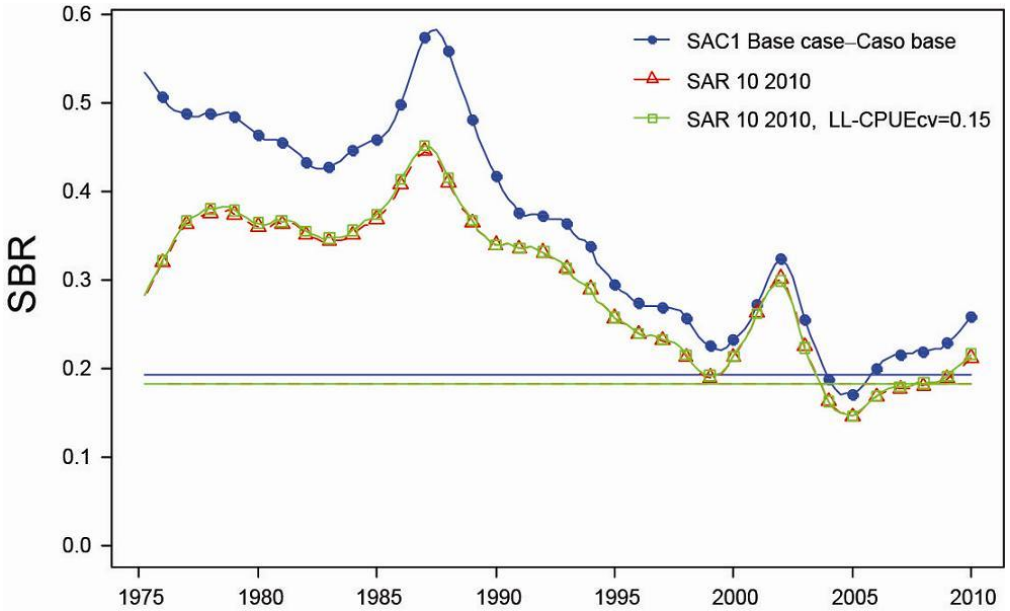
			3-year F average		
			2007-2009	2006-2008	2005-2007
	SAC1	SAR10-2009	SAR10-2010	SAR10-2010	SAR10-2010
MSY-RMS	90,538	83,615	87,959	89,076	87,010
B_{MSY}- B_{RMS}	332,331	289,475	298,578	301,717	308,928
S_{MSY}- S_{RMS}	73,690	60,631	61,947	62,381	64,986
B_{MSY}/B_0- B_{RMS}/B_0	0.25	0.25	0.24	0.25	0.25
S_{MSY}/S_0- S_{RMS}/S_0	0.19	0.19	0.18	0.18	0.19
C_{recent}/MSY-C_{recent}/RMS	1.17	1.19	1.18	1.17	1.2
B_{recent}/B_{MSY}- B_{recent}/B_{RMS}	1.33	0.99	1.2	1.19	1.16
S_{recent}/S_{MSY}-S_{recent}/S_{RMS}	1.33	0.89	1.16	1.15	1.11
F multiplier-Multiplicador de F	1.13	0.81	1.04	0.93	0.86

Fix CV of LL-CPUE to 0.15

Transition from SAR10 to SAC1







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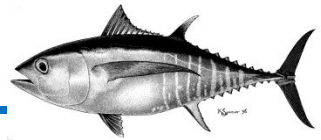
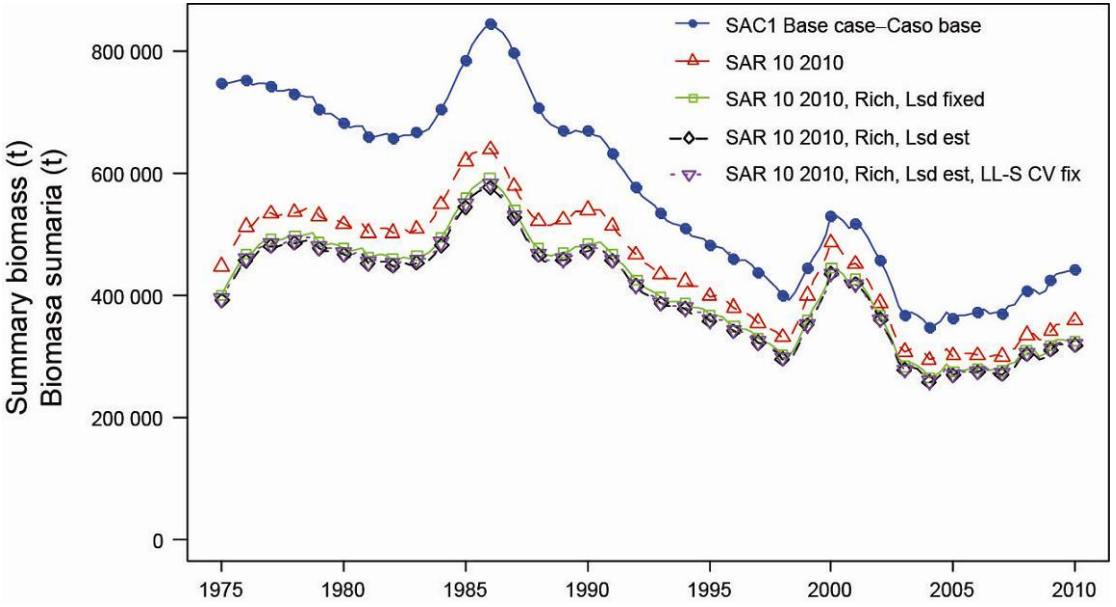
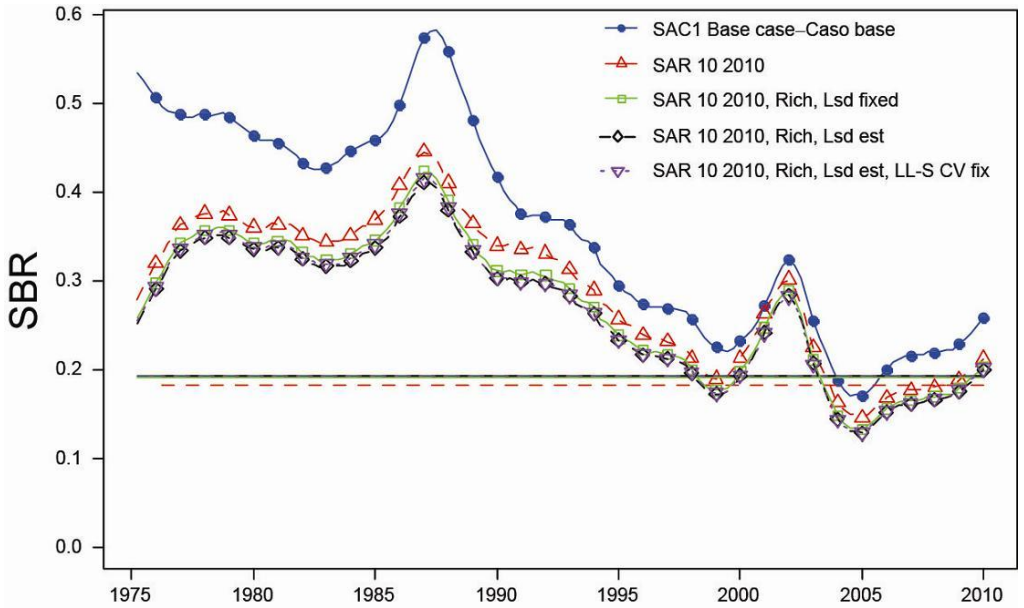
Change from VB to Richards growth

Transition from SAR10 to SAC1



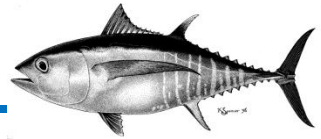


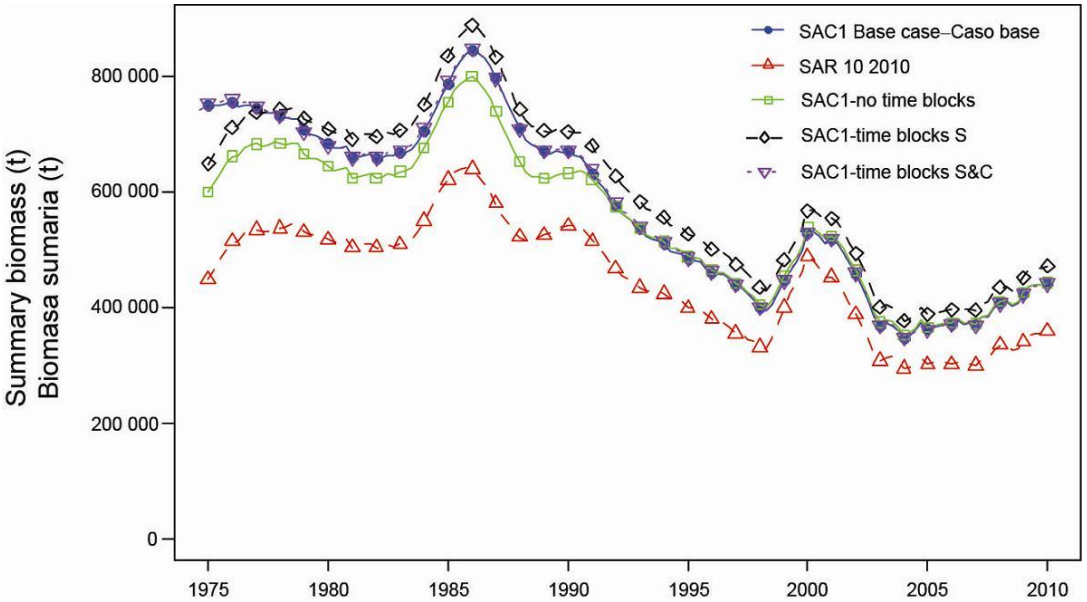


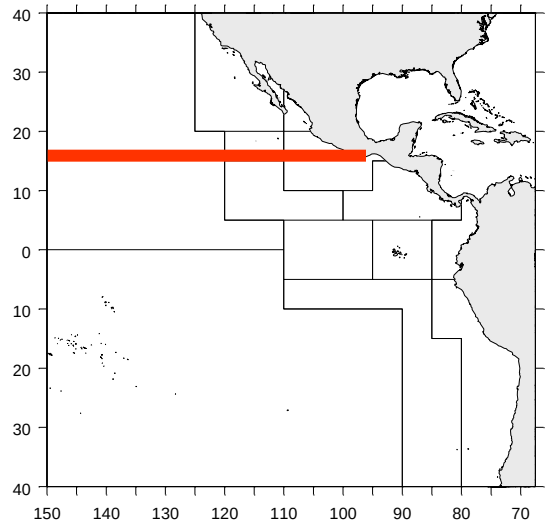
CIAT IATTC

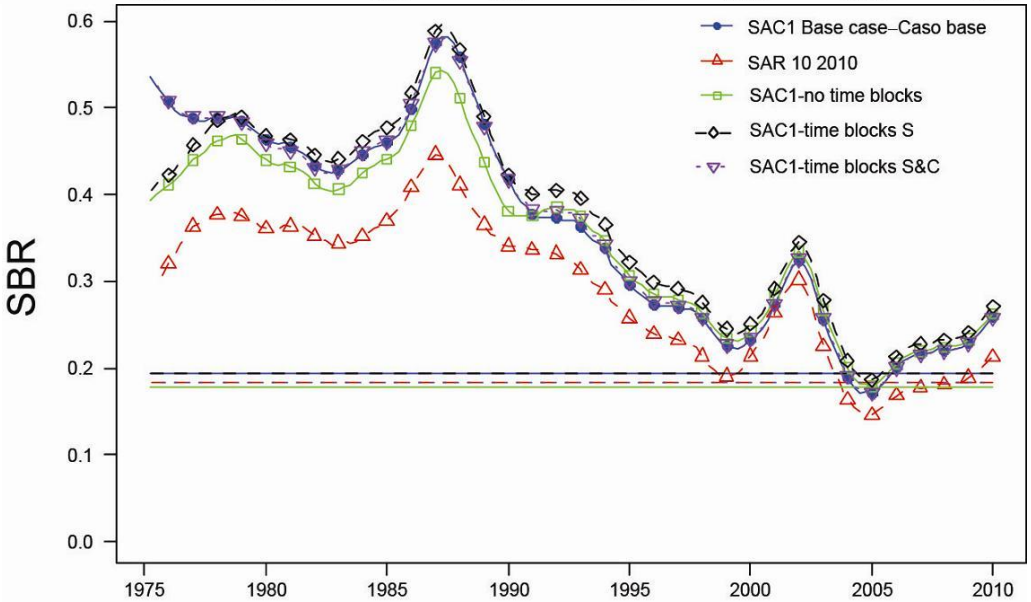
New LL fishery definitions

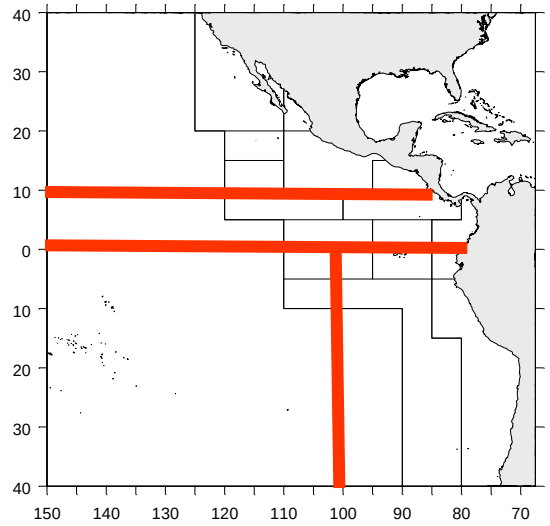
Transition from SAR10 to SAC1

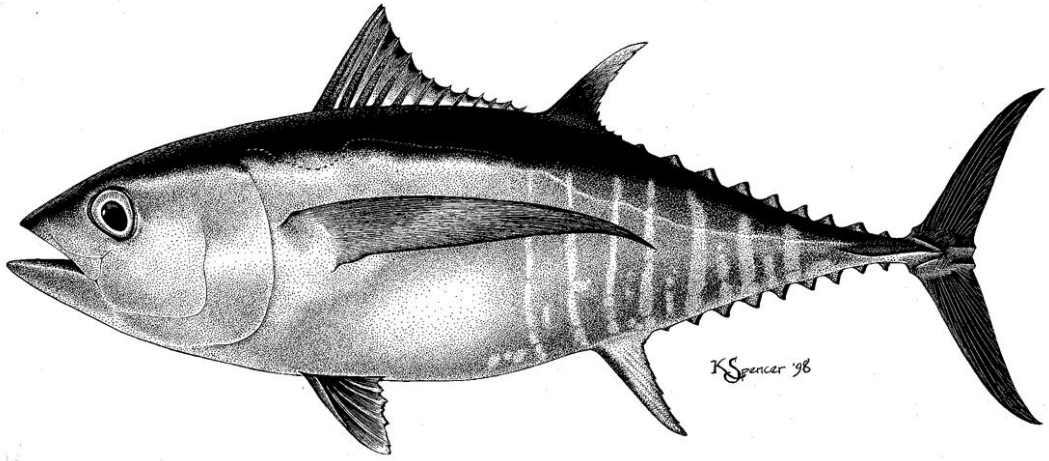










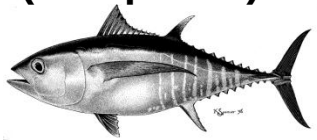


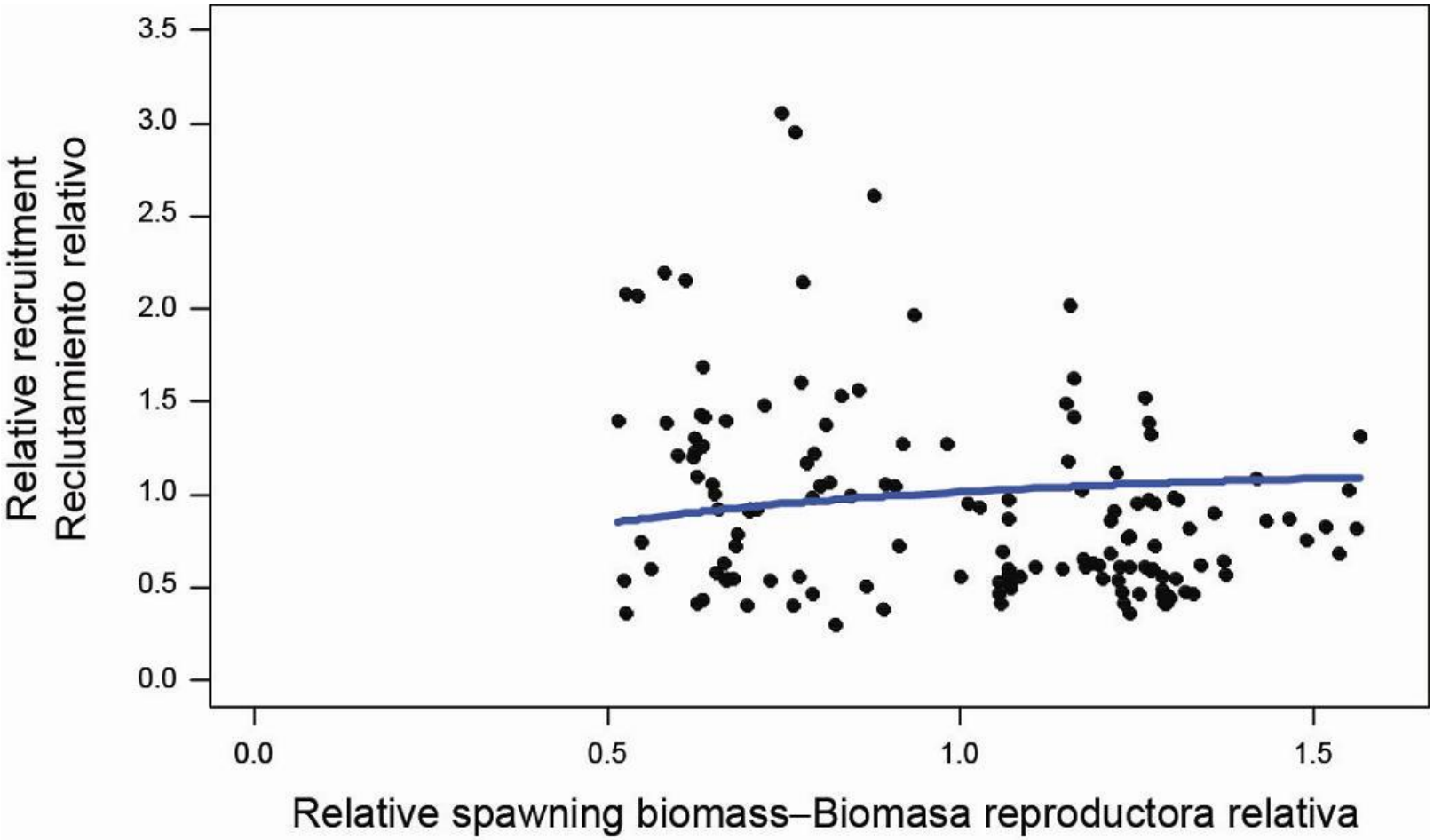
Sensitivity analyses

- Steepness of SR relationship (Appendix A)
- Average size of oldest fish L_2 (Appendix B)
- Adult natural mortality (Appendix C)
- Assessment with data from 1995-2009 only (Appendix D)

Spawner-recruitment curve

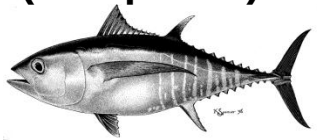
Sensitivities (Steepness)

