Can we estimate the abundance of yellowfin tuna?

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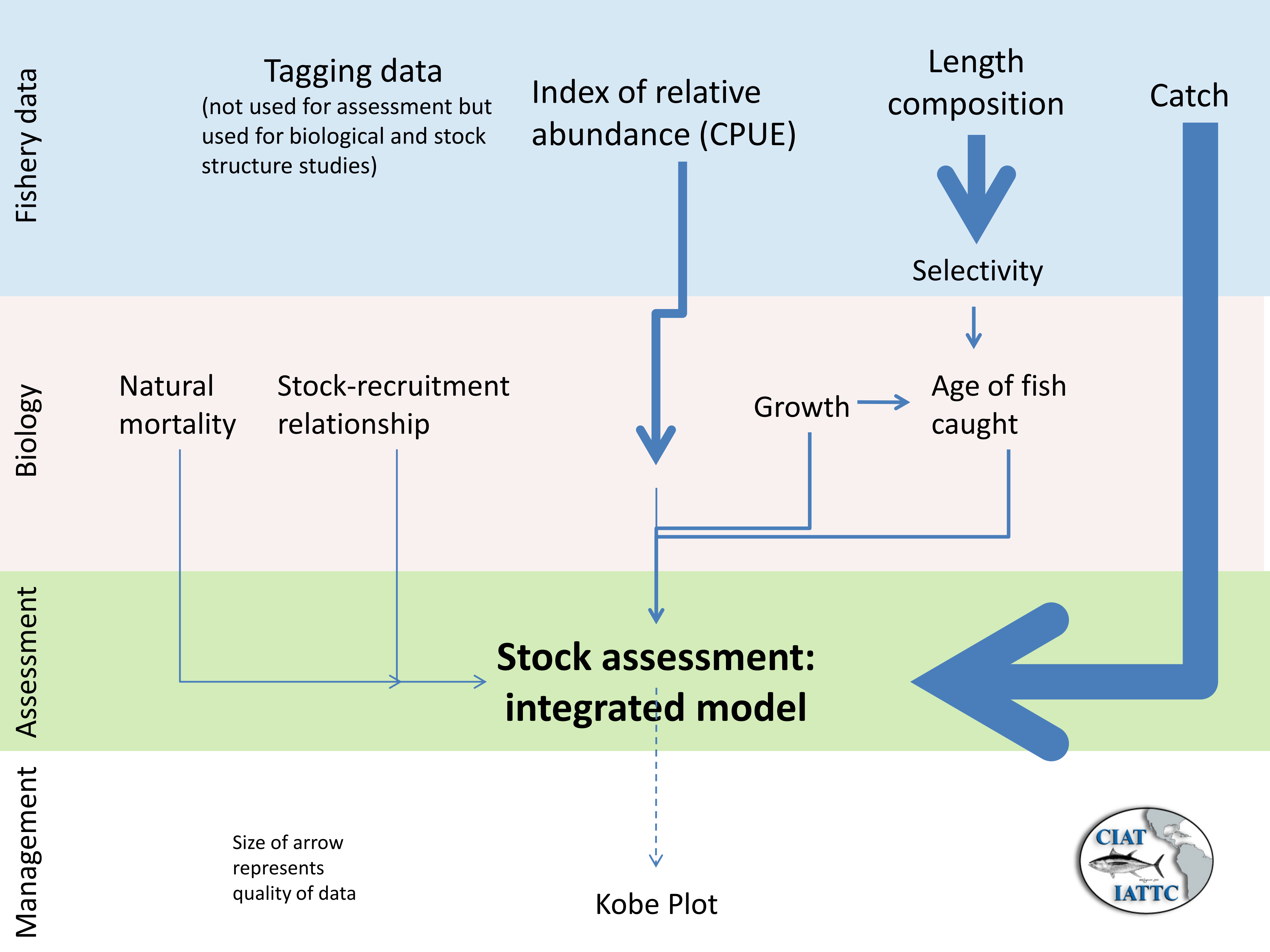
Alexandre Aires-da-Silva

How we estimate the abundance of yellowfin tuna in the EPO?

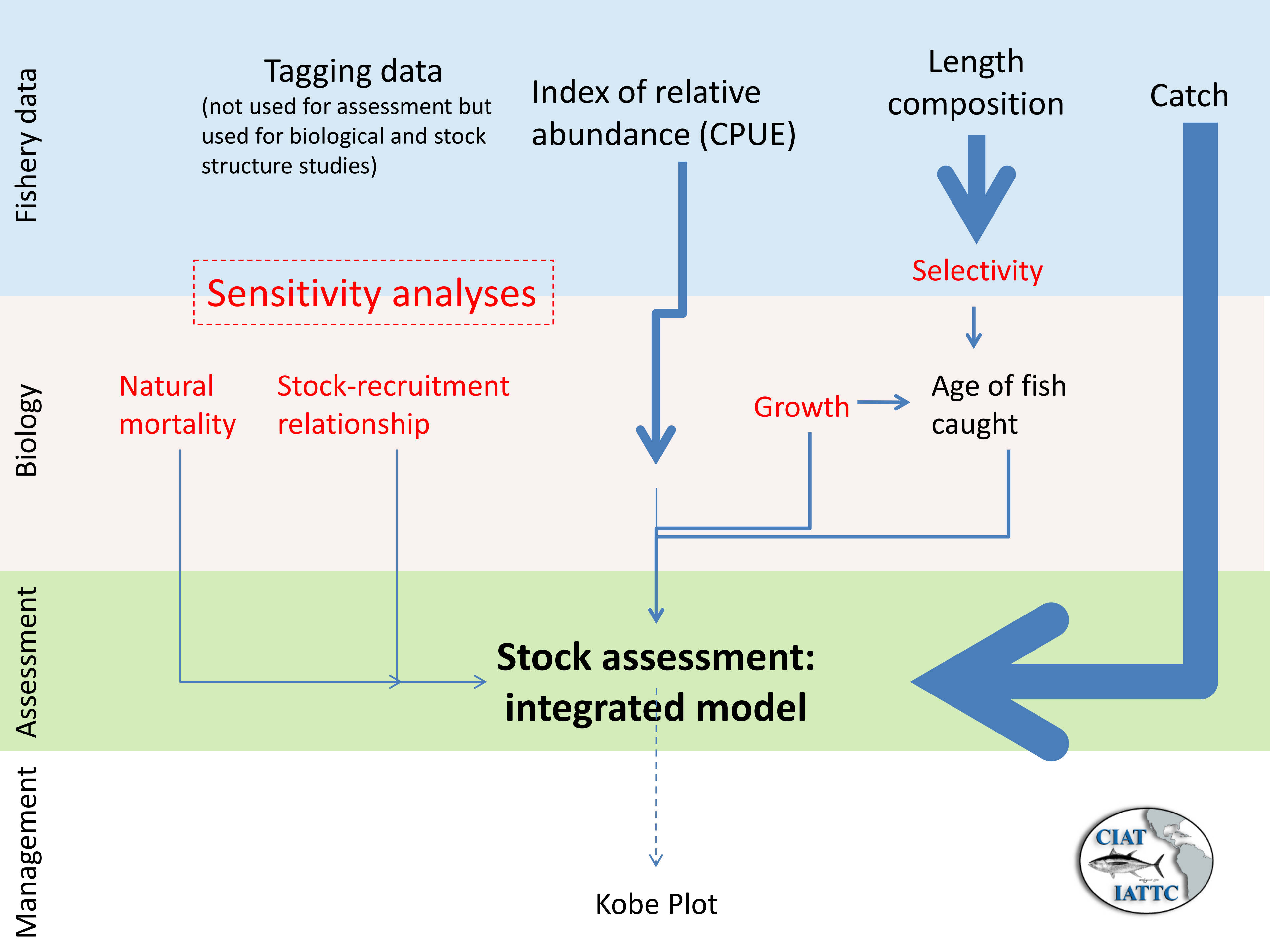
Current method:
Integrated statistical age-structured population dynamics model