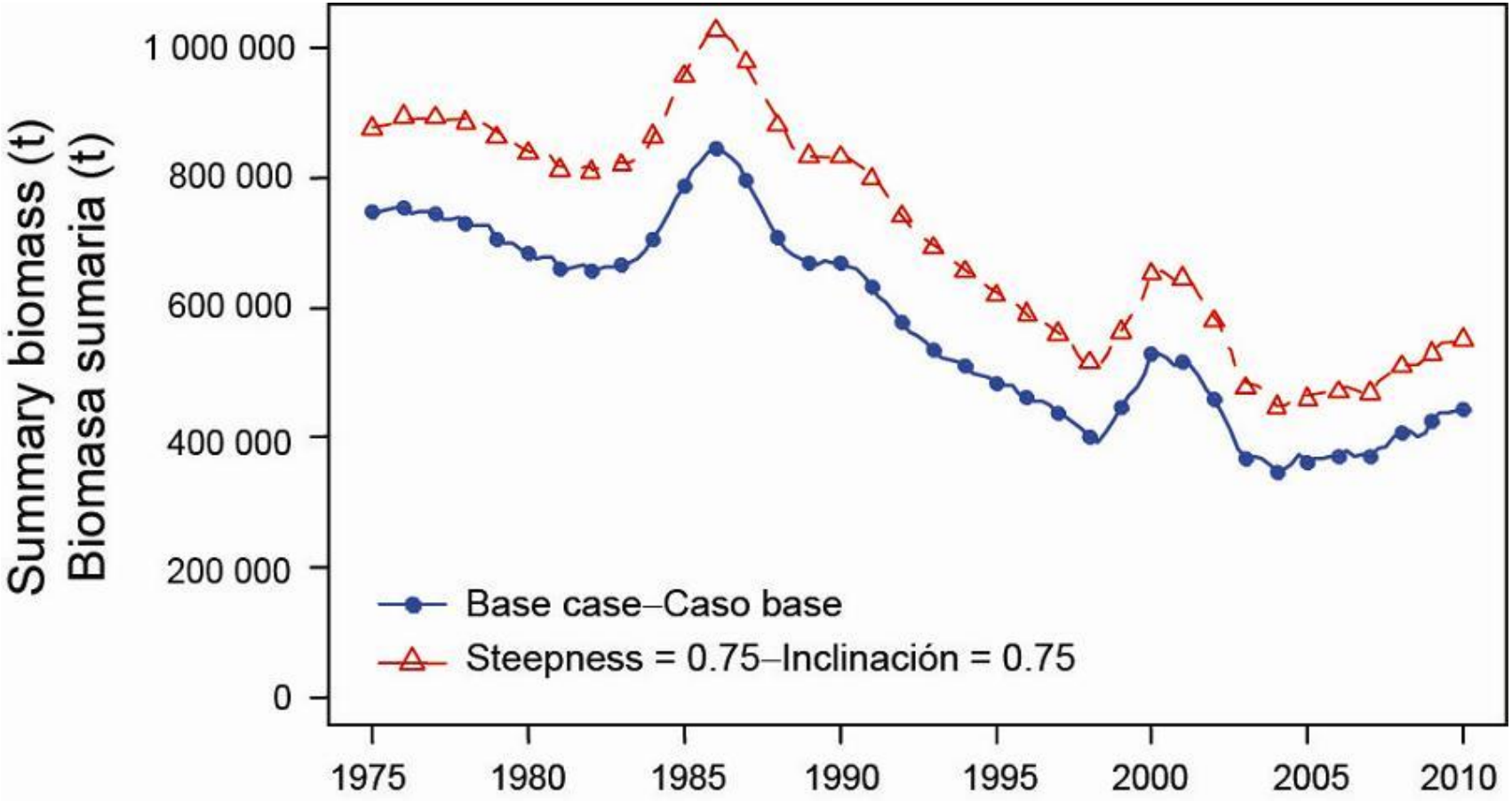




Summary biomass

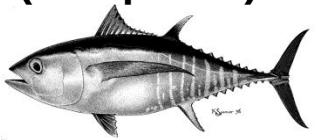
Sensitivities (Steepness)

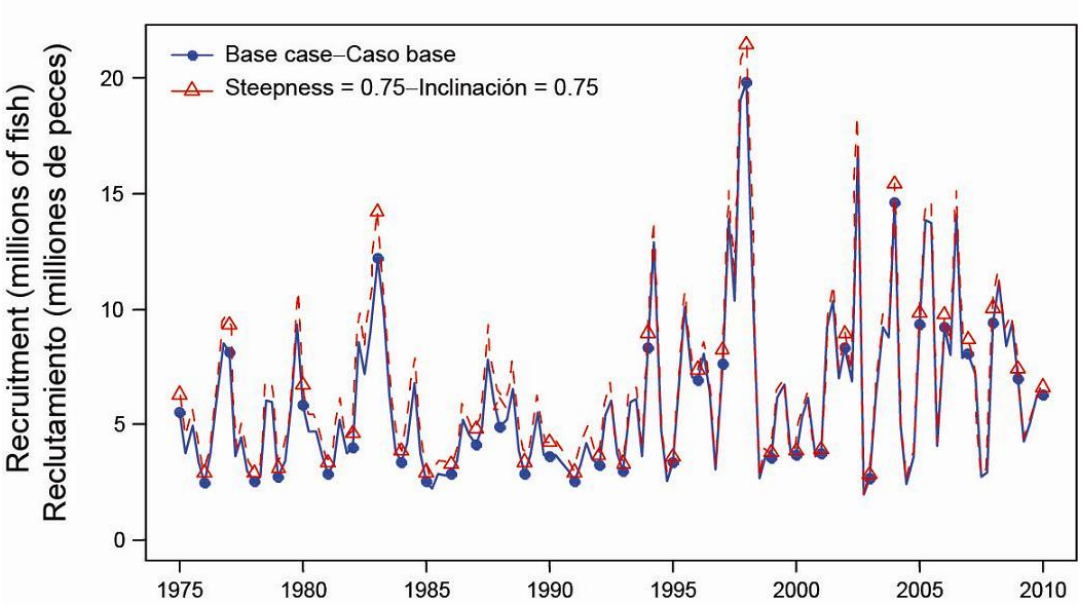


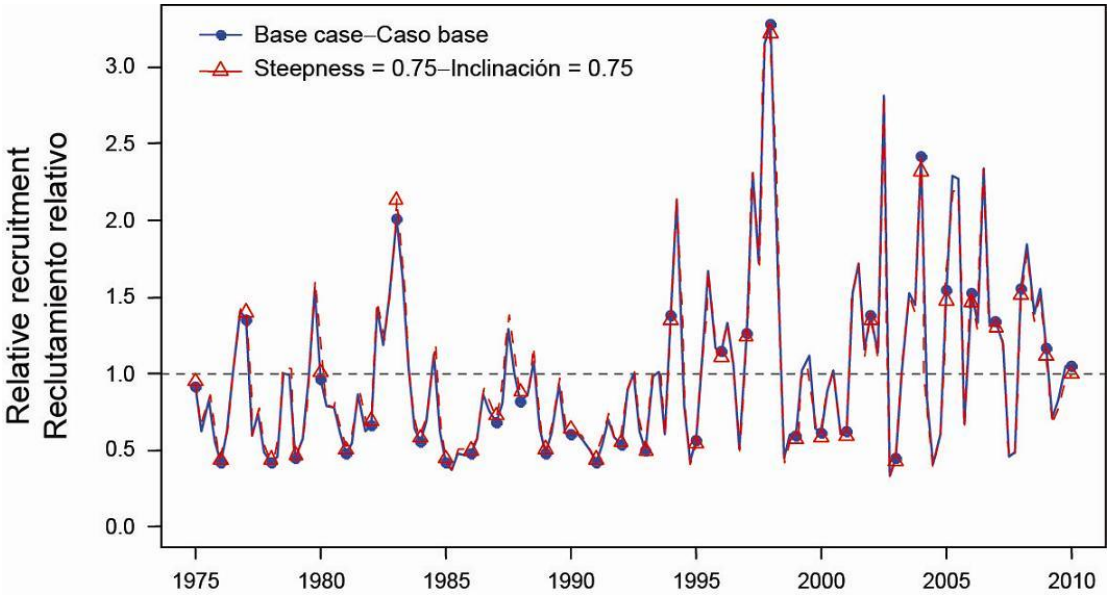


Recruitment

Sensitivities (Steepness)

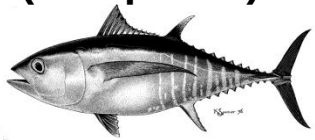


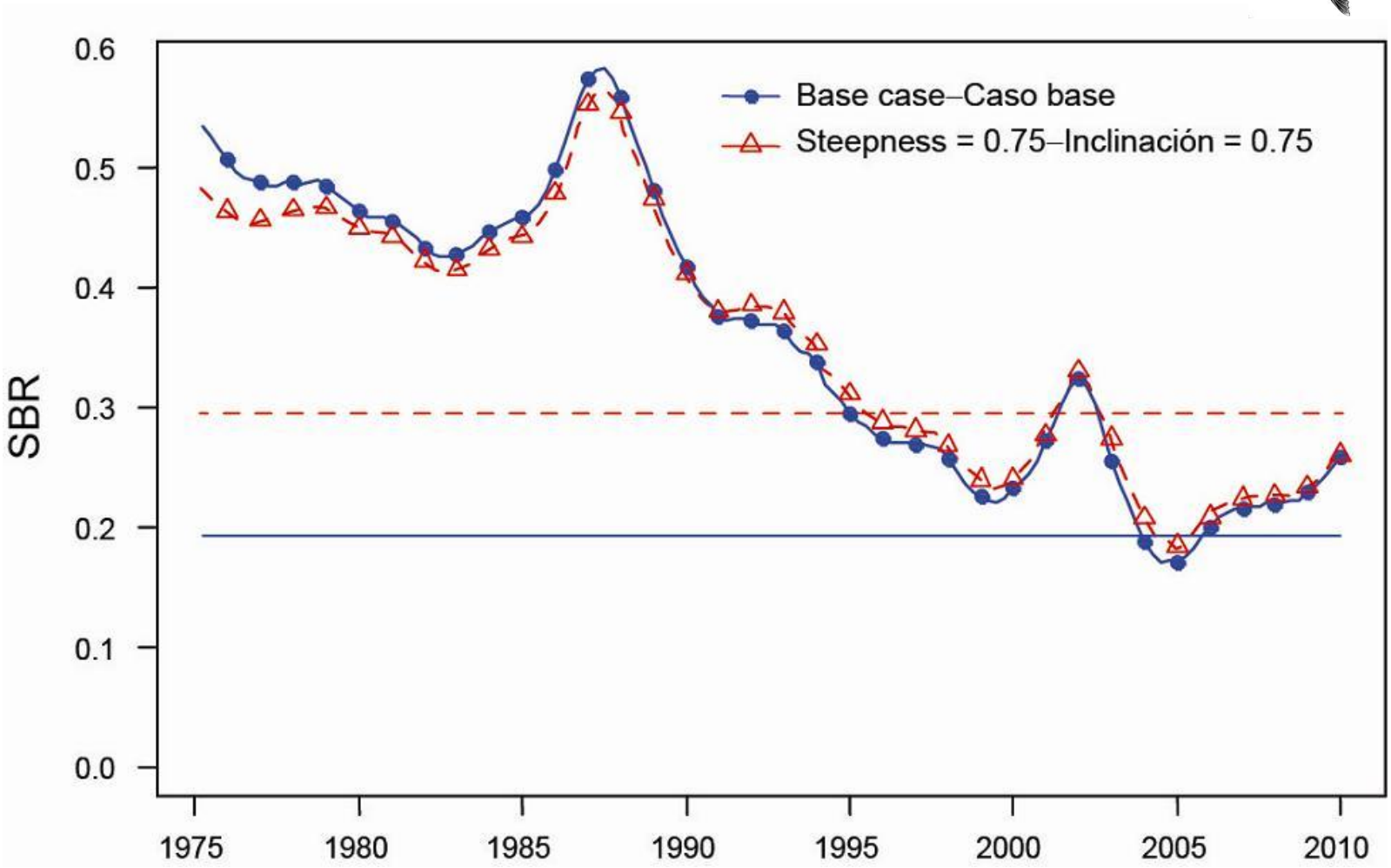




Spawning biomass ratio

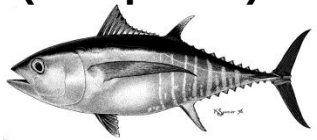
Sensitivities (Steepness)





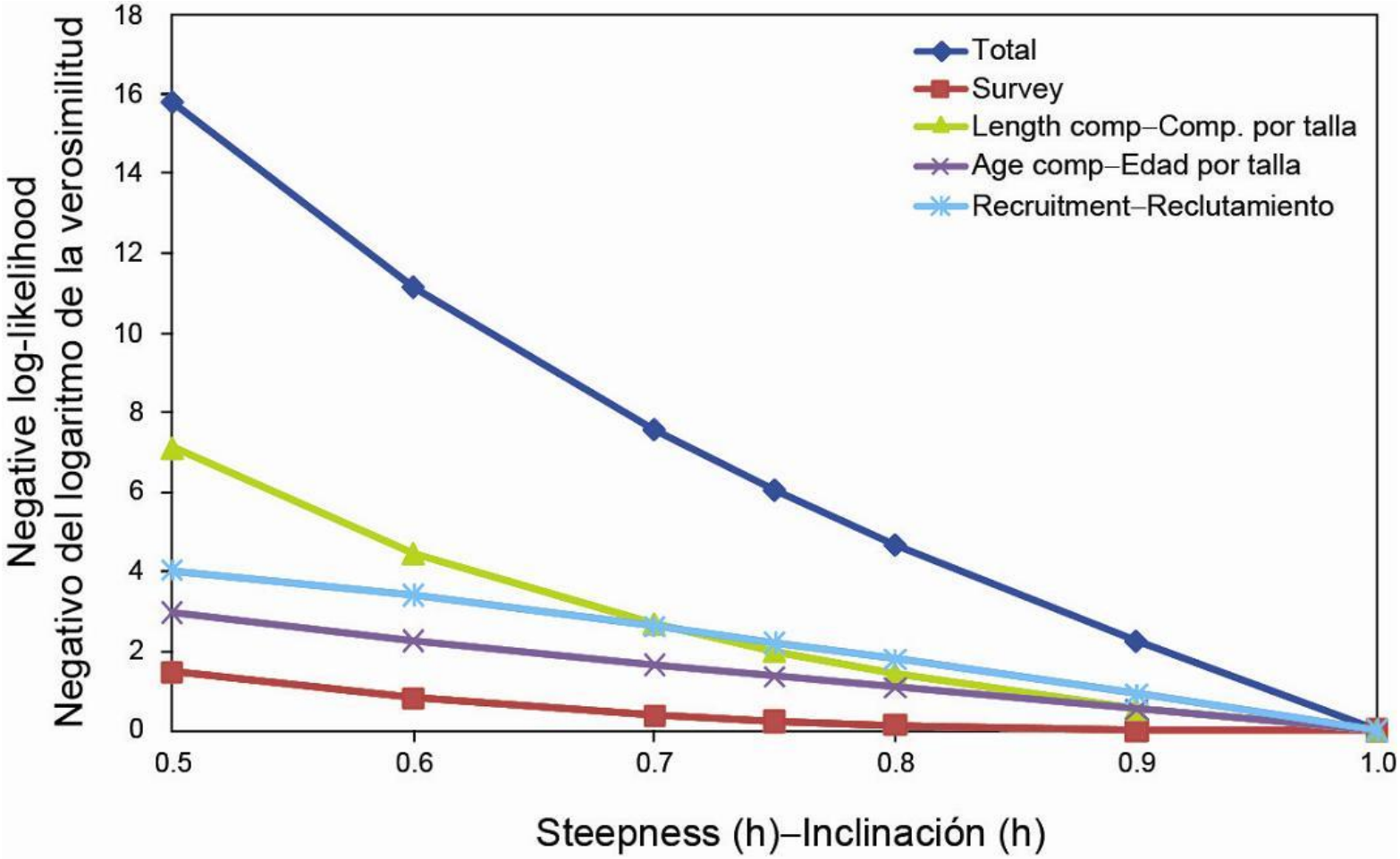
Management quantities

Sensitivities (Steepness)



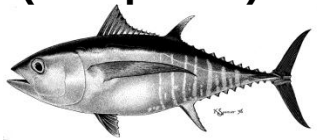
	Basecase	h = 0.75
MSY	90,538	86,321
Bmsy	332,331	582,233
Smsy	73,690	145,123
Bmsy/B0	0.25	0.34
Smsy/S0	0.19	0.30
Crecent/AMSY	1.17	1.23
Brecent/Bmsy	1.33	0.95
Srecent/Smsy	1.33	0.88
Fmultiplier	1.13	0.83

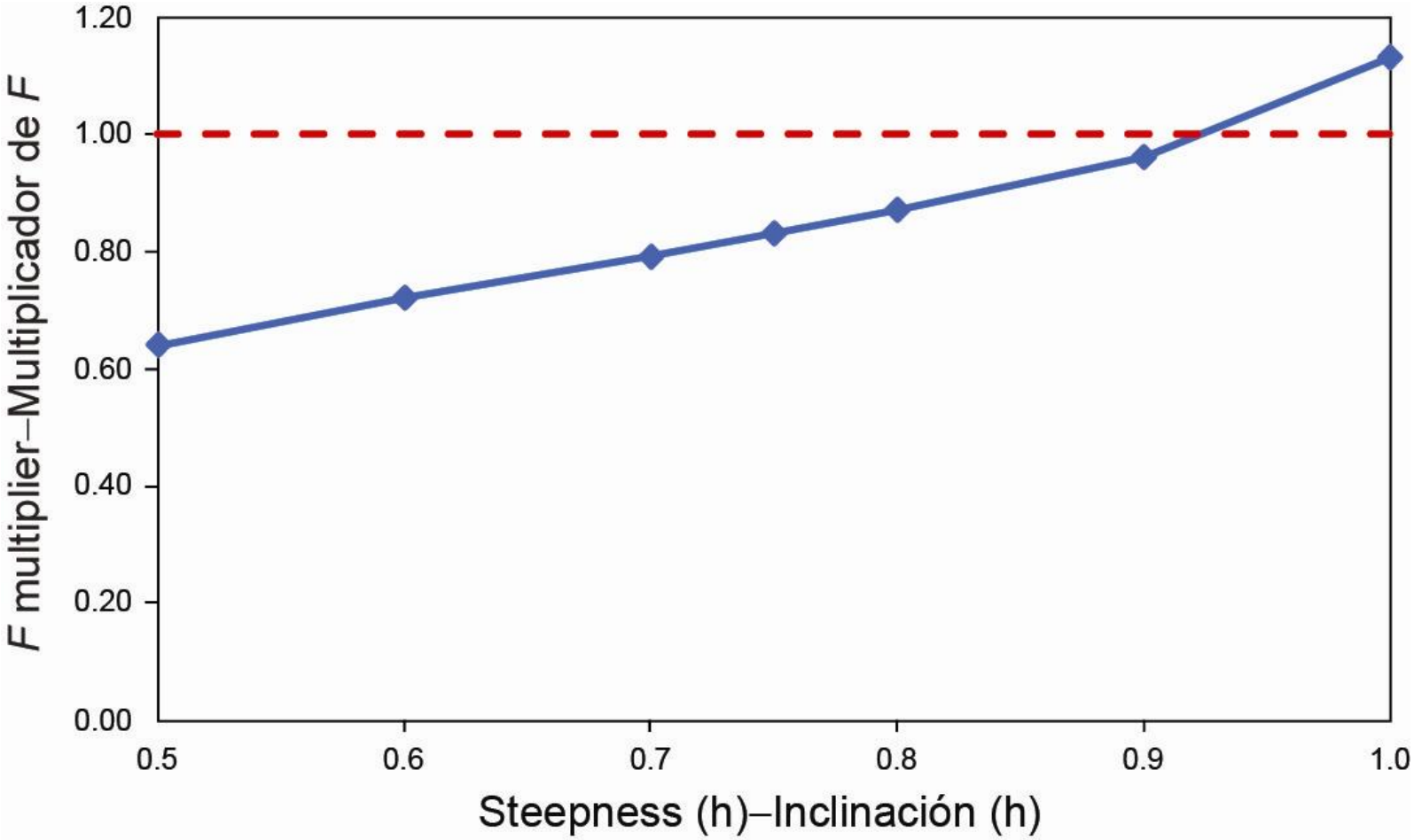
Likelihood profile on steepness

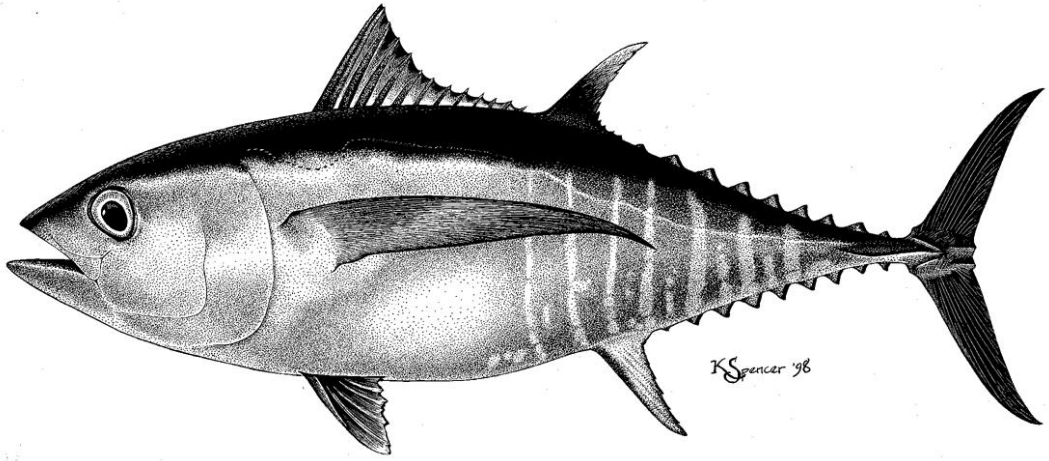


F multiplier and steepness

Sensitivities (Steepness)





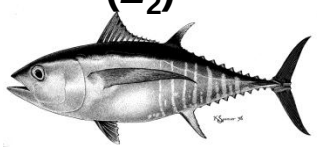


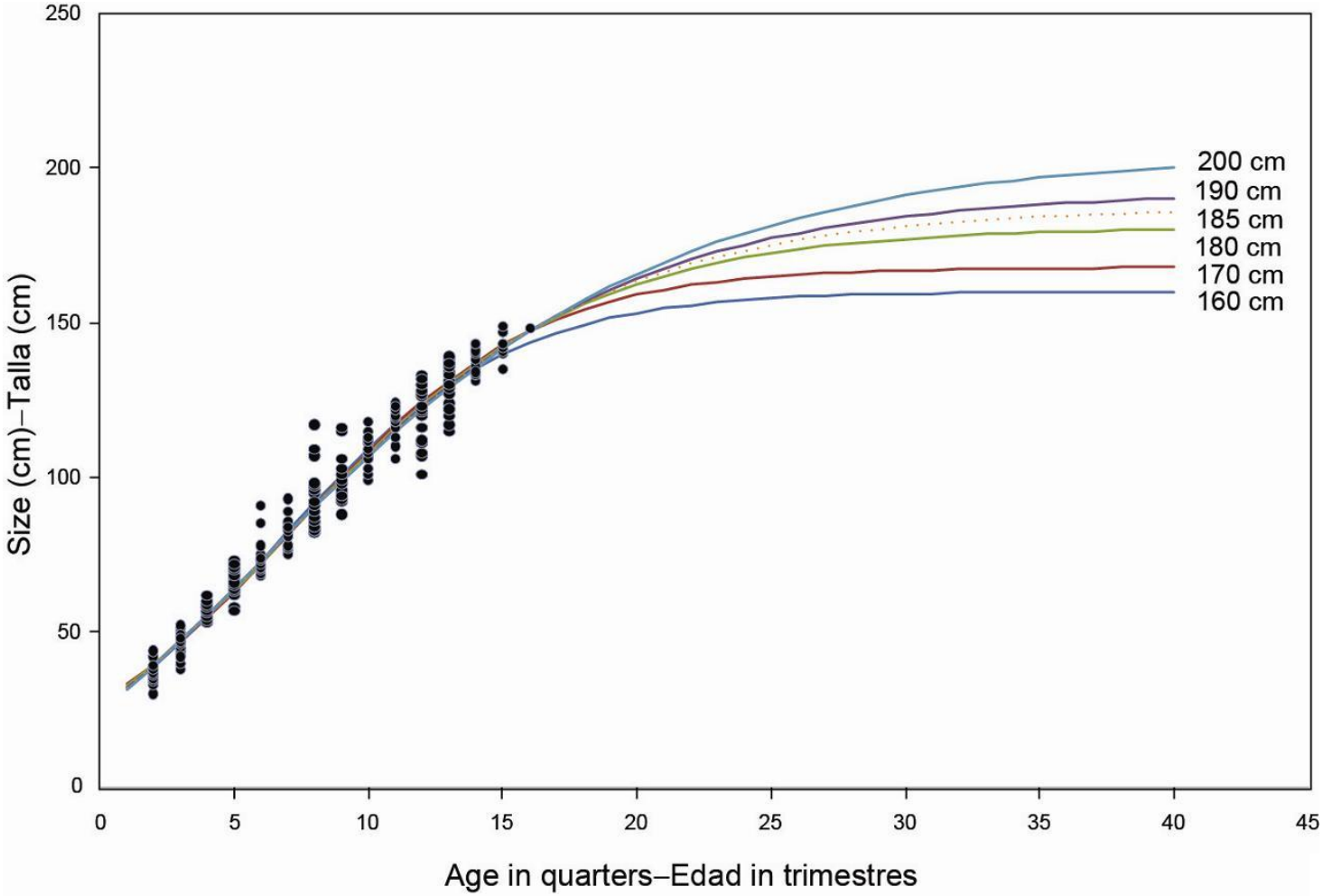
Sensitivity analyses

- Steepness of SR relationship (Appendix A)
- Average size of oldest fish L_2 (Appendix B)
- Adult natural mortality (Appendix C)
- Assessment with data only from 1995-2009 (Appendix D)

Richards growth curve

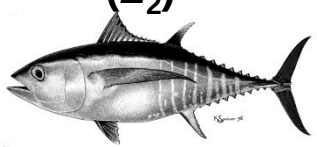
Sensitivities (L_2)

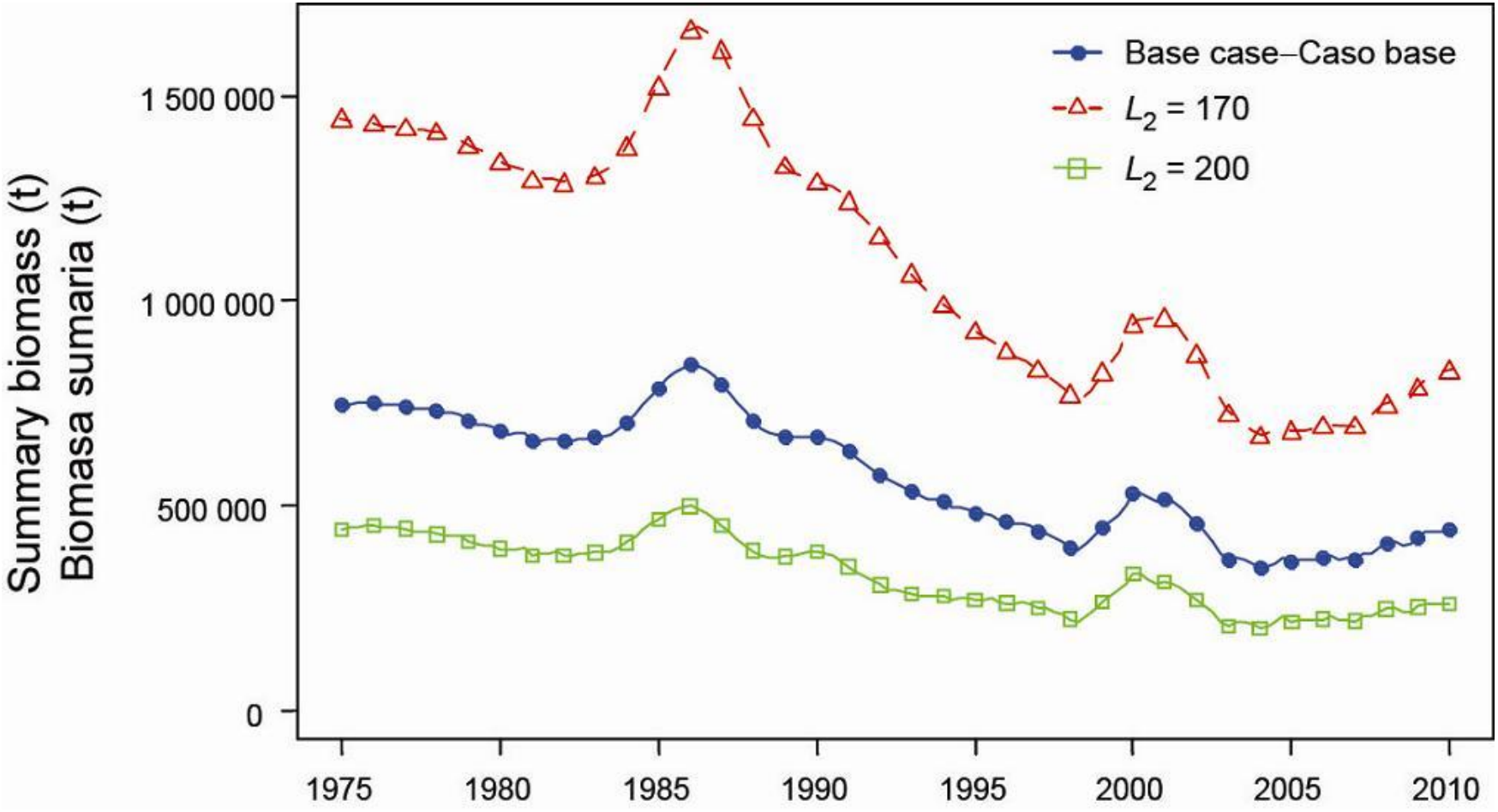




Summary biomass

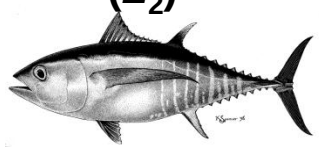
Sensitivities (L_2)

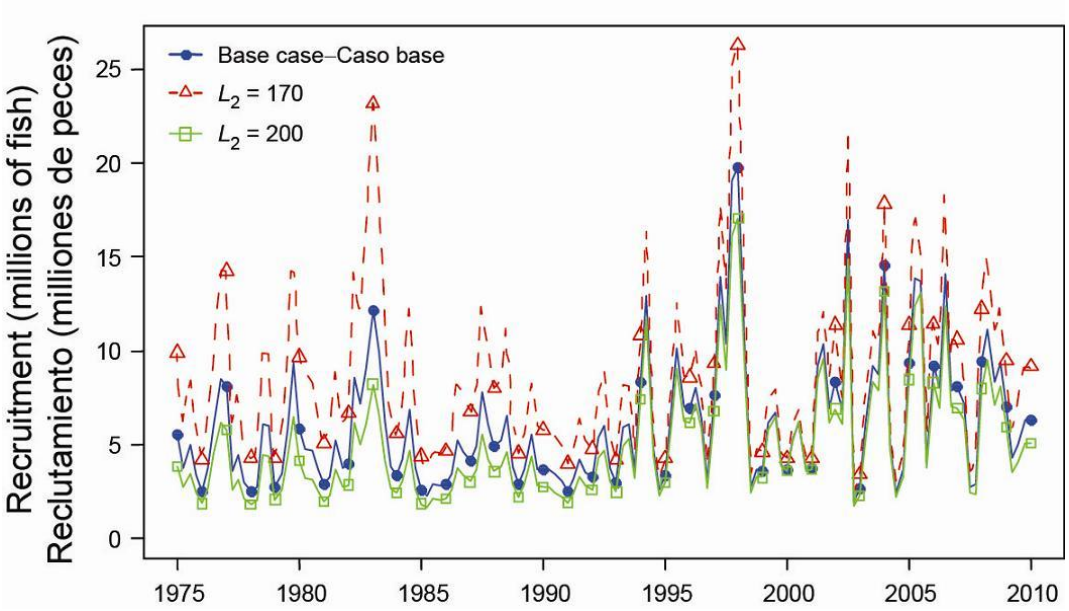


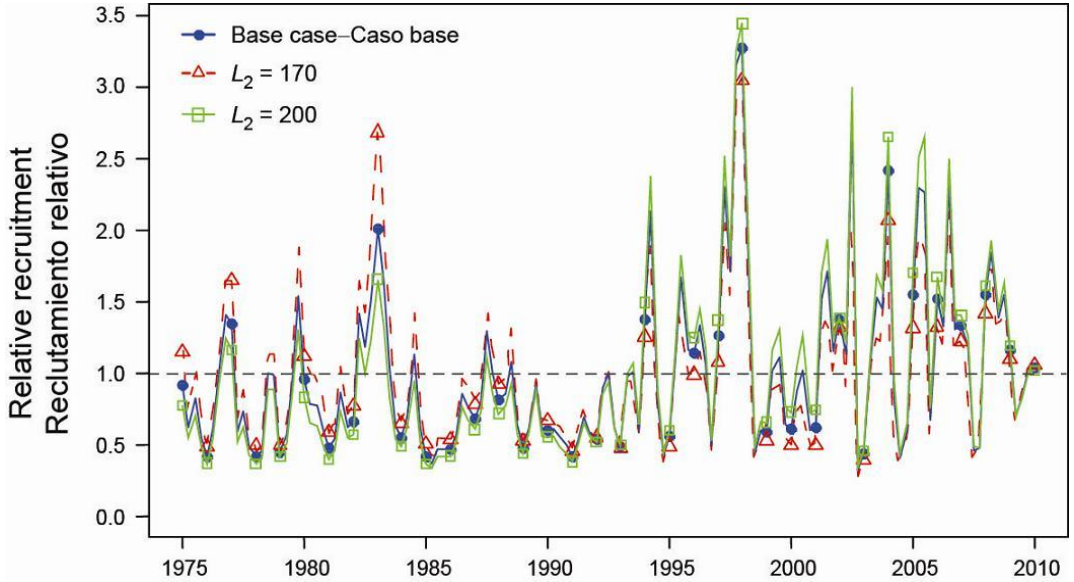


Recruitment

Sensitivities (L_2)

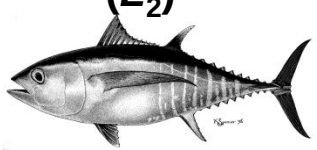


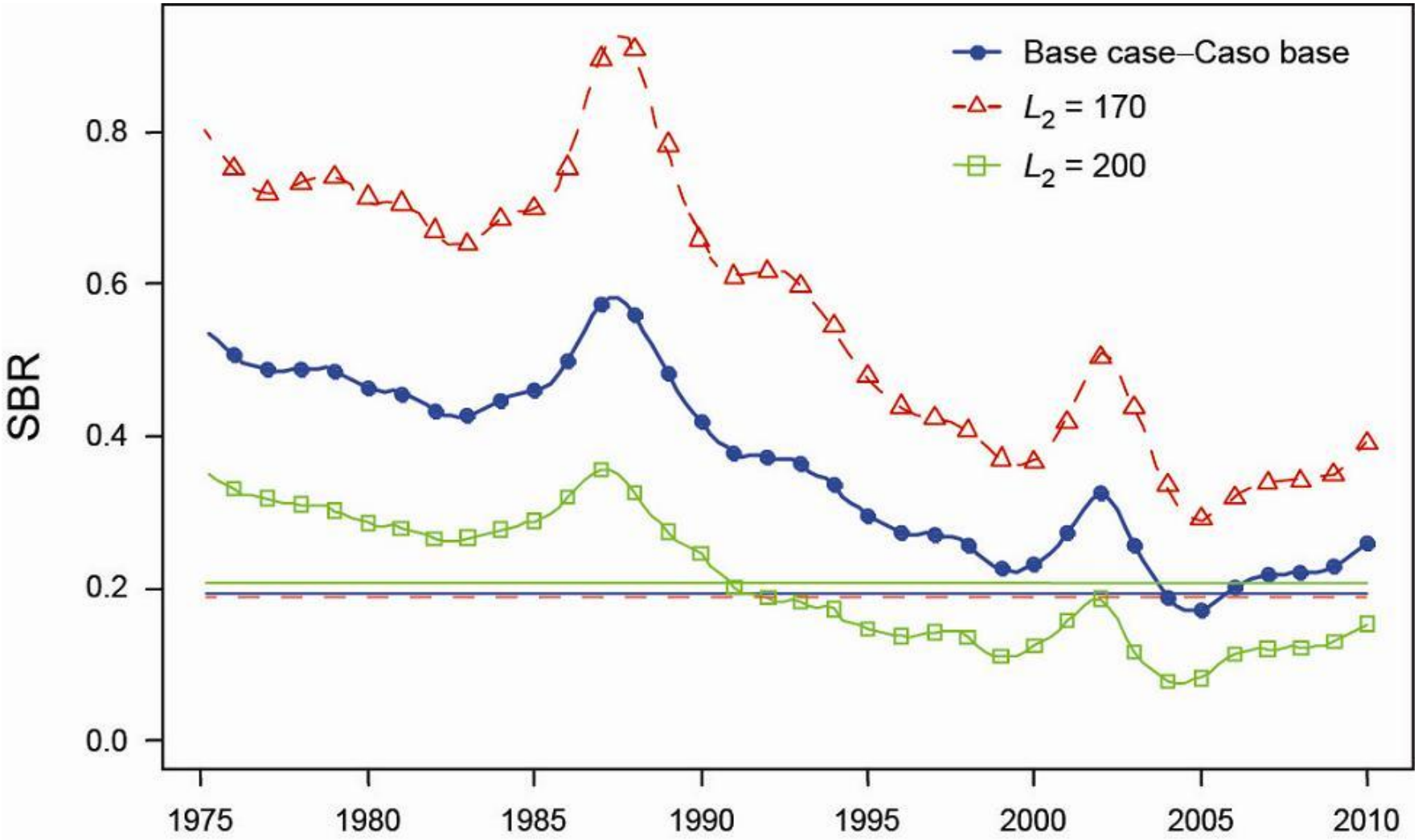




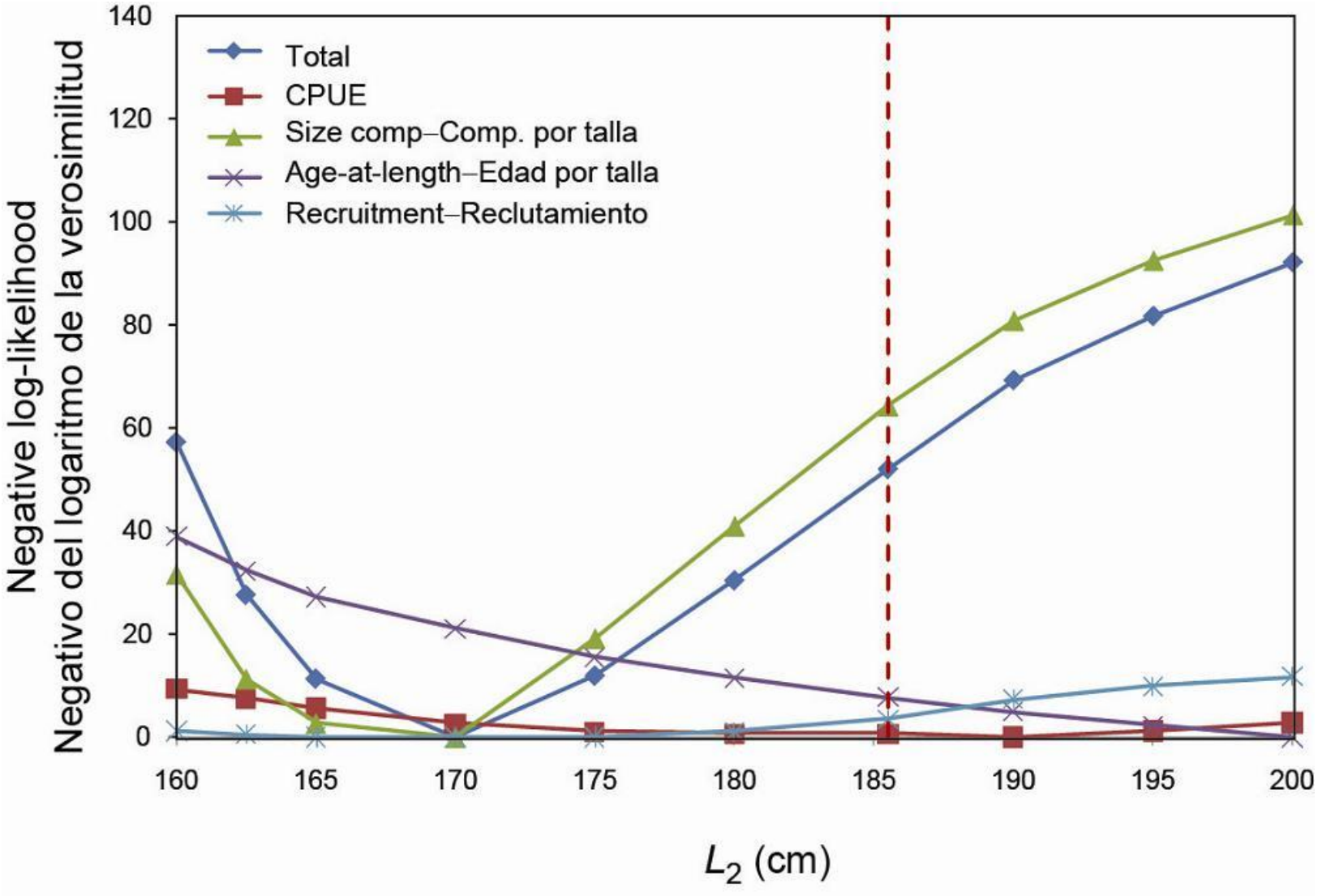
Spawning biomass ratio

Sensitivities (L_2)