Assumptions:
- one stock in the eastern Pacific Ocean
- 16 fisheries
- Sex-specific natural mortality
- One growth curve
- …

Fit to indices of relative abundance and length-frequency data
Using likelihood techniques



Fishery data
Tagging data
(not used for assessment but used for biological and stock structure studies)
Index of relative abundance (CPUE)
Length composition
Catch
Selectivity
Biology
Natural mortality
Stock-recruitment relationship
Growth
Age of fish caught
Assessment
Stock assessment: integrated model
Management
Size of arrow represents quality of data
Kobe Plot
CIAT
IATTC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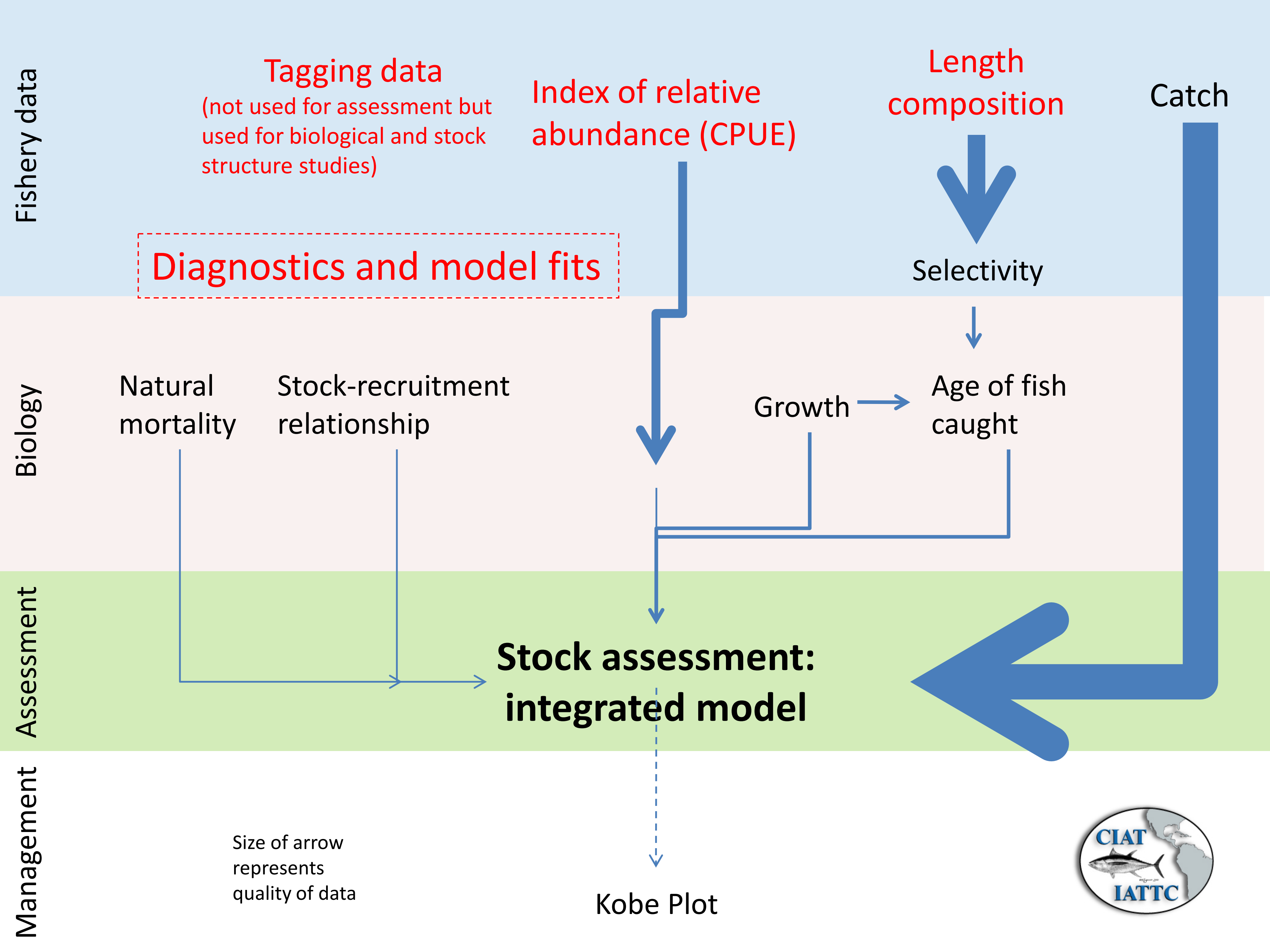
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Diagnostics and model fits
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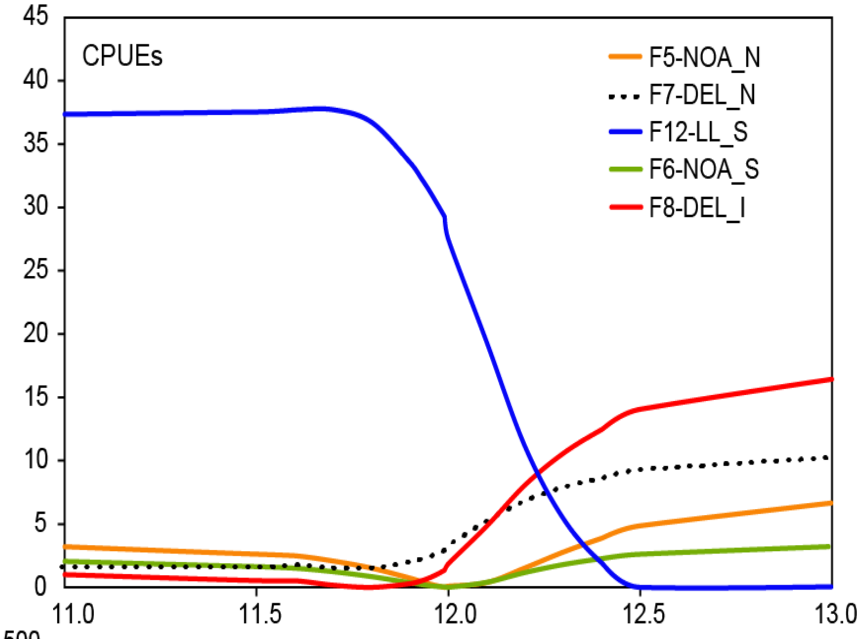
Diagnostics for integrated models