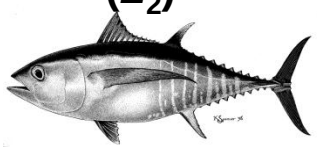


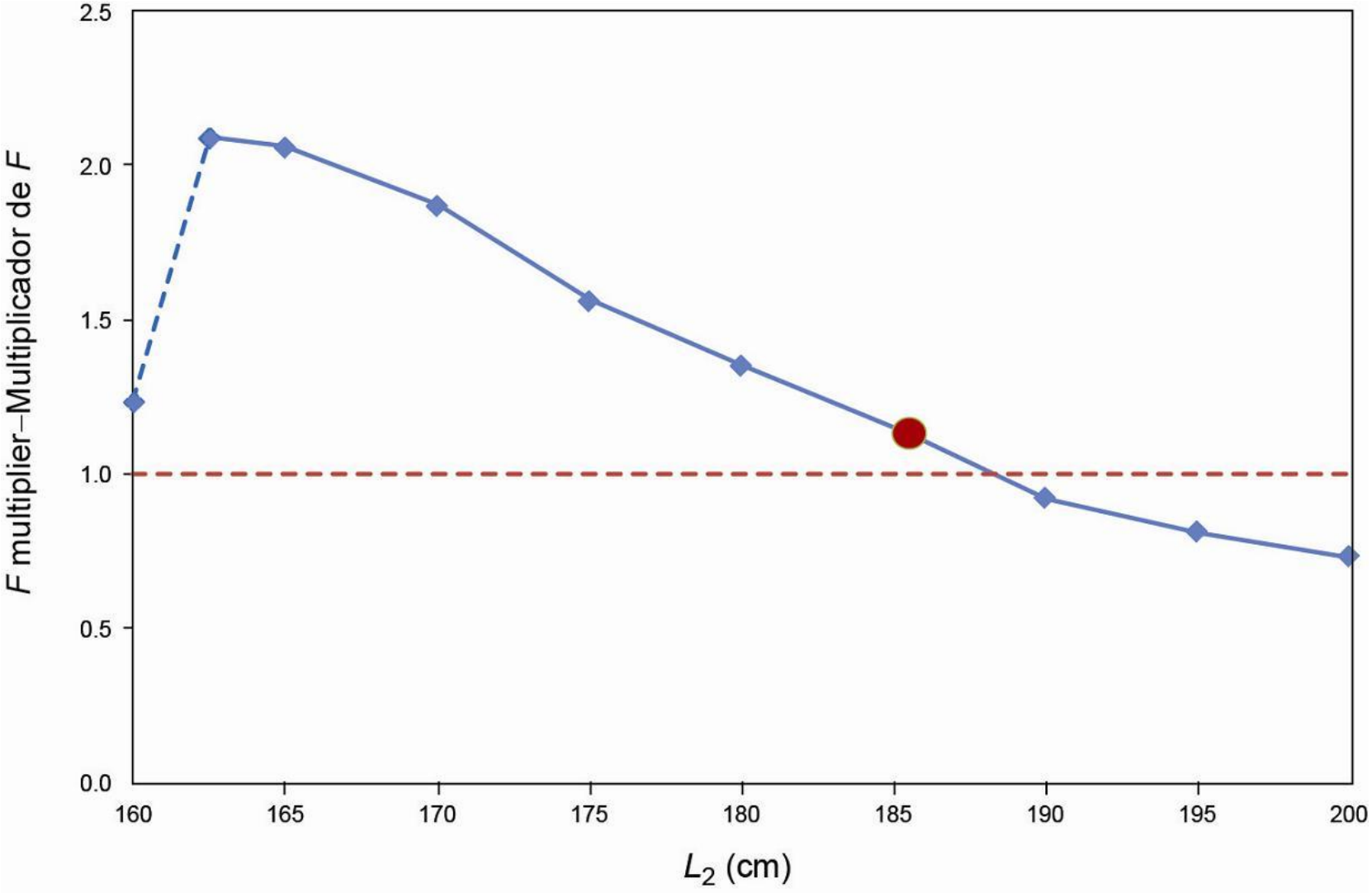


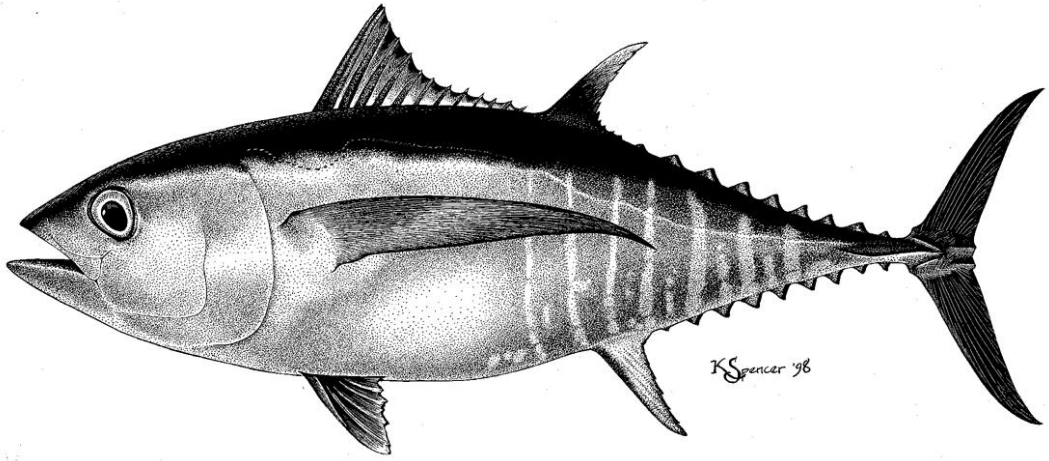
Likelihood profile on L_2



Fmultiplier and L_2







Sensitivity analyses

- Steepness of SR relationship (Appendix A)
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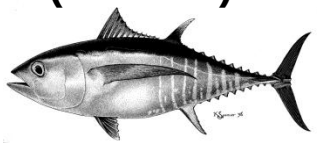
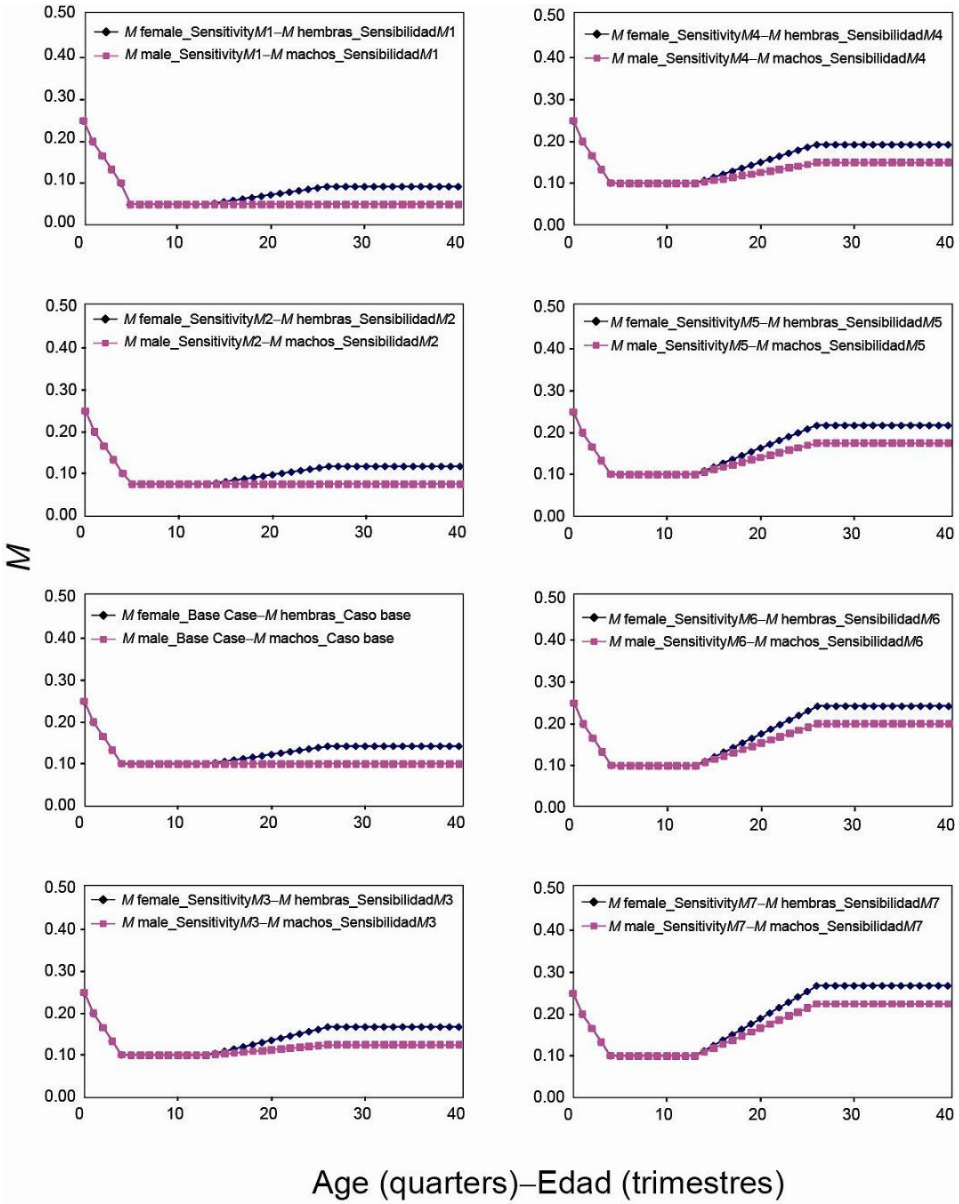
- Assessment with data only from 1995-2009 (Appendix D)

Natural mortality M schedules

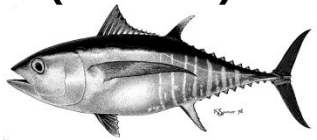
Sensitivities (Adult *M*)

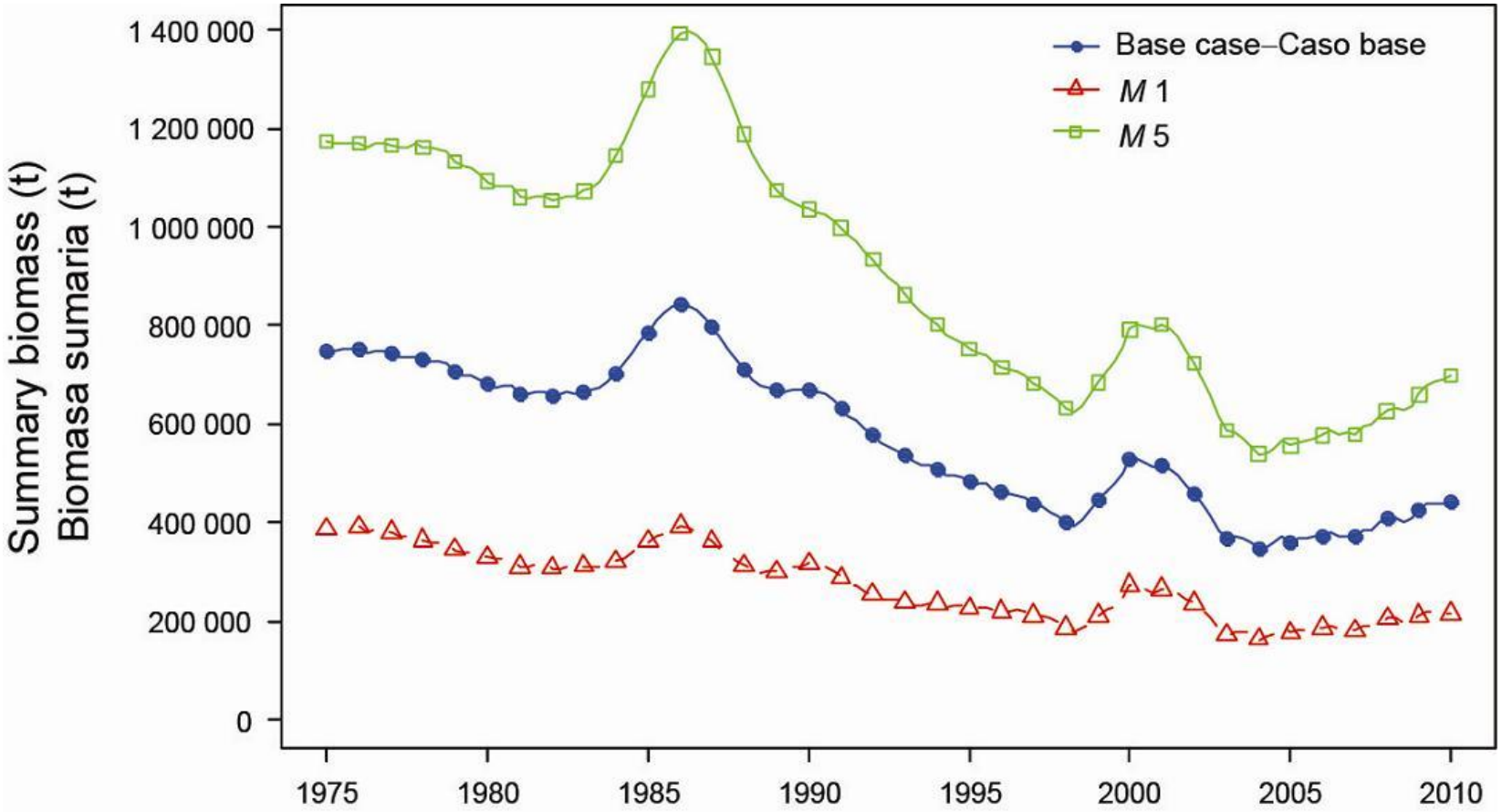




Summary biomass

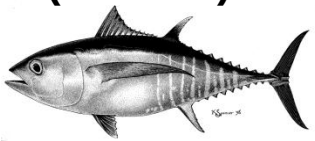
Sensitivities (Adult *M*)

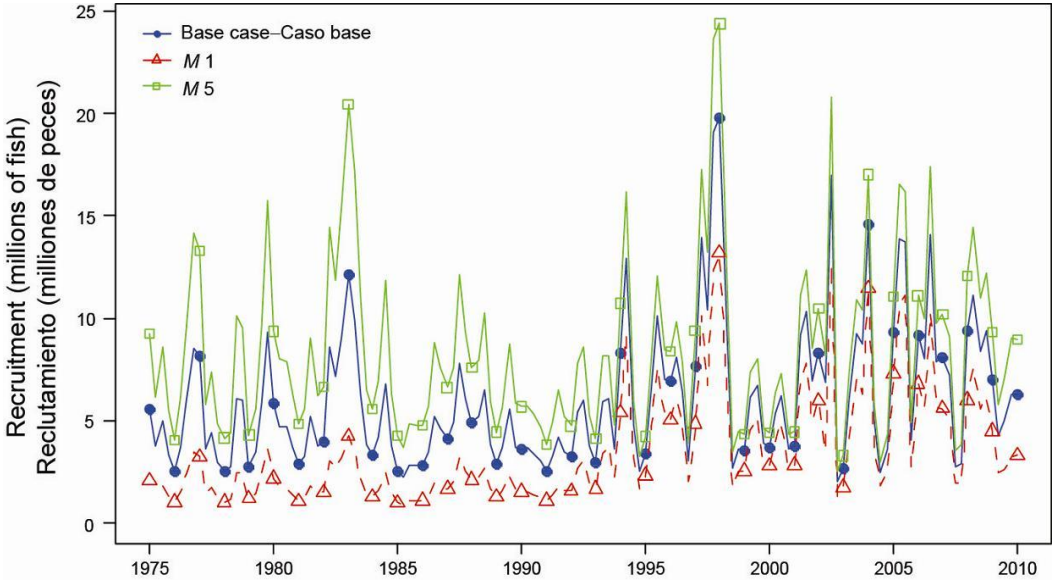


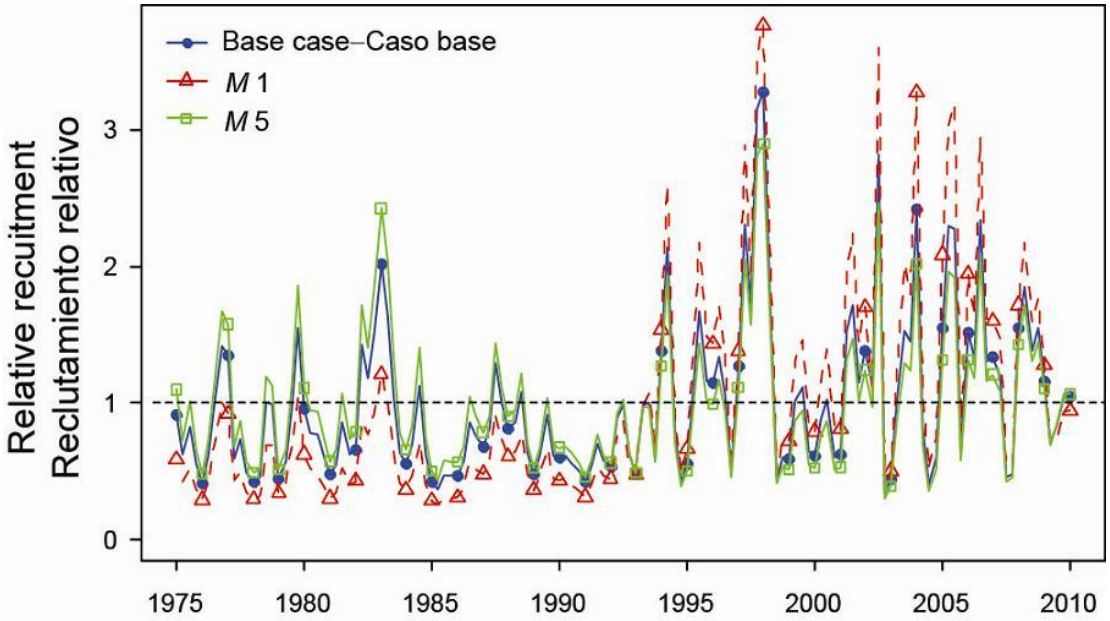


Recruitment

Sensitivities (Adult *M*)

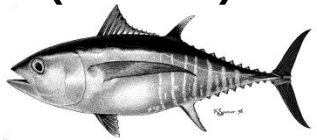


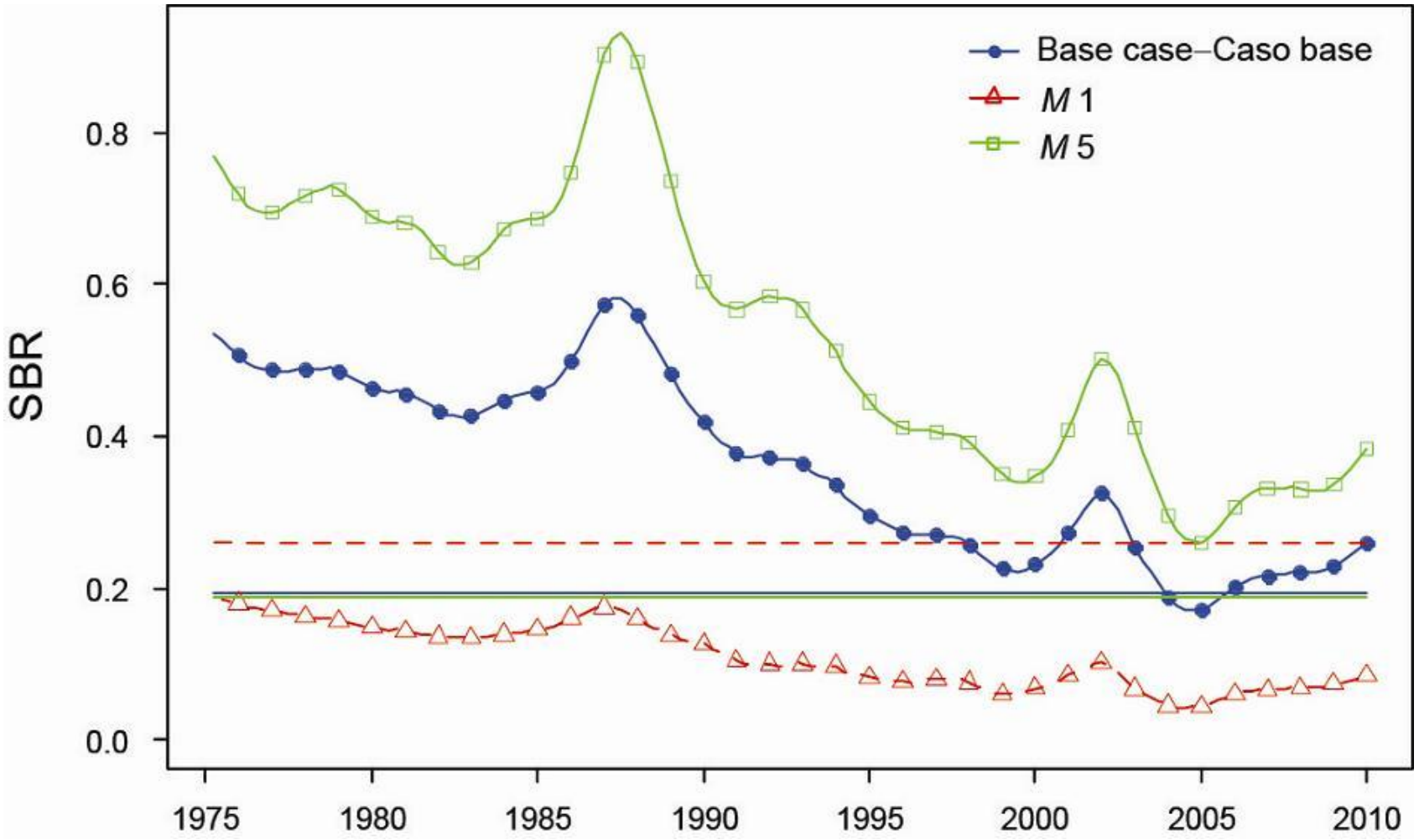




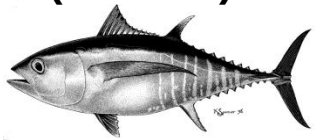
Spawning biomass ratio

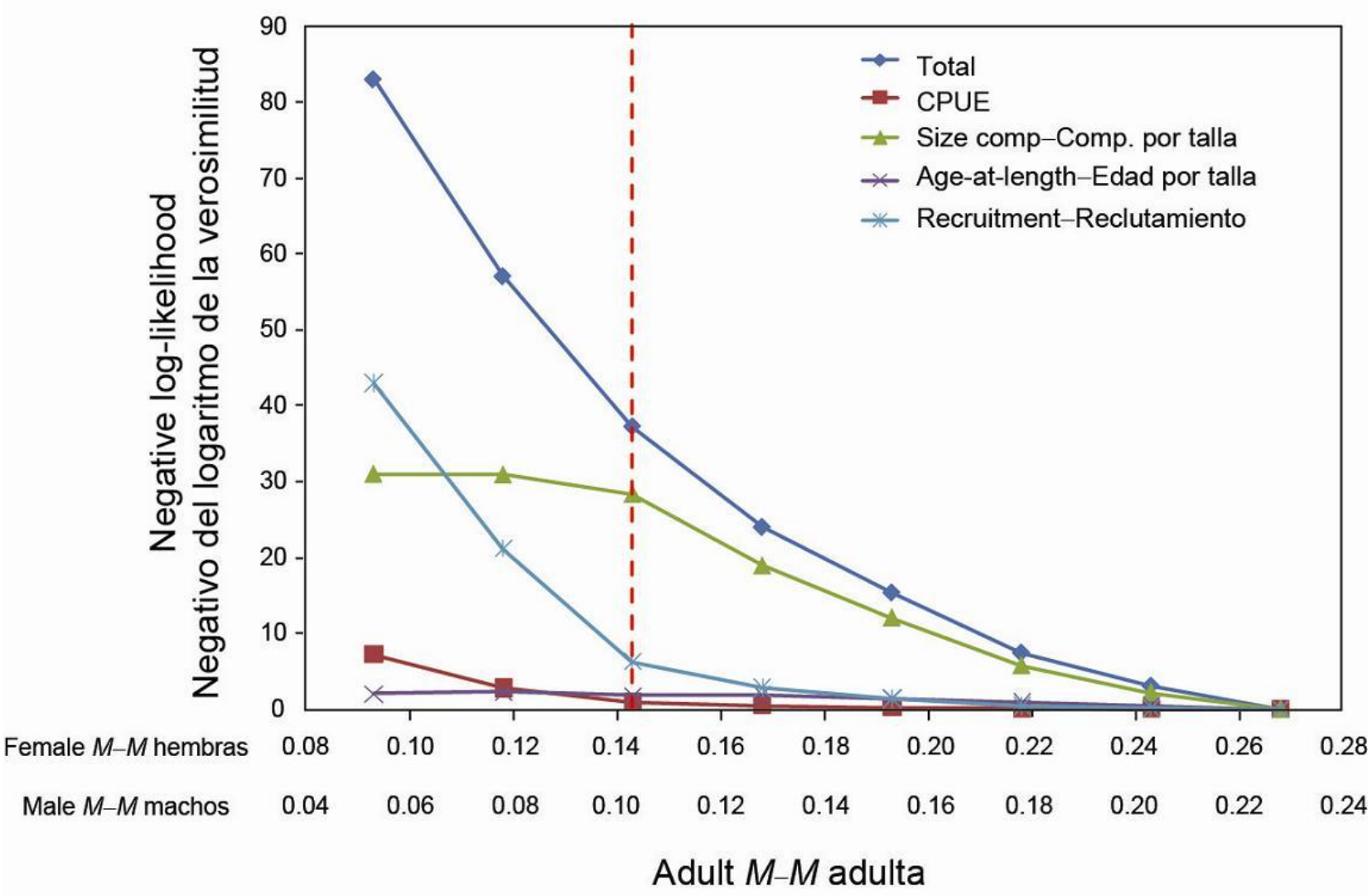
Sensitivities (Adult *M*)





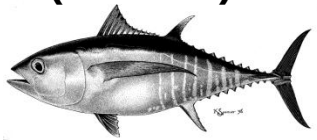
Likelihood profile on adult *M*

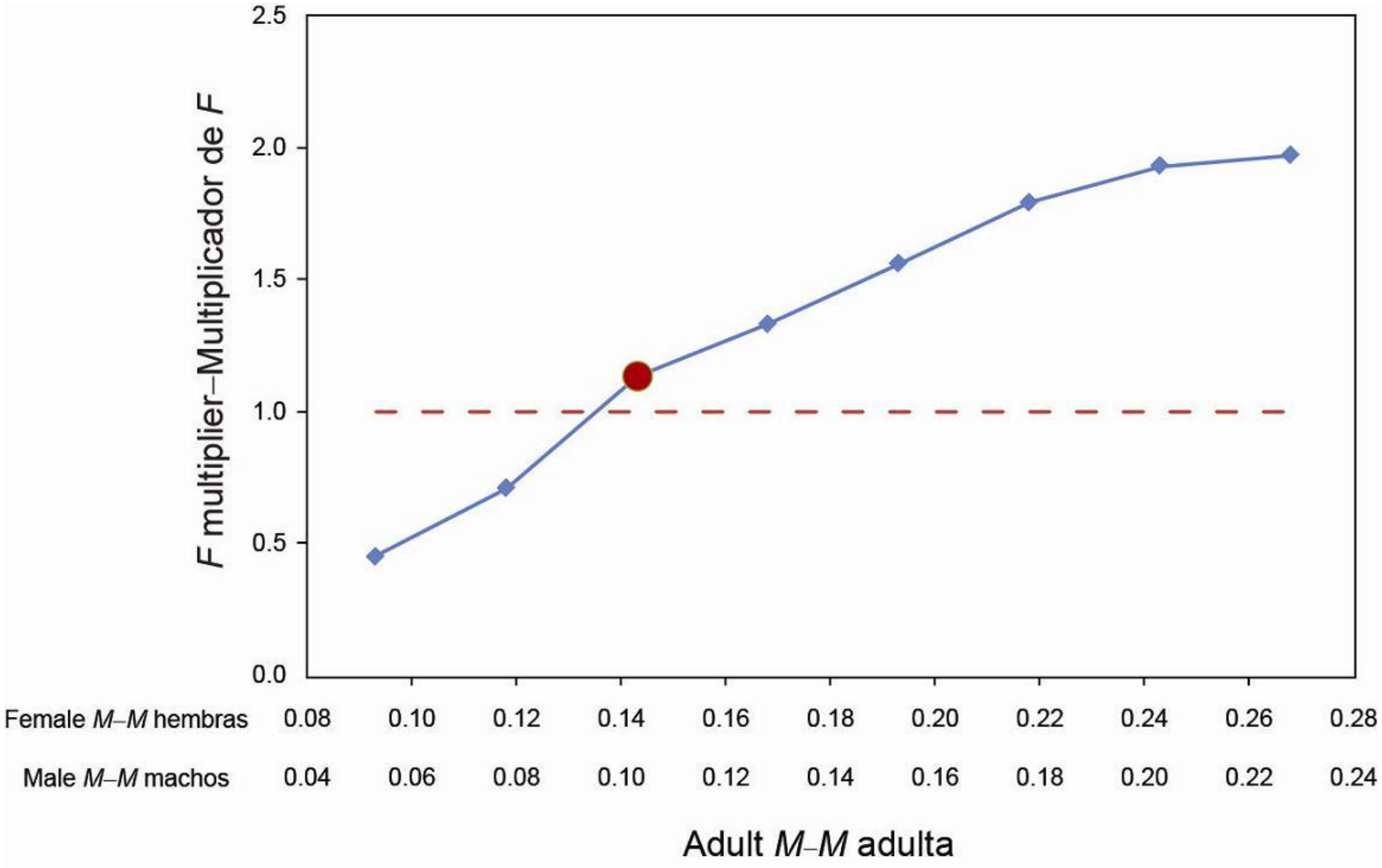


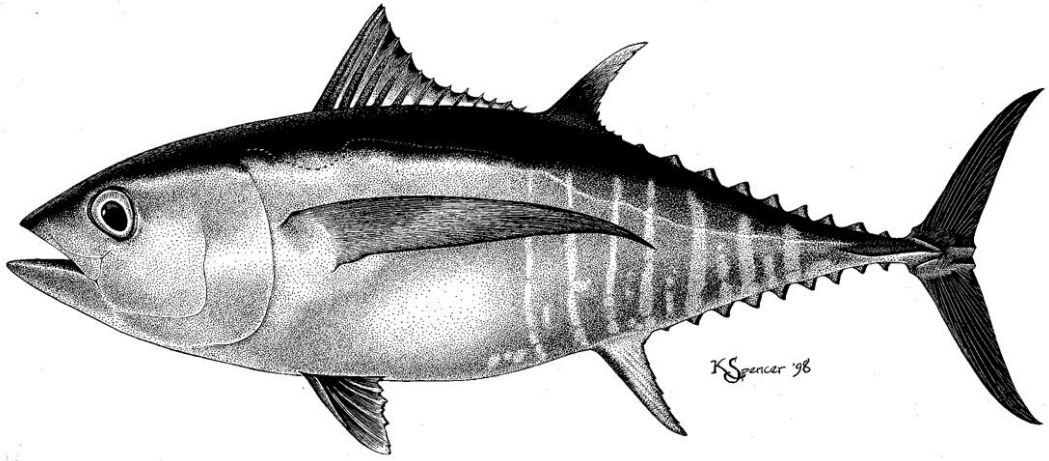


F multiplier on adult *M*

Sensitivities (Adult *M*)





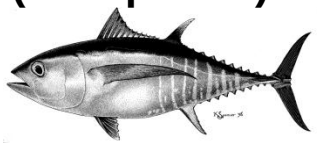


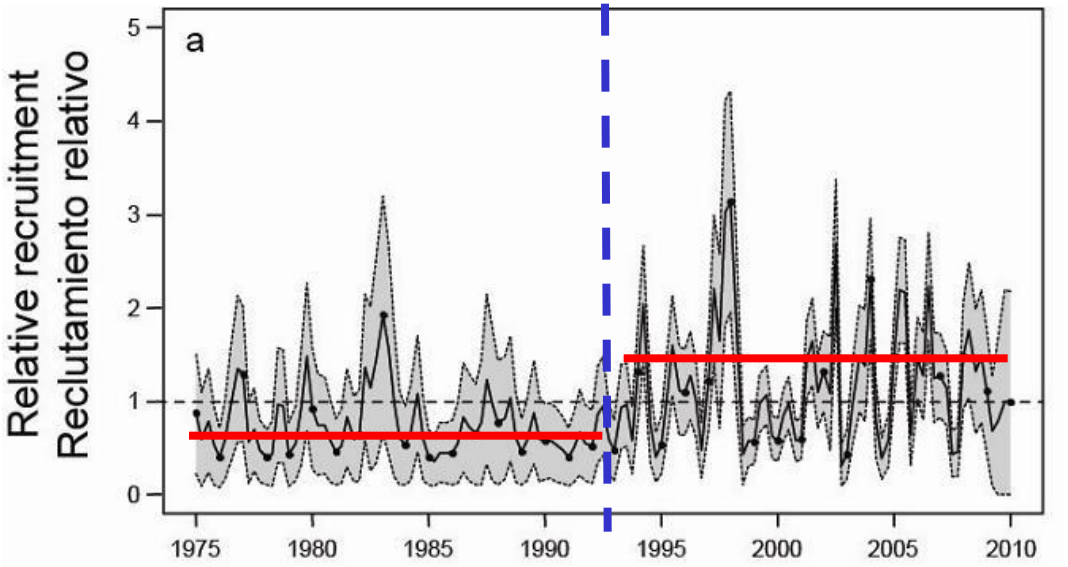
Sensitivity analyses

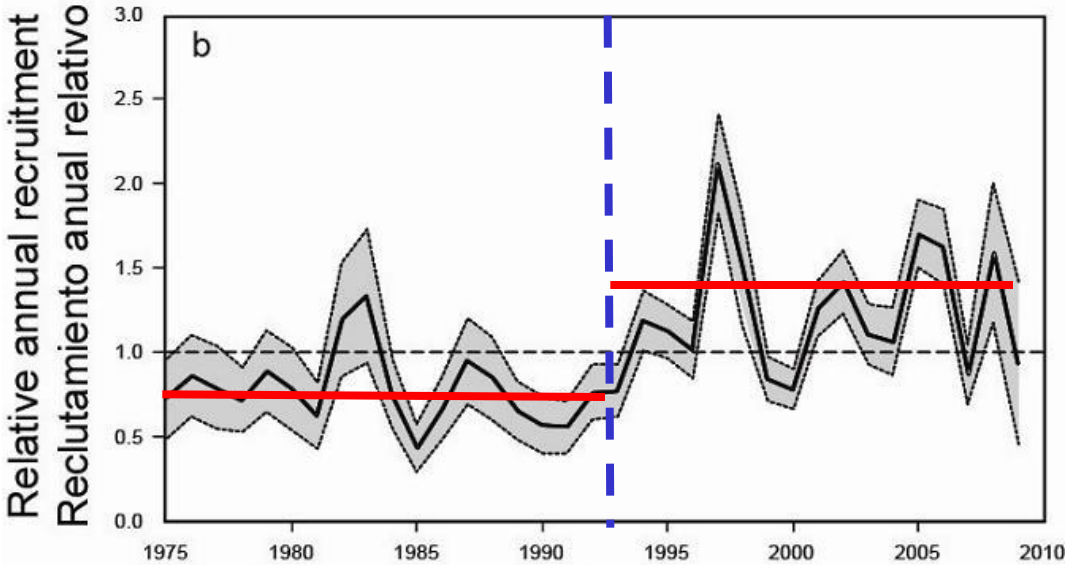
- Steepness of SR relationship (Appendix A)
- Average size of oldest fish L_2 (Appendix B)
- Adult natural mortality (Appendix C)
- Assessment with data only from 1995-2009 (Appendix D)

Increasing recruitments?

Sensitivities (Late period)

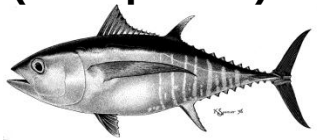


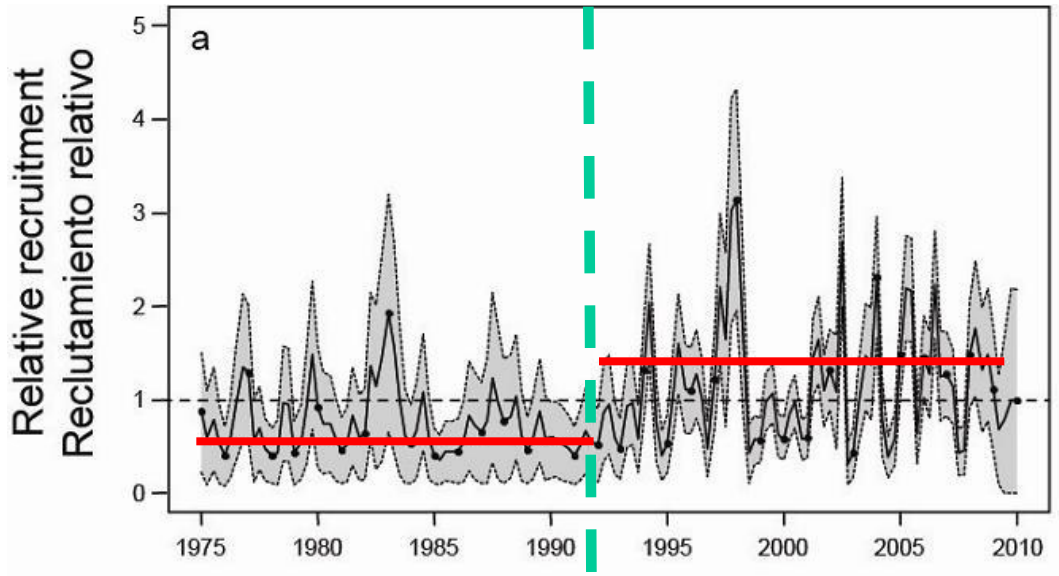


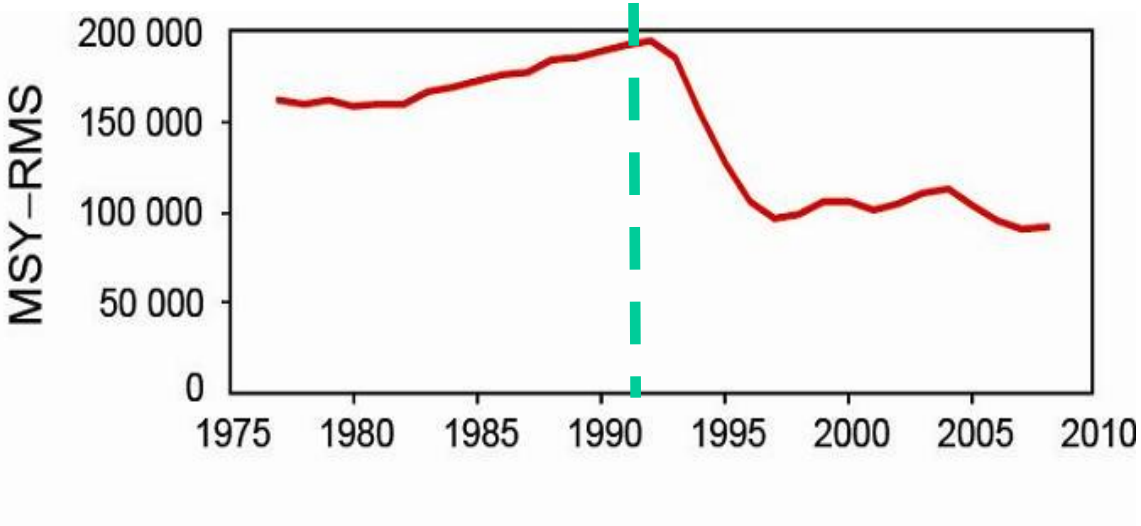


Alternative approach

Sensitivities (Late period)



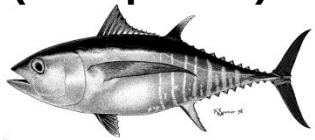


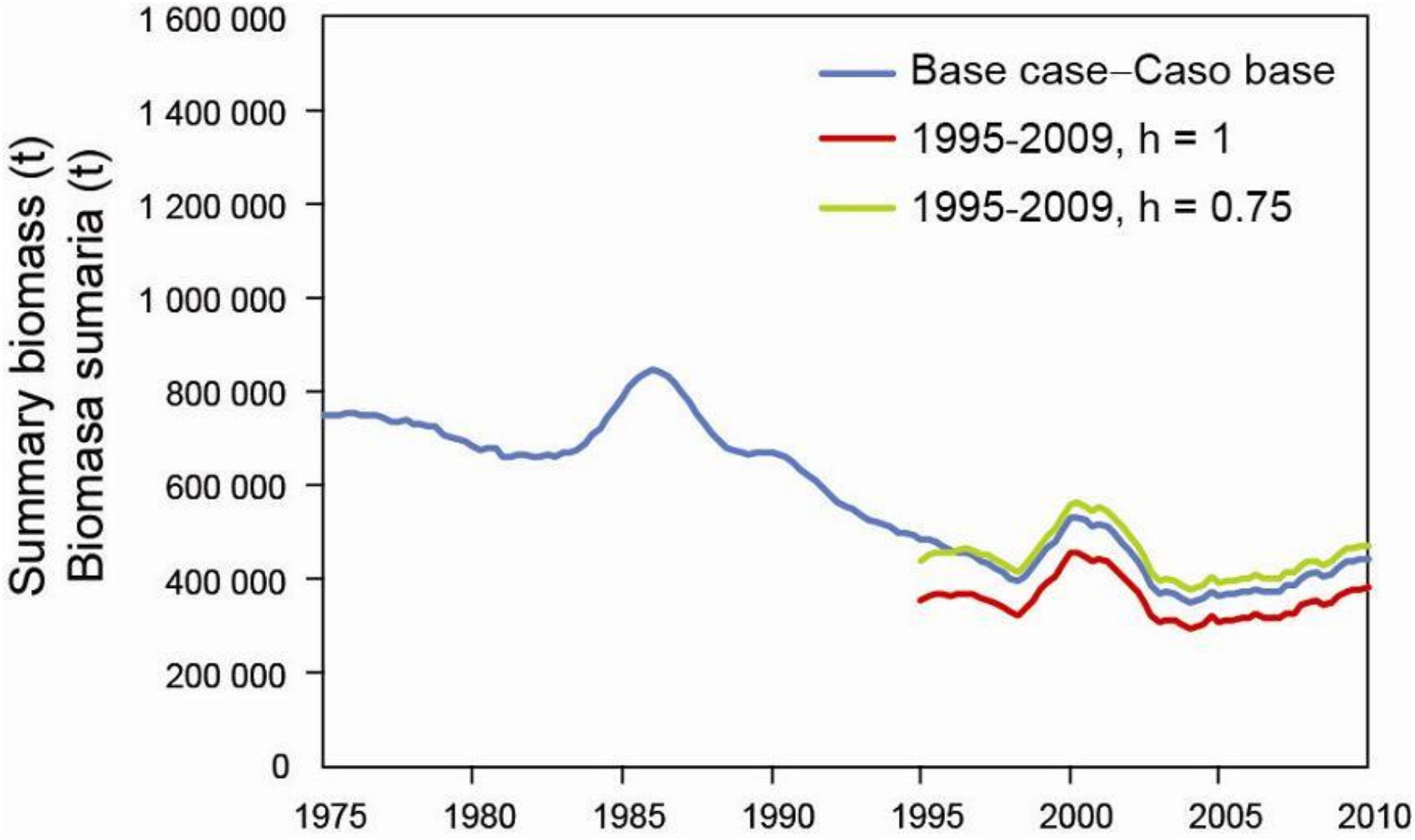


- Use data from 1994-2008 only (best reflective of the current fishery)

Summary biomass

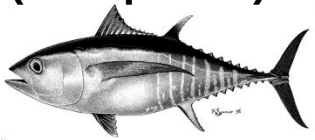
Sensitivities (Late period)