- Likelihood profile on the scaling parameter
- Age-structure production model – fit only to indices of relative abundance
- Catch curve analysis – fit only to length-frequency data
- Depletion model - simplified population dynamics model, fit only to purse-seine CPUE

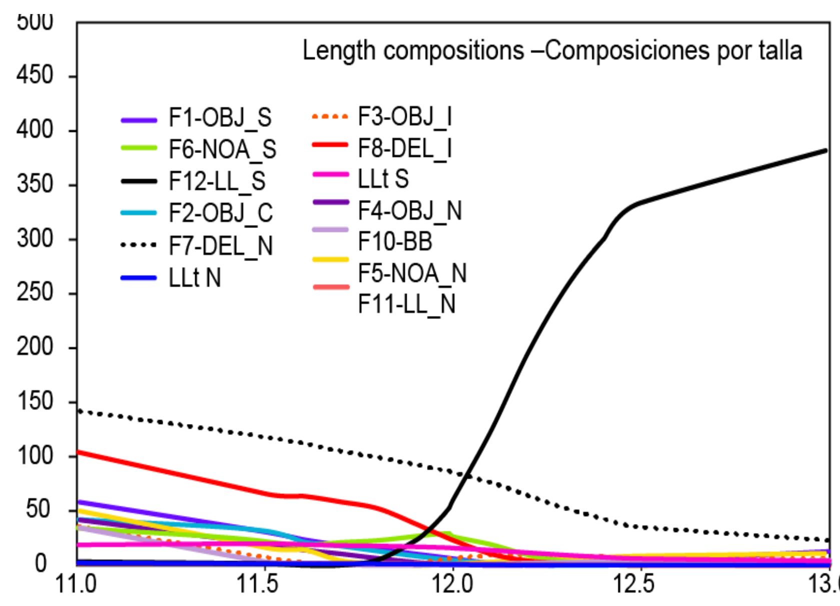
R0 likelihood profile

R0 is the virgin recruitment (the parameter that gives the absolute scale of the model)

Negative log-likelihood difference to the best fitting model



ln (R0)



ln (R0)

Age-structure production model (ASPM)

Production and loss in a population

$$B_{t+1} = B_t + \boxed{\underbrace{(A+G)}_{\text{production}} - \underbrace{M^*}_{\text{loss (natural mortality)}}} - \underbrace{C}_{\text{loss (fishing mortality)}}$$

production function

$$B_{t+1} = B_t + f(B_t) - C_t$$

A production model aggregate the production and natural losses in a **production function**

- An age-structure production model takes into account how those processes change with **age** (size at age, natural mortality at age) and assumes a constant recruitment
- If the **production function** is constant, then the changes in biomass **Bt** are due to **loss to fishing**

Fit to CPUE as indices of relative abundance

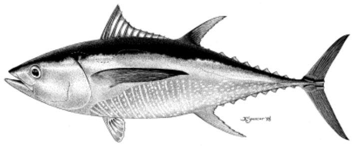
$$C_t = f\,(E_t \times B_t)$$

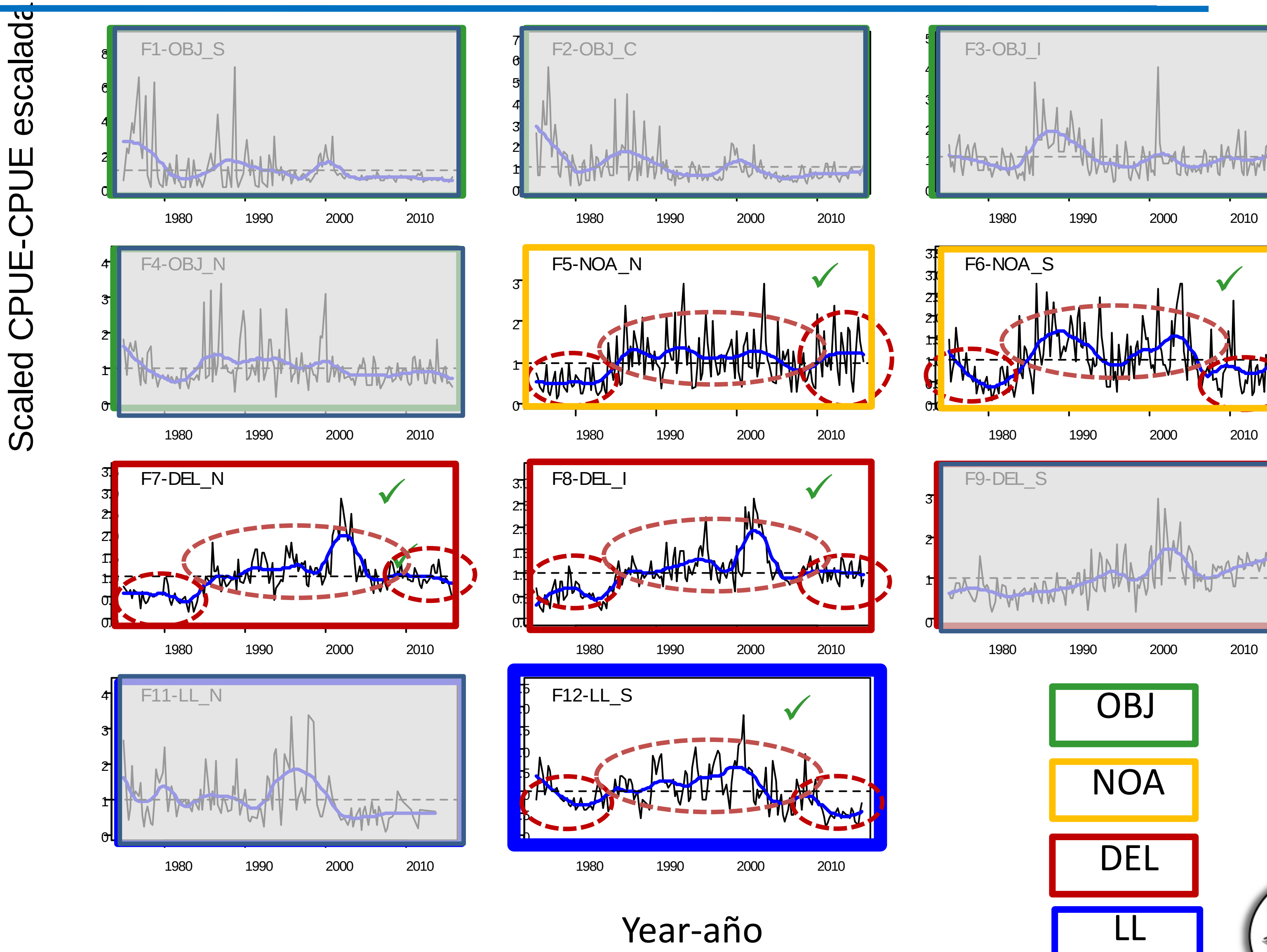
$$C_t / E_t = f\,(B_t)$$

- Ct / Et is the "catch per unit of effort" (CPUE)
- CPUE is proportional to the biomass of the stock Bt