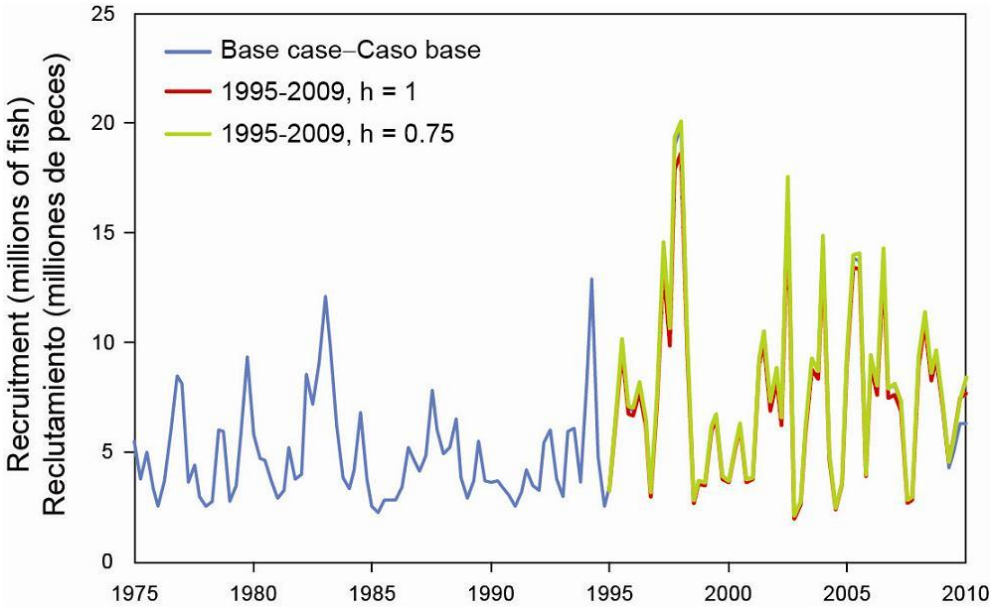


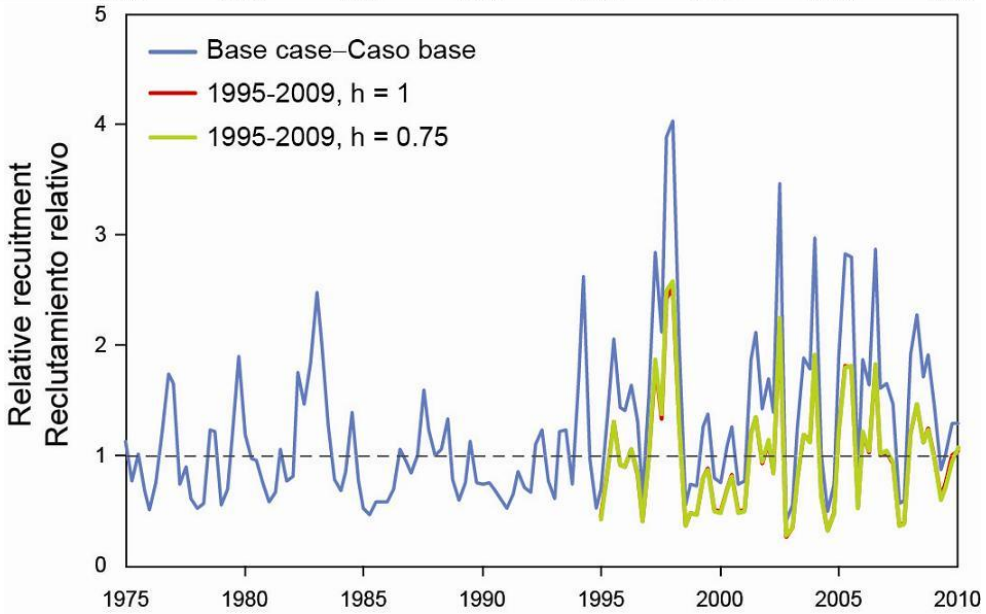


Recruitment

Sensitivities (Late period)

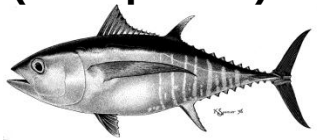


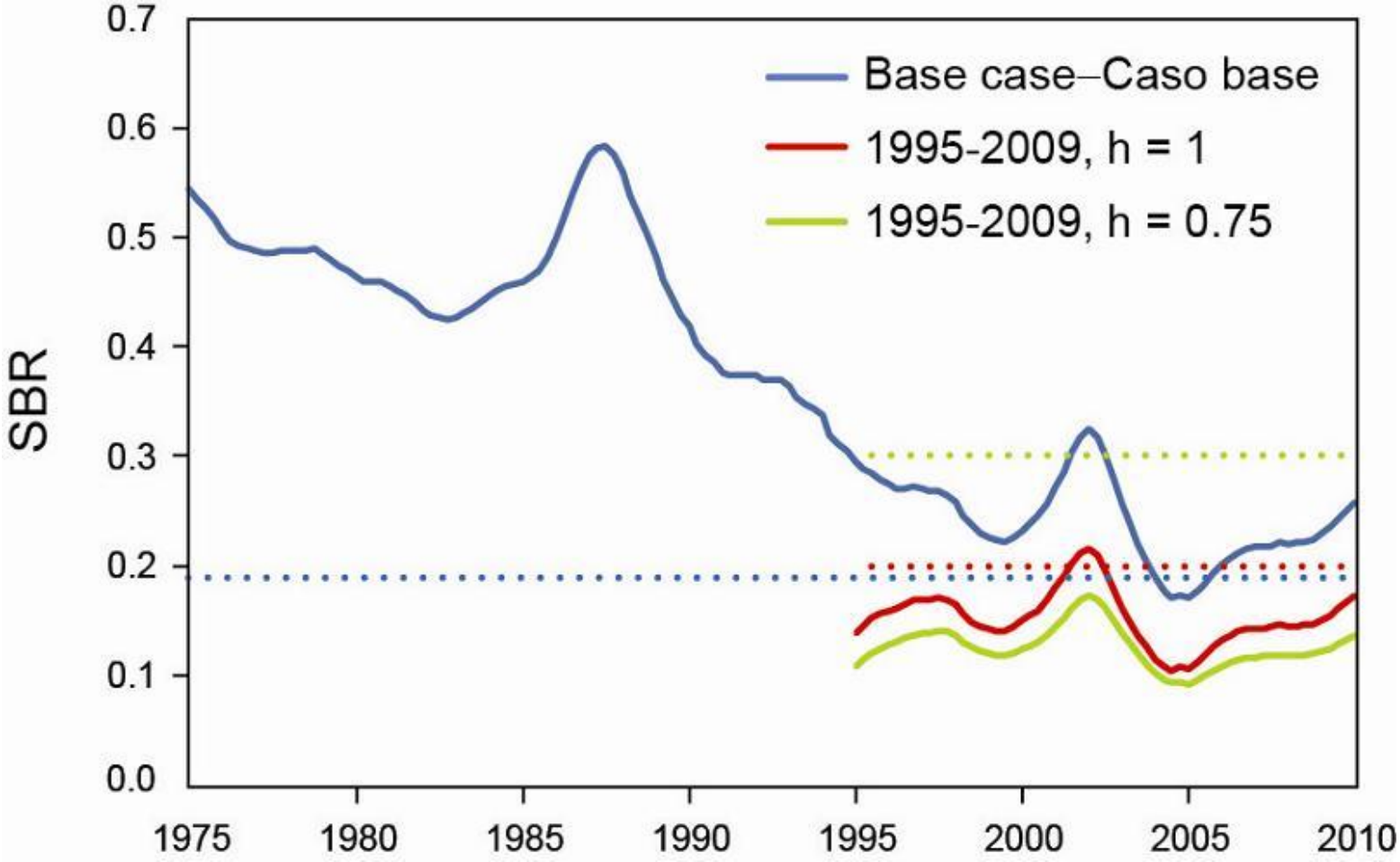




Spawning biomass ratio

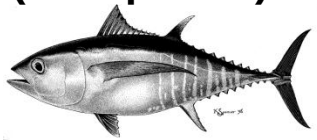
Sensitivities (Late period)





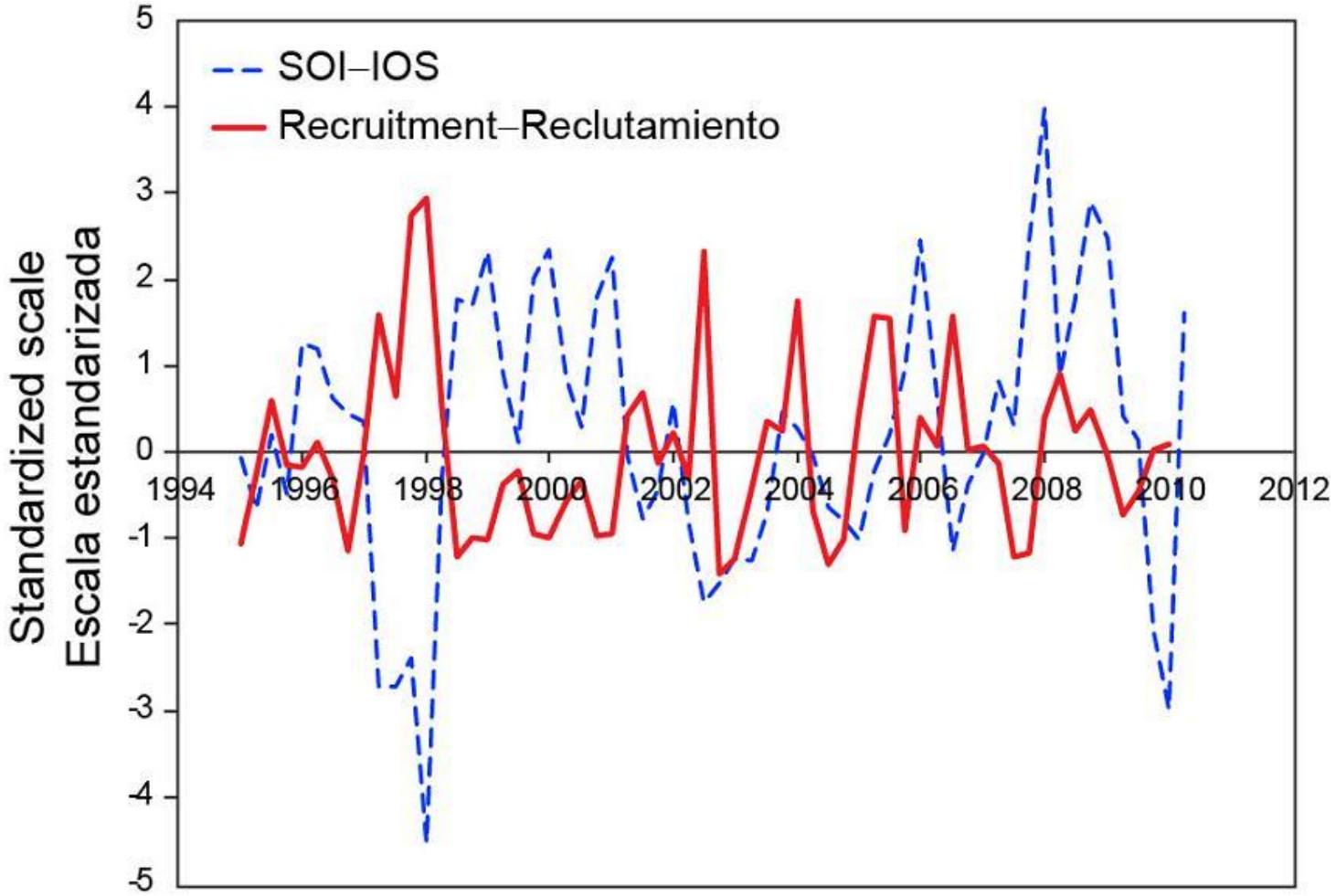
Management quantities

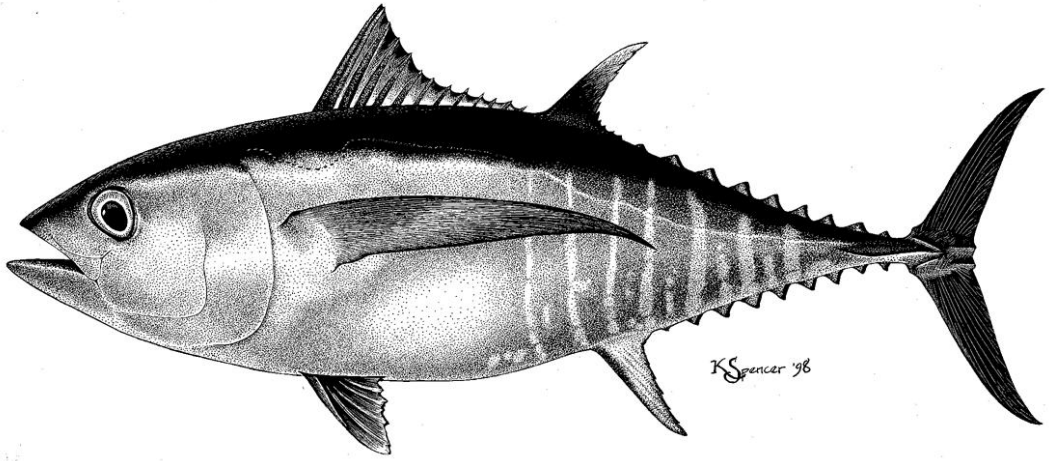
Sensitivities (Late period)



		Late period (1995-2009)	
	Basecase	*h* =1	*h* =0.75
MSY	90,538	115,781	141,283
Bmsy	332,331	418,608	928,017
Smsy	73,690	92,177	230,675
Bmsy/B0	0.25	0.25	0.34
Smsy/S0	0.19	0.20	0.30
Crecent/AMSY	1.17	0.92	0.75
Brecent/Bmsy	1.33	0.91	0.51
Srecent/Smsy	1.33	0.87	0.46
Fmultiplier	1.13	1.00	0.73

Recruitment and SOI



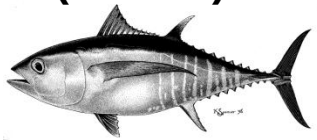


Sensitivity analyses

- Overall results

Management quantities

Sensitivities (Overall)



	Basecase	h = 0.75	L_2		Adult M		Late period (1995-2009)	
			170 cm	200 cm	Sens M 1	Sens M 5	h =1	h =0.75
MSY	90,538	86,321	114,492	86,001	88,294	113,917	115,781	141,283
Bmsy	332,331	582,233	428,532	306,662	516,205	375,778	418,608	928,017
Smsy	73,690	145,123	94,287	67,789	145,753	75,696	92,177	230,675
Bmsy/B0	0.25	0.34	0.24	0.27	0.27	0.25	0.25	0.34
Smsy/S0	0.19	0.30	0.19	0.21	0.26	0.19	0.20	0.30
Crecent/AMSY	1.17	1.23	0.91	1.24	1.21	0.92	0.92	0.75
Brecent/Bmsy	1.33	0.95	1.93	0.85	0.42	1.86	0.91	0.51
Srecent/Smsy	1.33	0.88	2.06	0.74	0.33	2.02	0.87	0.46
Fmultiplier	1.13	0.83	1.87	0.73	0.45	1.79	1.00	0.73

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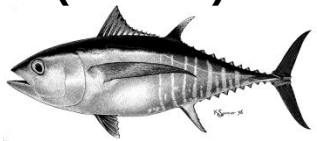
Likelihoods

Sensitivities (Overall)



Data Datos	Base case Caso base	h = 0.75	L_2		Adult M – M adultos	
			170 cm	200 cm	Sens $M1$	Sens $M5$
CPUE						
2	-31.13	-30.72	-29.14	-32.93	-33.11	-29.69
3	-7.18	-7.08	-6.55	-7.58	-7.92	-7.15
5	-3.94	-3.56	-3.01	-4.39	-5.12	-2.99
12	-30.92	-30.90	-30.35	-31.25	-30.30	-31.20
13	-24.60	-24.50	-24.45	-26.41	-24.69	-27.51
14	-66.20	-66.04	-66.11	-65.91	-66.71	-66.01
15	-79.23	-80.20	-81.63	-74.68	-74.25	-79.35
16	-95.15	-94.83	-93.82	-95.68	-94.02	-96.24
17	-113.82	-113.85	-113.85	-112.50	-110.26	-116.12
18	-41.41	-41.42	-41.39	-41.57	-43.15	-40.38
19	-28.19	-28.41	-29.39	-26.70	-26.02	-29.05
Total	**-521.76**	**-521.53**	**-519.69**	**-519.59**	**-515.55**	**-525.70**
Size compositions – Composición por talla						
1	164.11	164.09	164.41	164.54	164.84	163.52
2	226.15	226.61	222.73	229.93	222.99	228.20
3	313.81	312.33	313.29	317.77	317.74	313.11
4	79.07	78.57	78.05	80.84	80.36	78.21
5	167.13	167.68	165.95	168.66	162.82	168.15
6	127.41	127.77	127.45	127.67	127.08	127.99
7	134.37	132.80	128.88	142.34	134.44	132.57
12	33.61	33.62	34.16	33.08	33.28	33.93
13	54.29	53.86	54.39	54.84	54.64	66.70
14	32.43	32.53	33.07	32.55	32.50	32.38
15	49.34	51.00	39.60	49.99	49.53	41.97
16	39.13	38.92	36.89	41.61	40.05	38.86
17	129.94	133.10	86.94	142.58	132.29	110.14
18	54.21	54.17	54.29	54.98	54.86	53.75
19	59.69	59.64	60.30	60.48	59.93	60.31
Total	**1664.68**	**1666.68**	**1600.38**	**1701.87**	**1667.34**	**1649.78**
Age at length **Talla por edad**	278.34	279.71	291.63	270.48	278.55	276.61
Recruitment **Reclutamiento**	-28.01	-25.80	-31.42	-19.66	8.77	-33.84
Total	**1393.25**	**1399.06**	**1340.90**	**1433.10**	**1439.12**	**1366.85**

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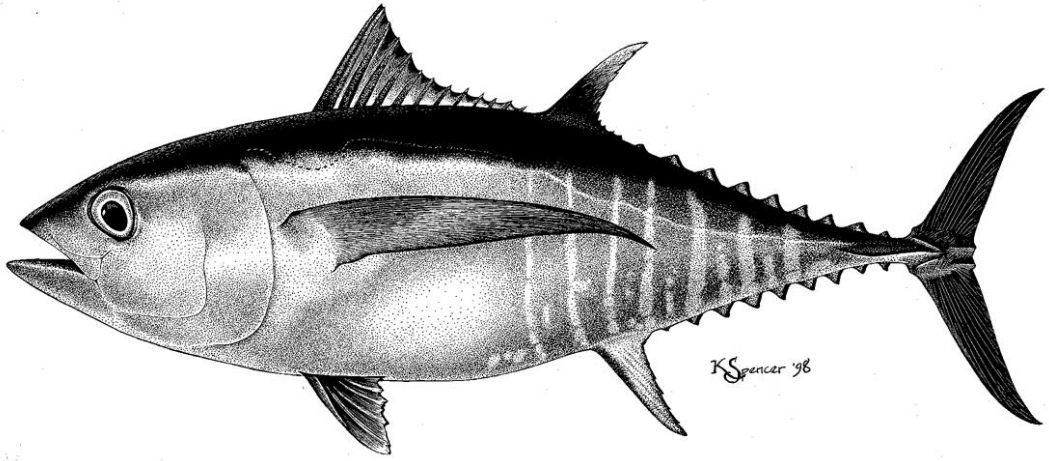
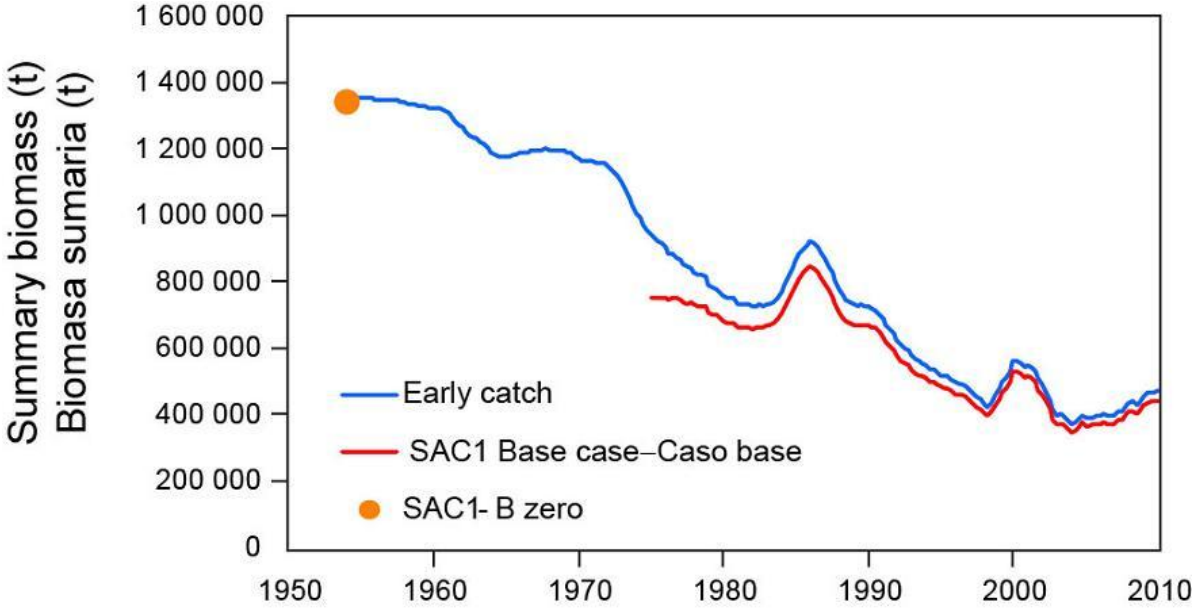
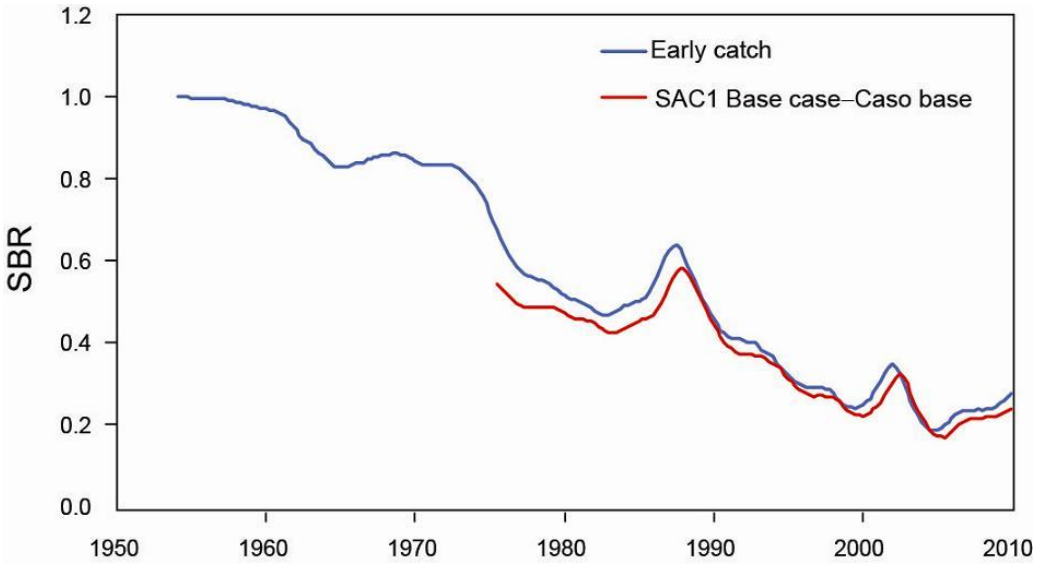


Additional sensitivity analyses (DOCUMENT SAC-01-08B)

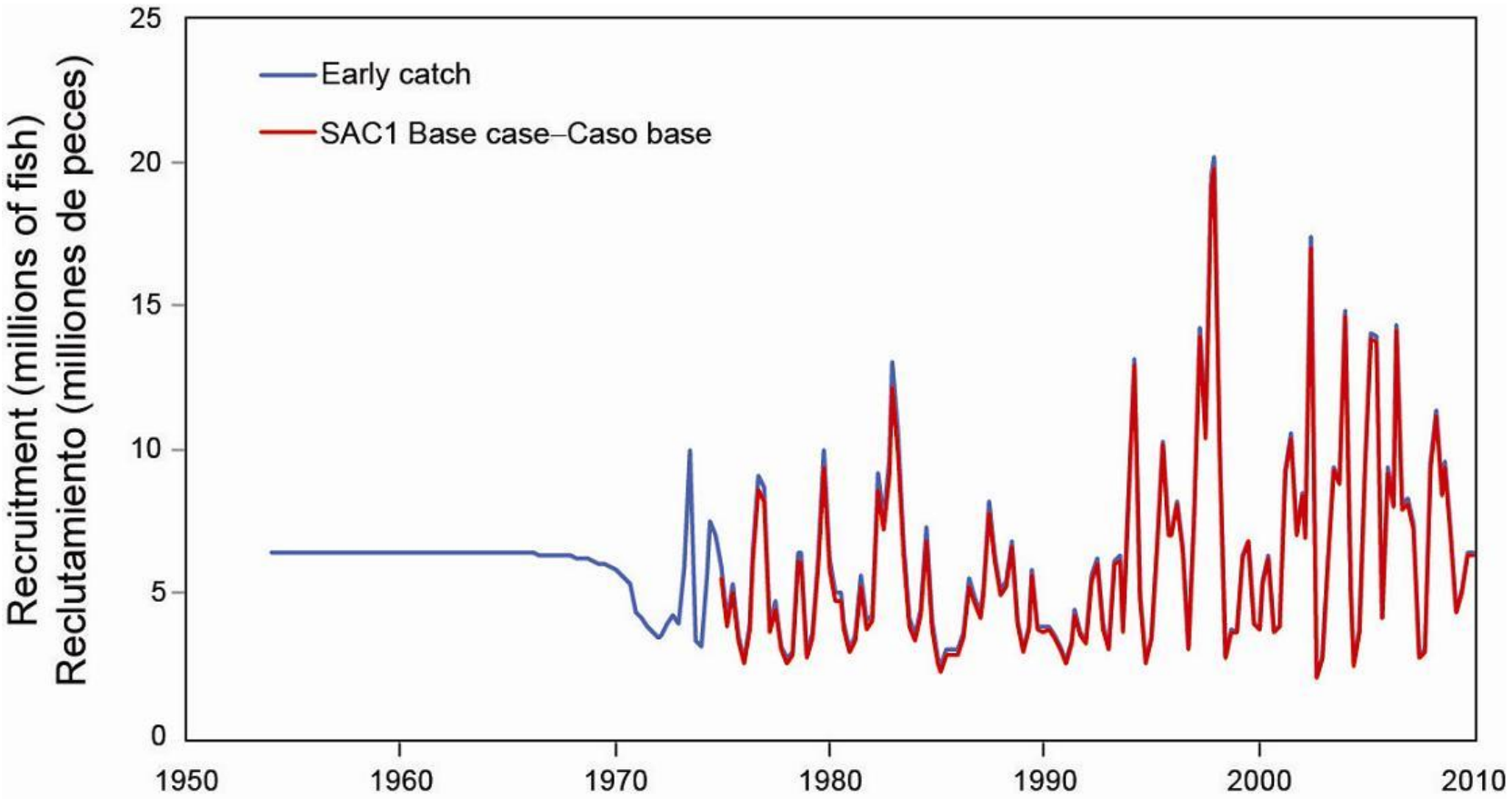
- Including early historic catch (1954-1975)
- Weighting of the longline size-composition data

Including early catch (1954-1975)

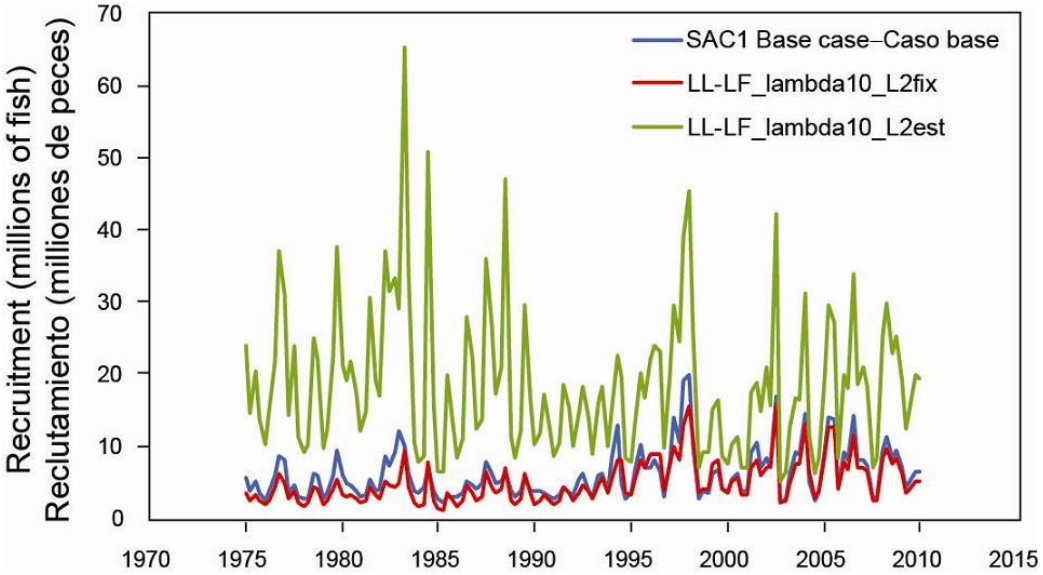


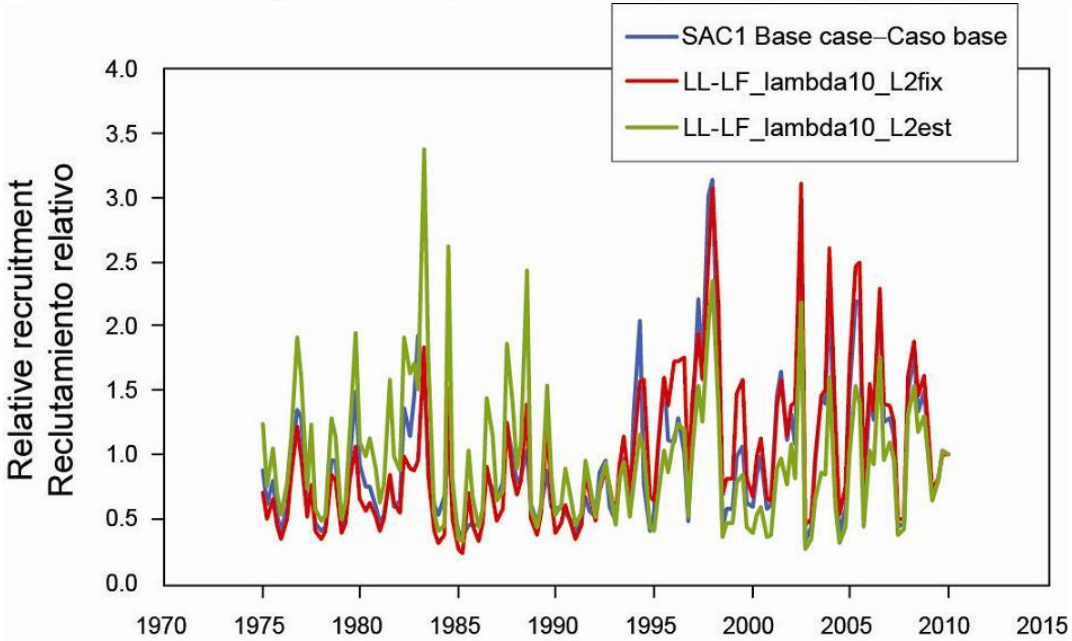


Including early catch (1954-1975)

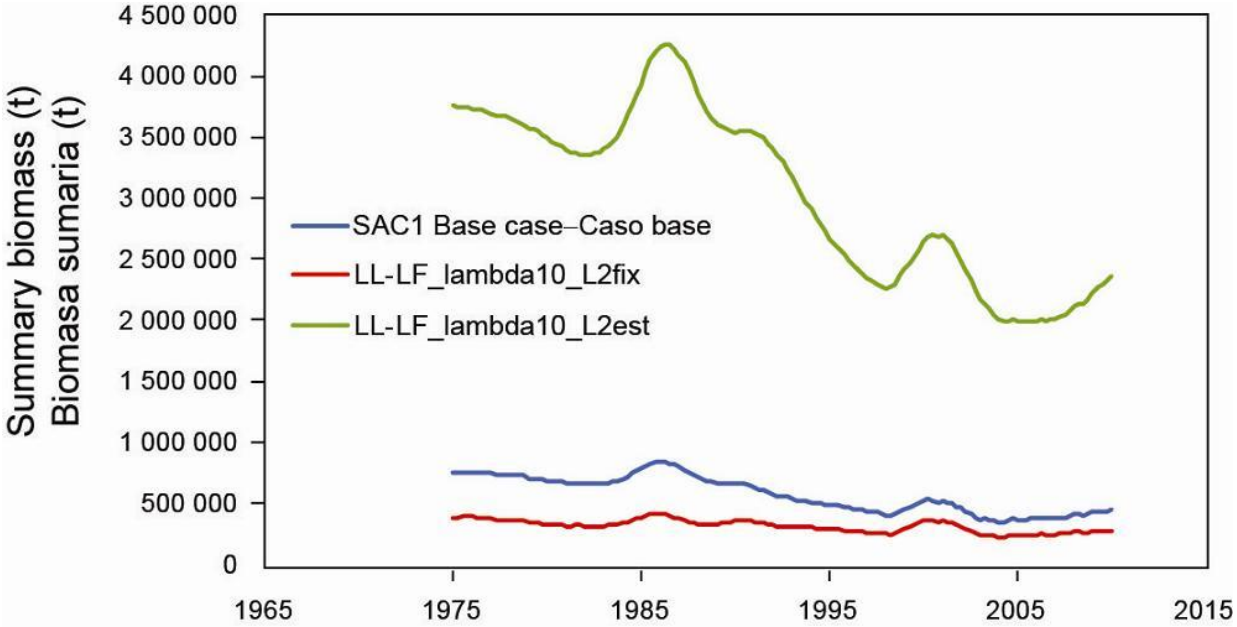


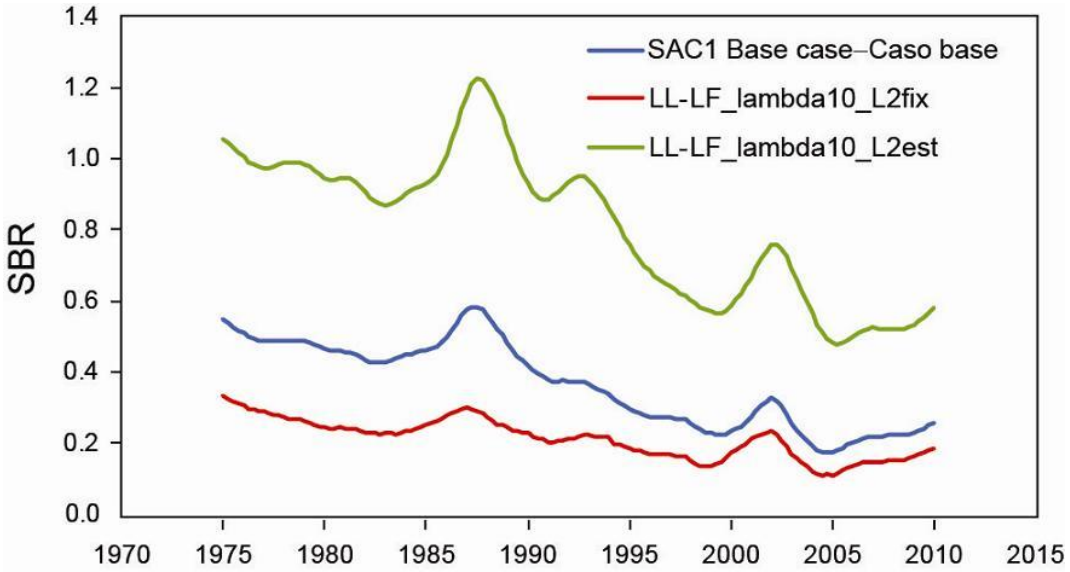
Weighting of LL size comp. data



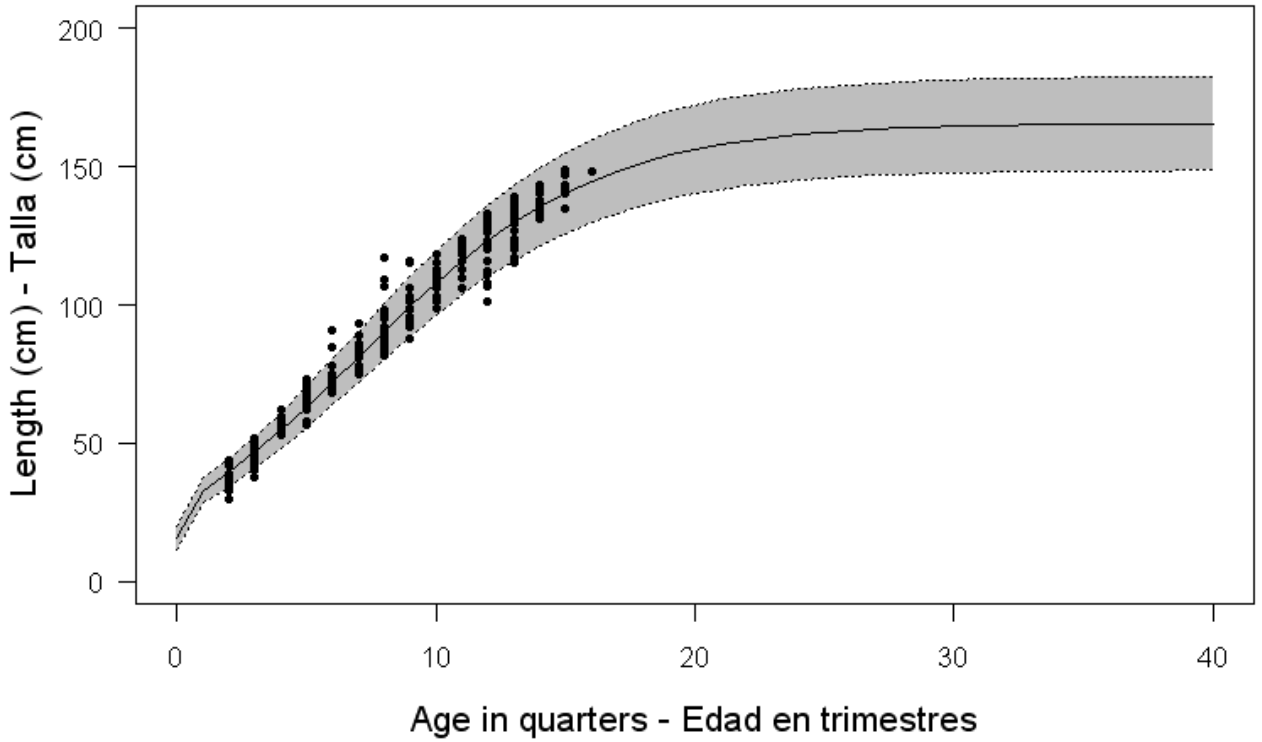


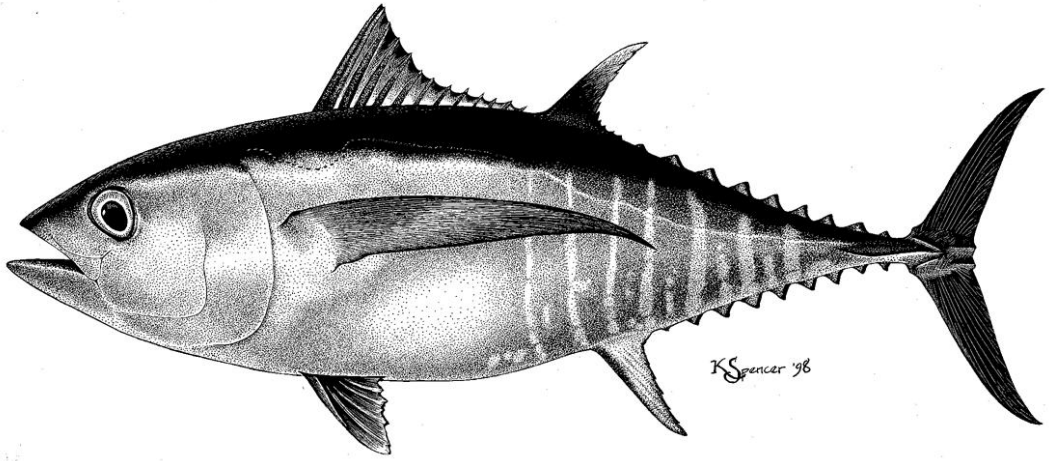
Weighting of LL size comp. data





Weighting of LL size comp. data

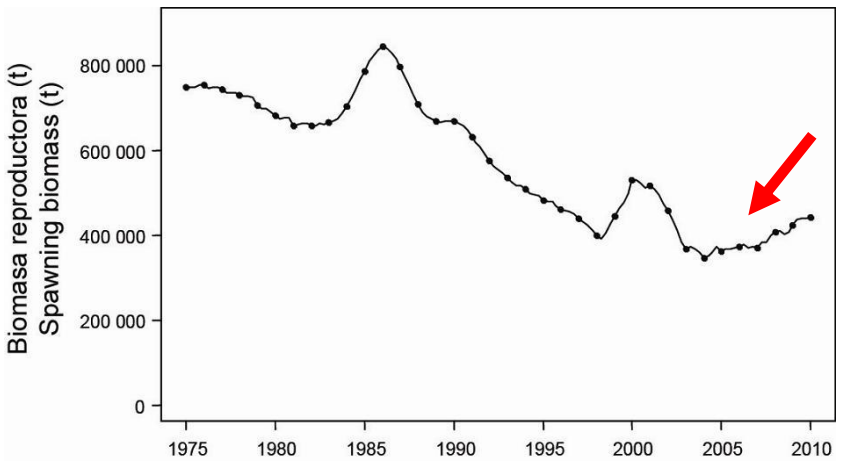


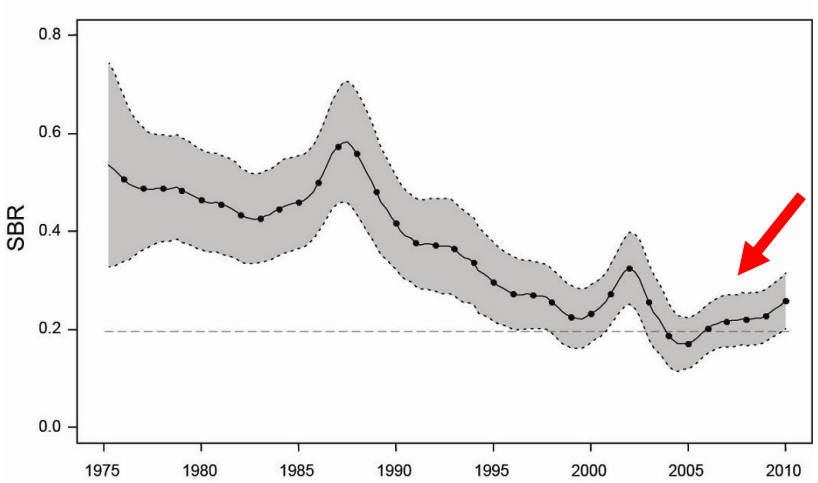


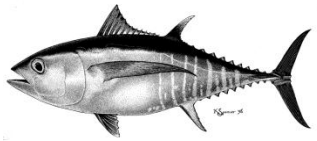
Summary

Summary: key results

- Current biomass level is low compared to average unexploited conditions
- But there are signs of a recent recovery trend from a historic low in 2004.