Fit to 5 CPUE series simultaneously

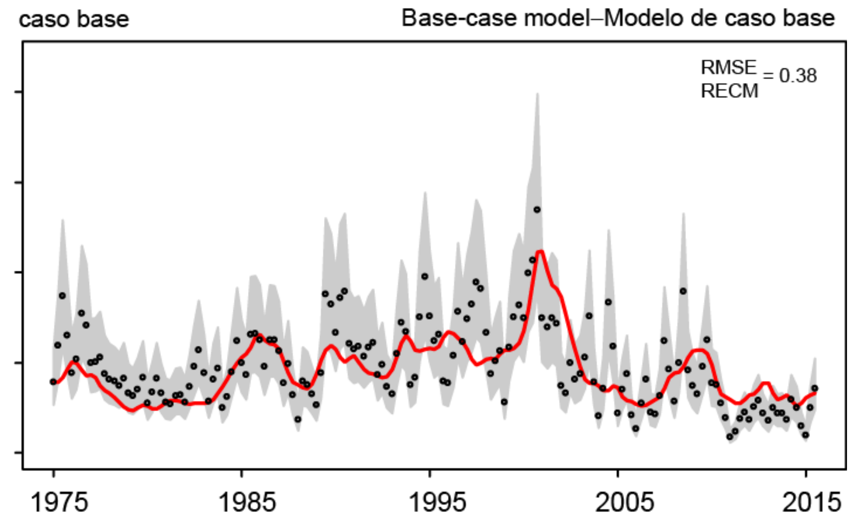
Fishery data



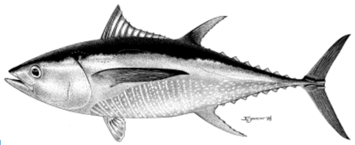


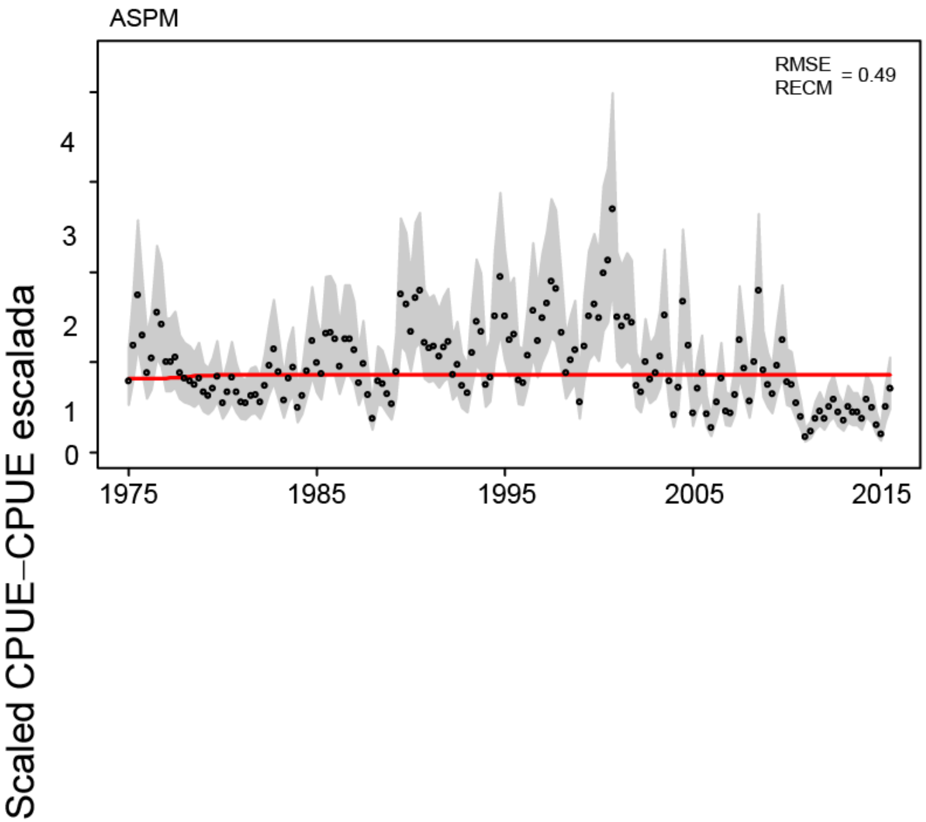
Age-structured production model

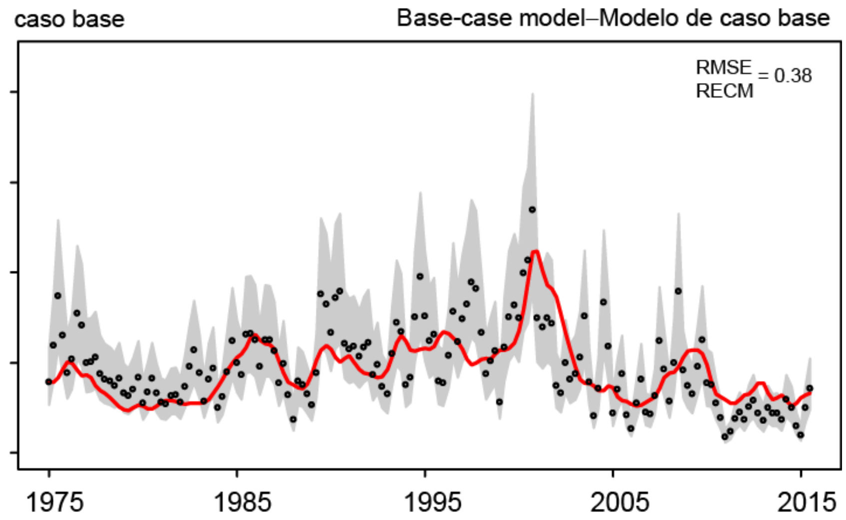
Scaled CPUE–CPUE escalada



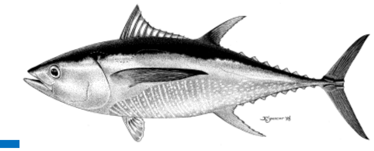
Age-structured production model

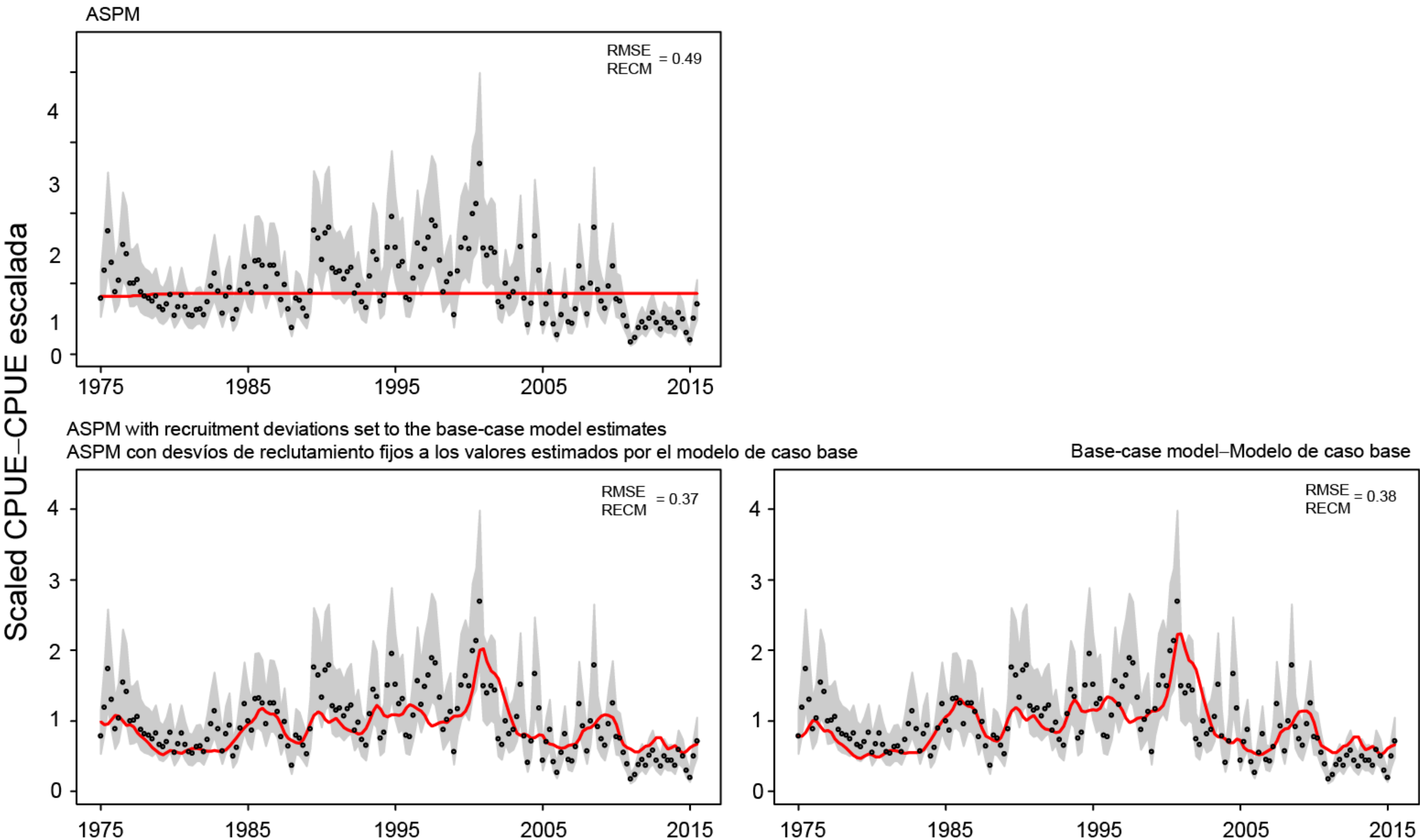




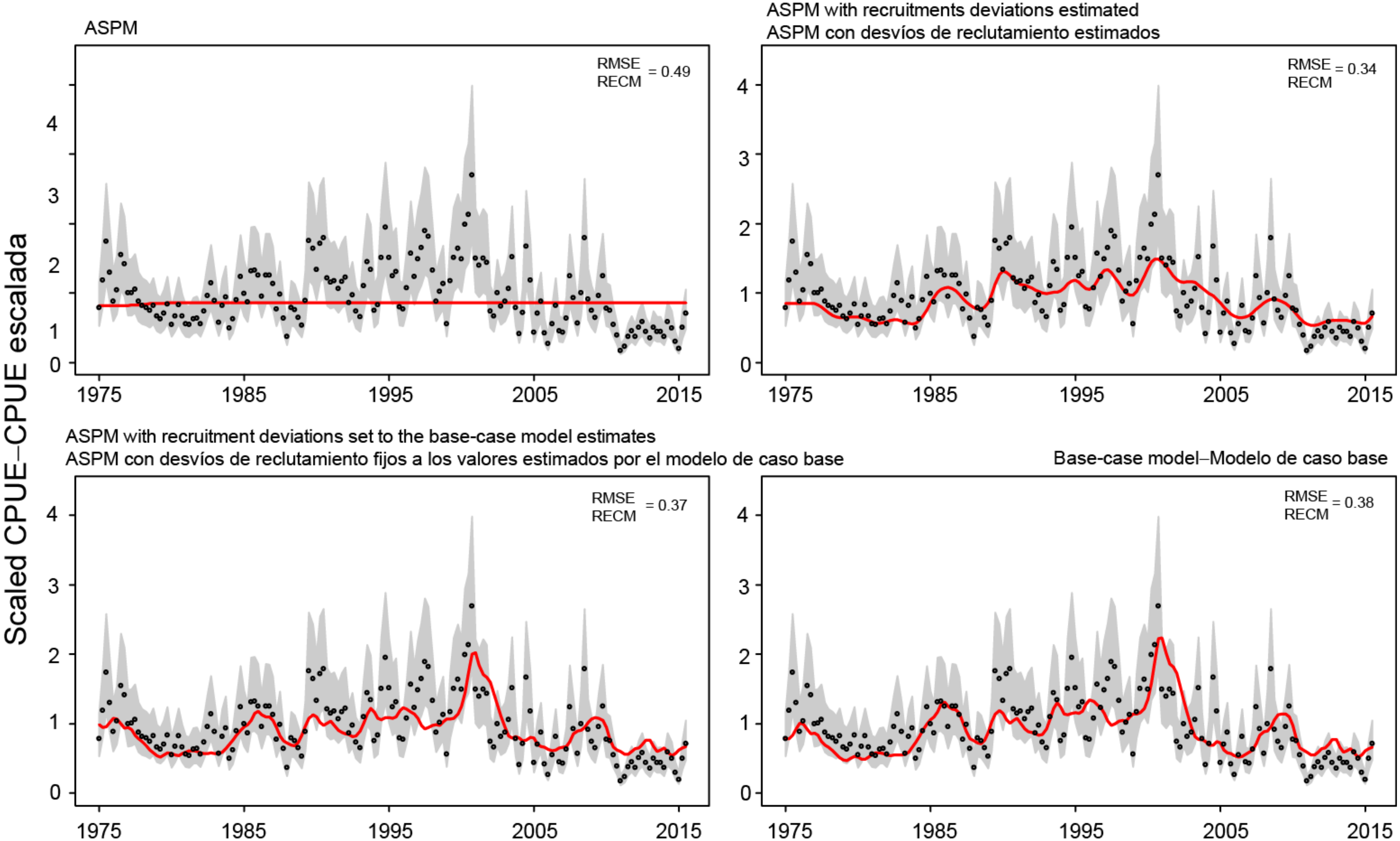