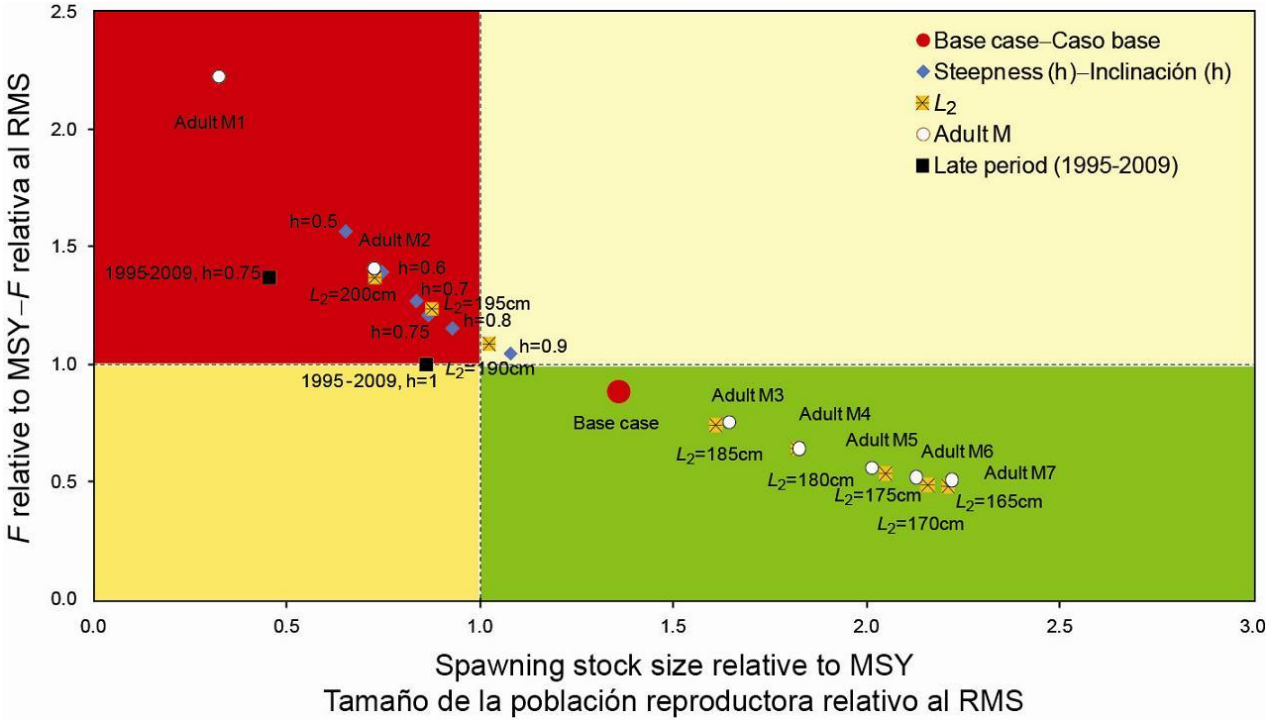


Summary: key results (cont.)

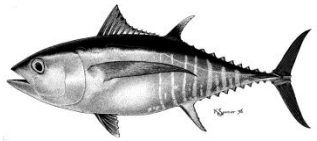
- The recent fishing mortality rates are estimated to be below the level corresponding to MSY ($F_{recent} < F_{MSY}$)
- The recent levels of spawning biomass are estimated to be above the MSY level ($S_{recent} > F_{MSY}$)

Summary: key results (cont.)

- However, these interpretations are highly sensitive about the following assumptions:
  - Steepness of stock-recruitment relationship
  - Average size of the oldest fish in the population (L_2)
  - Adult natural mortality levels
  - Historic period of the bigeye exploitation



Plausible Sensitivities and Uncertainties



- Results are more **pessimistic** with:
  - The inclusion of a stock-recruitment relationship
  - Higher values of the average size of the oldest fish (L_2 > 185 cm)
  - Lower rates of adult natural mortality (M)
  - If only the late period of the fishery (1995-2009) is used in the assessment

- Results are more **optimistic** with:
  - Lower values of the average size of the oldest fish (L_2 < 185 cm)
  - Higher rates of adult natural mortality (M)

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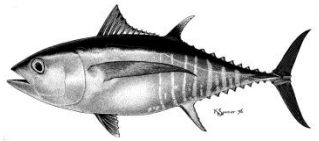
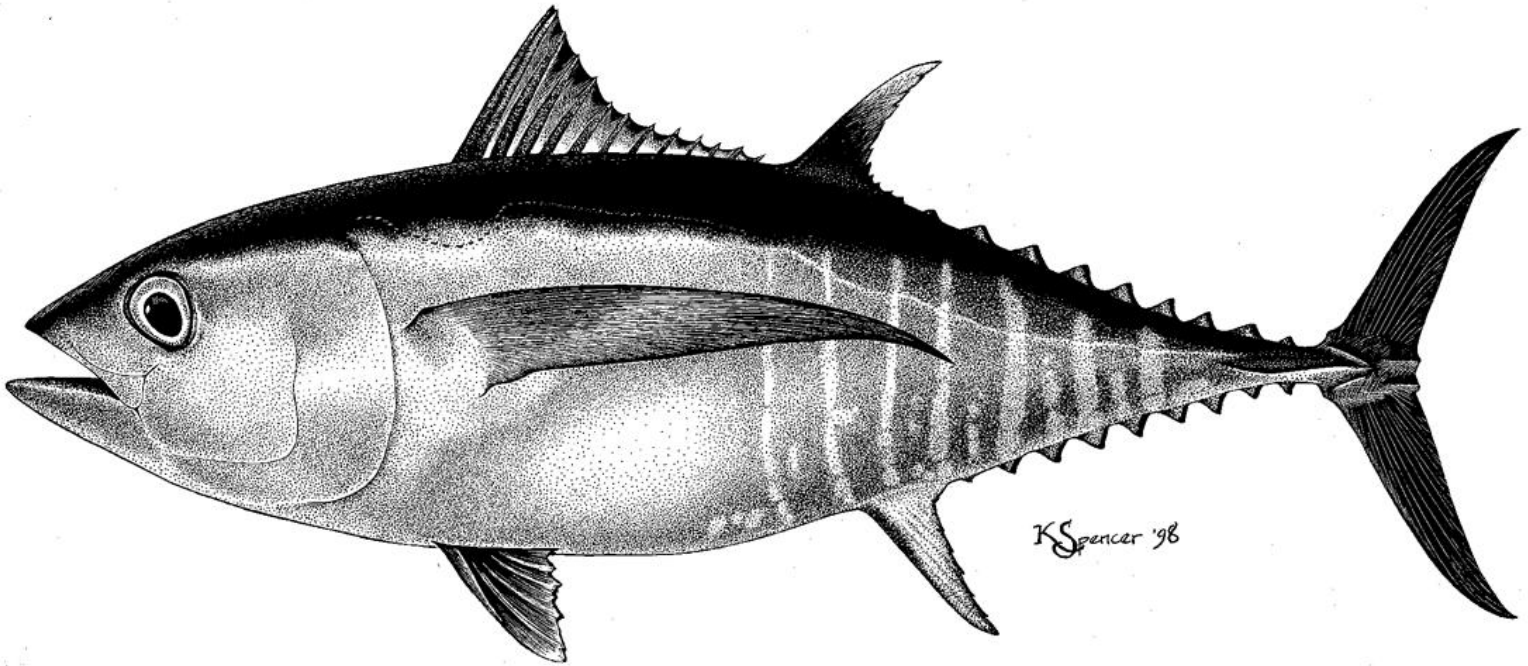


What is robust

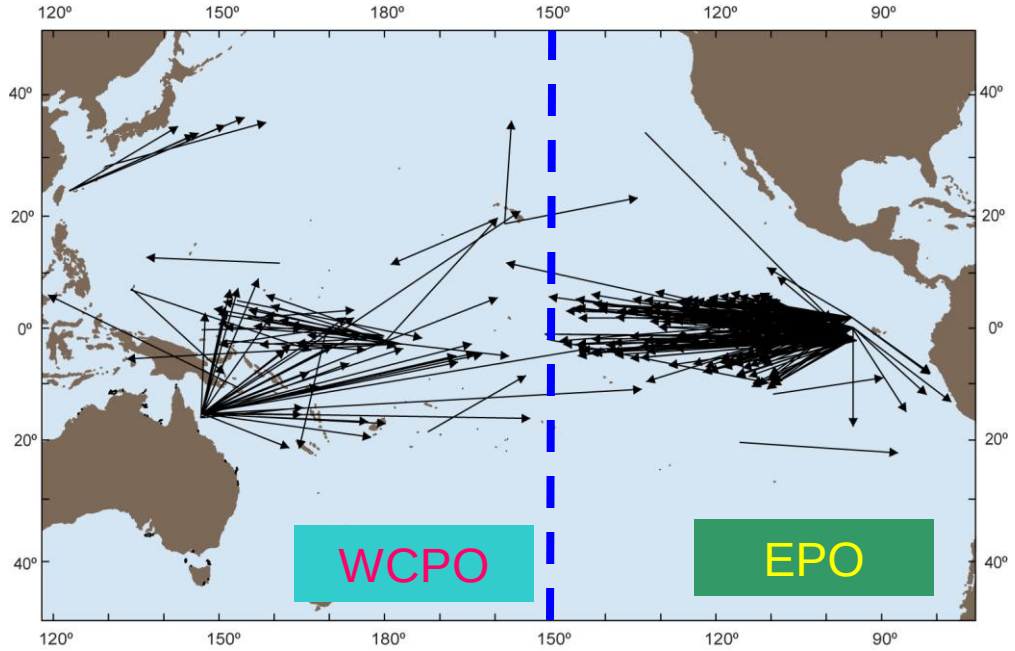
- The recent increasing trend since 2004

Questions?



BET movement

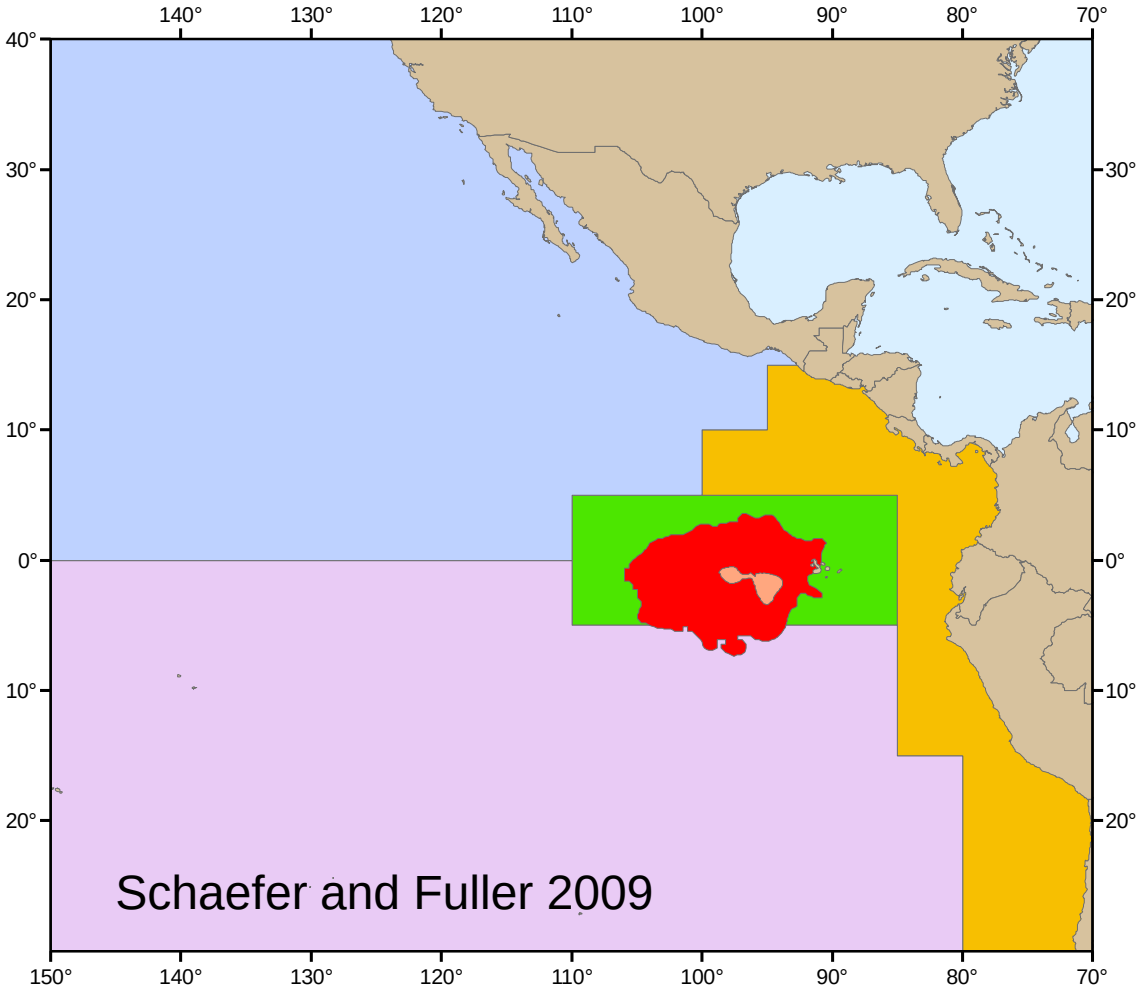
- Restricted movements in EPO and WCPO



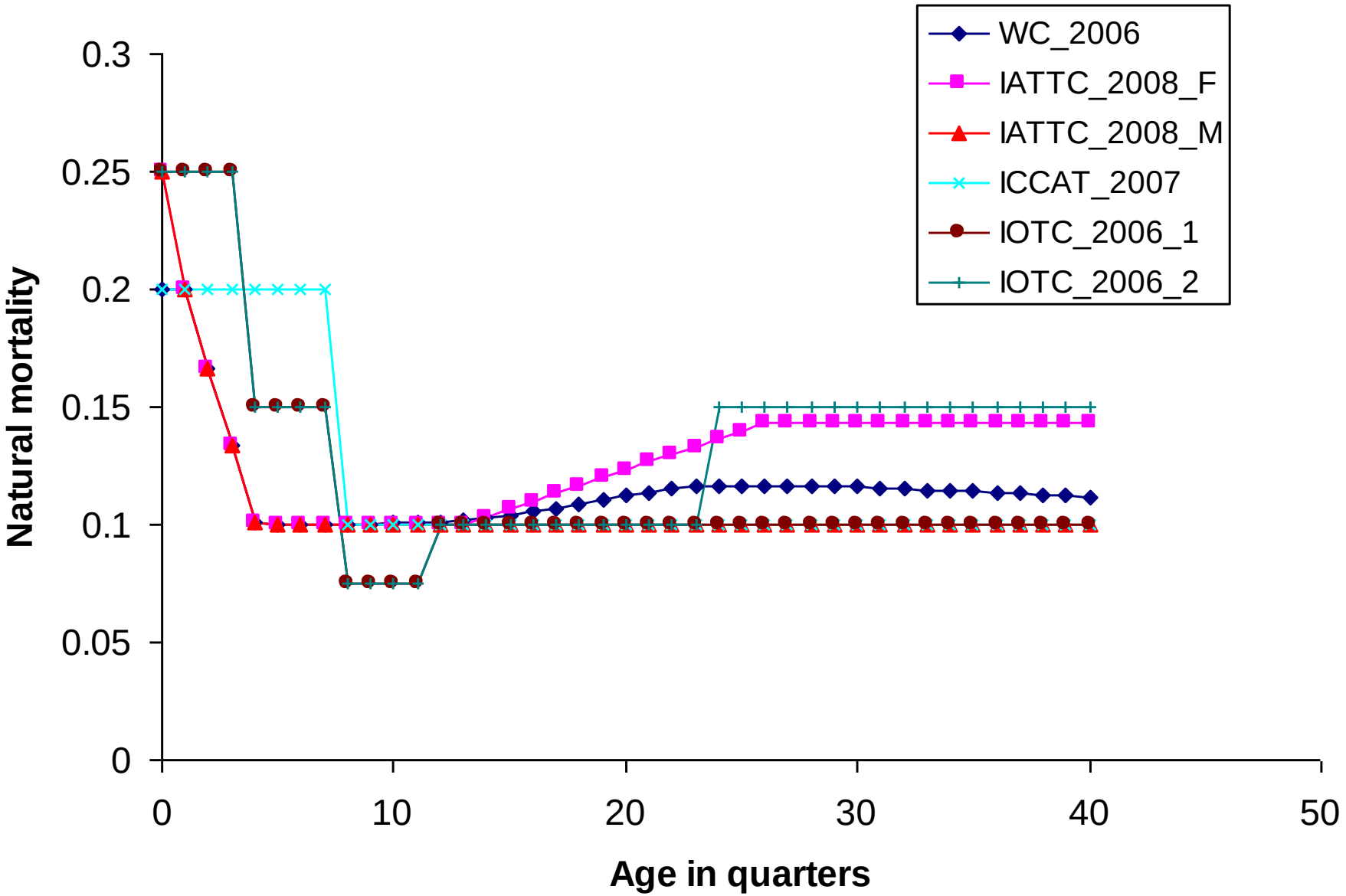
- Single stock of BET in EPO
  - Stock is randomly mixed in EPO

Archival tagging data

- Bigeye 95% and 50% Utilization Distributions April 2000 – March 2006

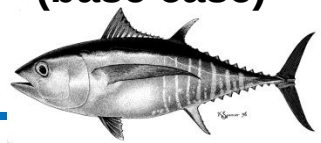


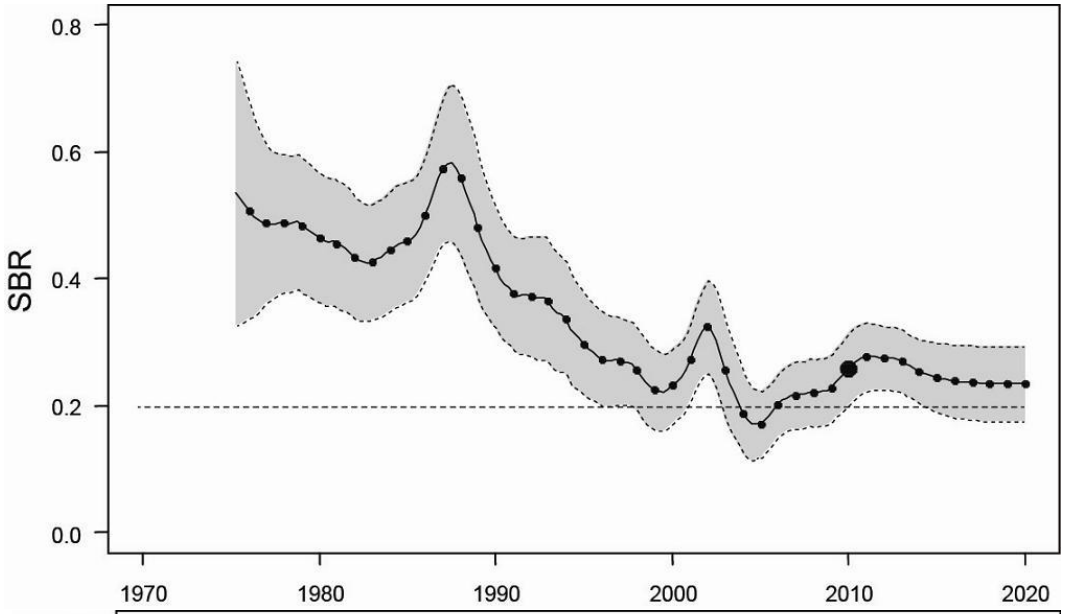
Sensitivities to Ms of other RMFOs

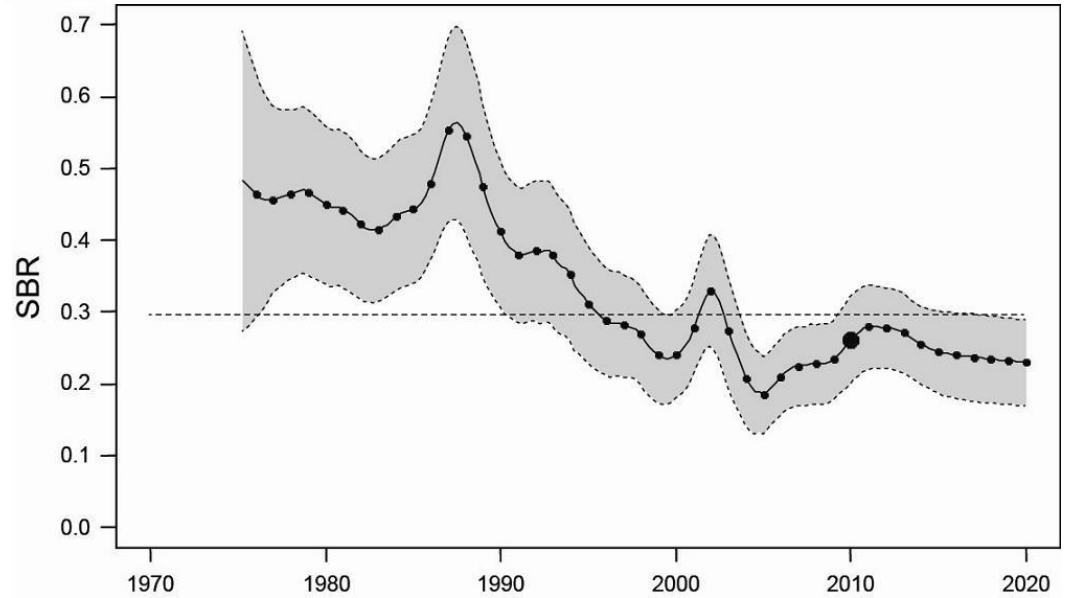


Spawning Biomass Ratio – *Status quo* (F_{cur})

Projections (base case)







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