Age-structured production model

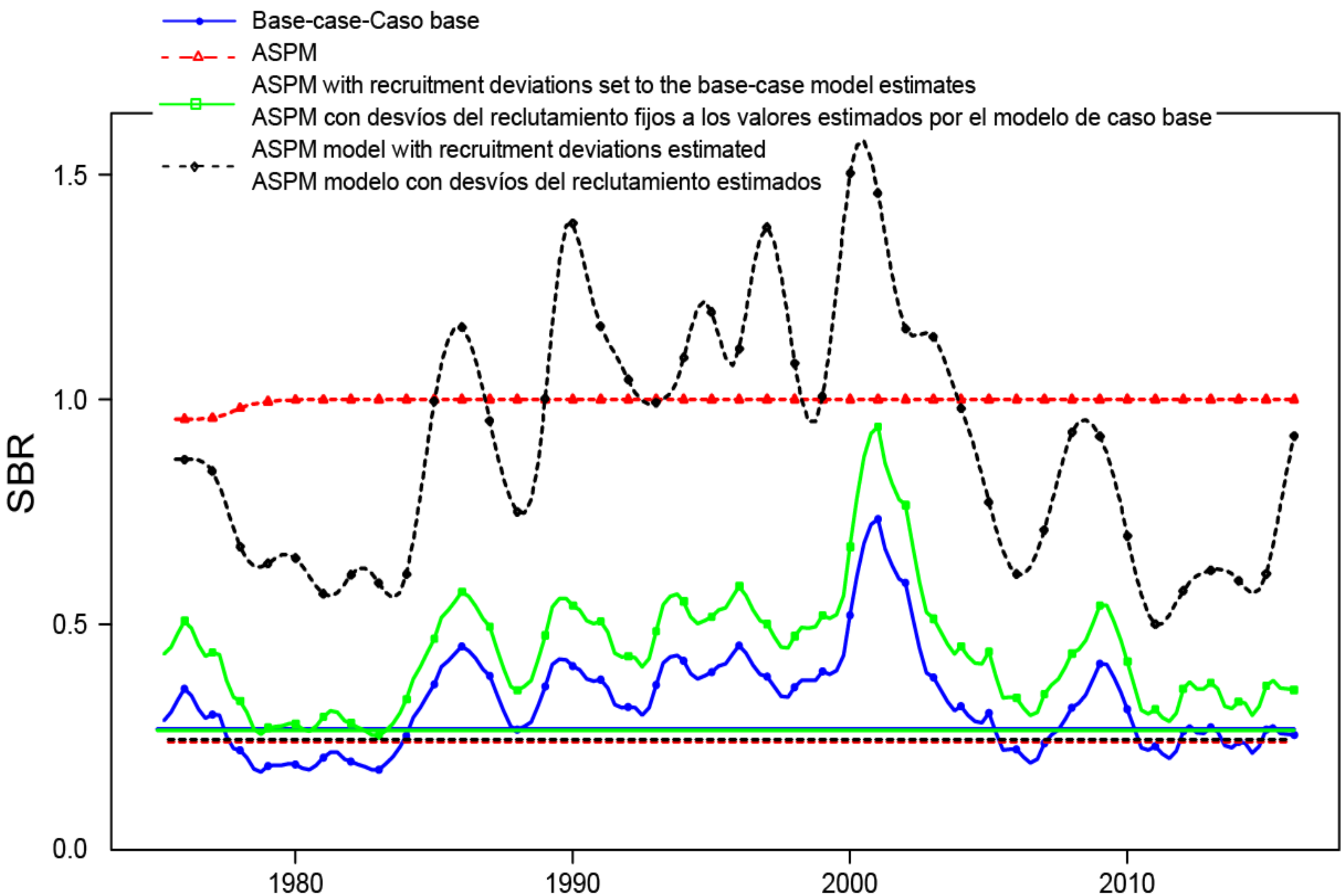




Age-structured production model

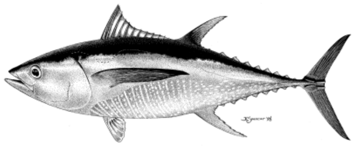


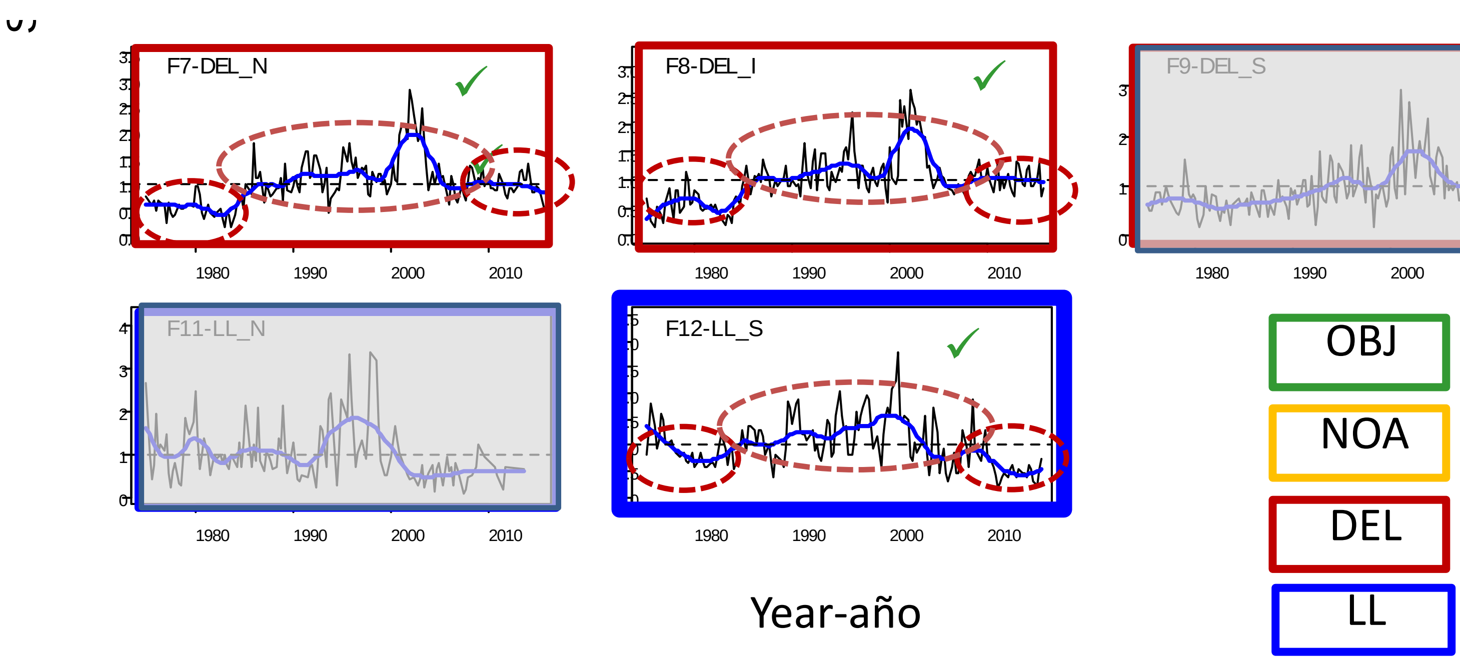
Age-structured production model

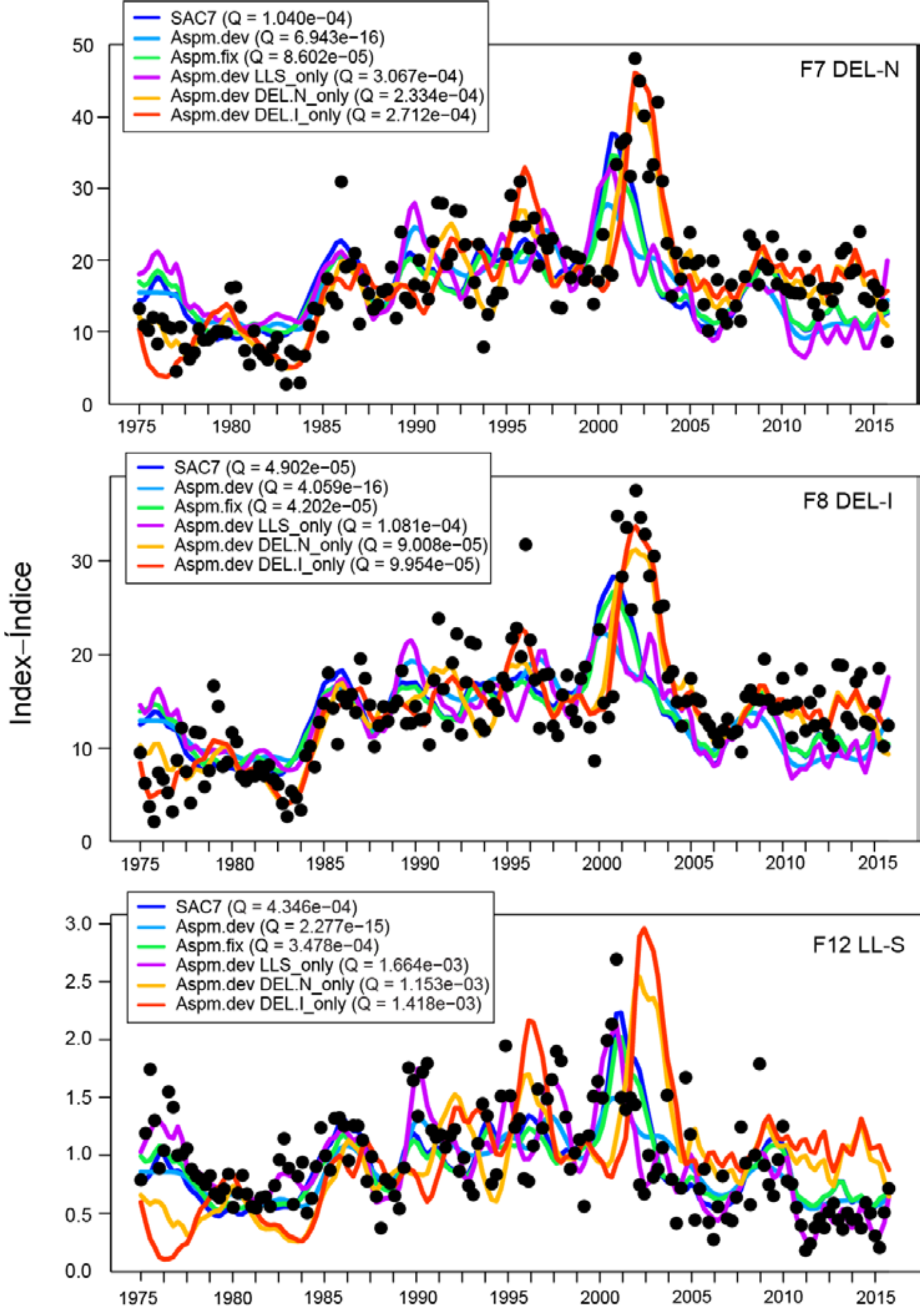


ASPM with one index only at a time

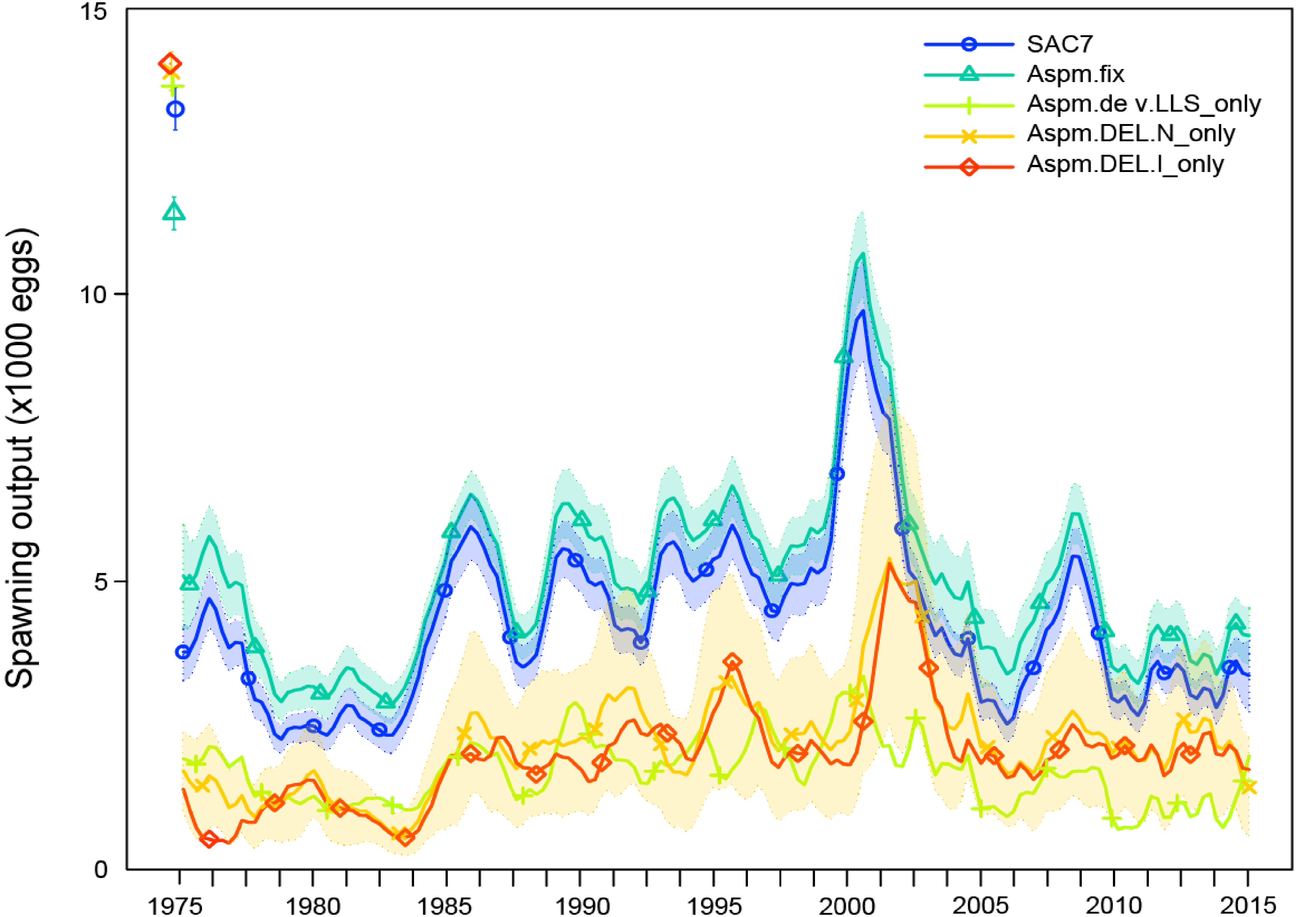
Fishery data







Fits to three CPUE series of the **SAC7** base case model, the **ASPMdev** and the ASPMdev fit to one cpue series at a time



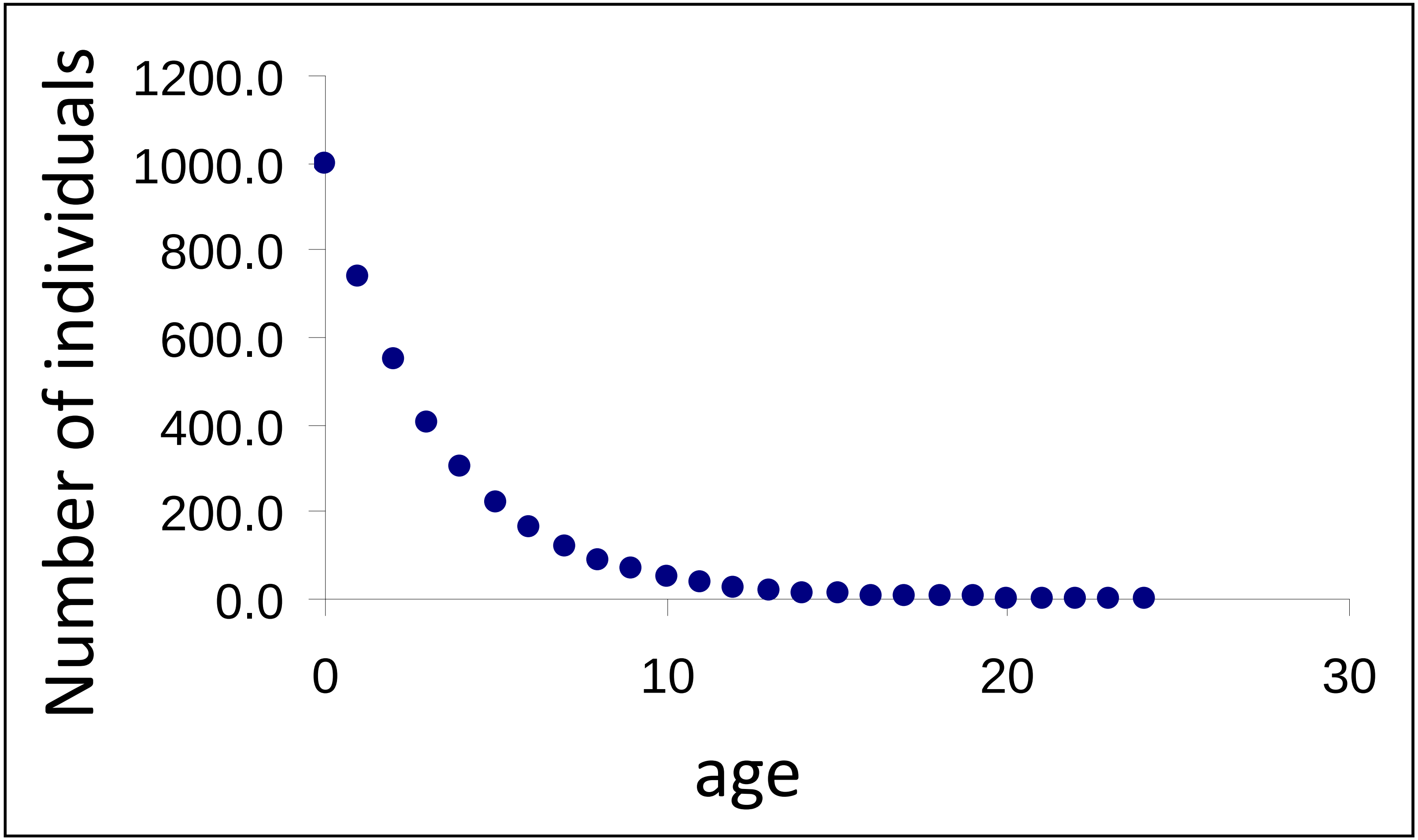
SAC7
Aspm.fix
Aspm.de v.LLS_only
Aspm.DEL.N_only
Aspm.DEL.I_only
Spawning output (x1000 eggs)
15
10
5
0
1975
1980
1985
1990
1995
2000
2005
2010
2015

Results ASPM

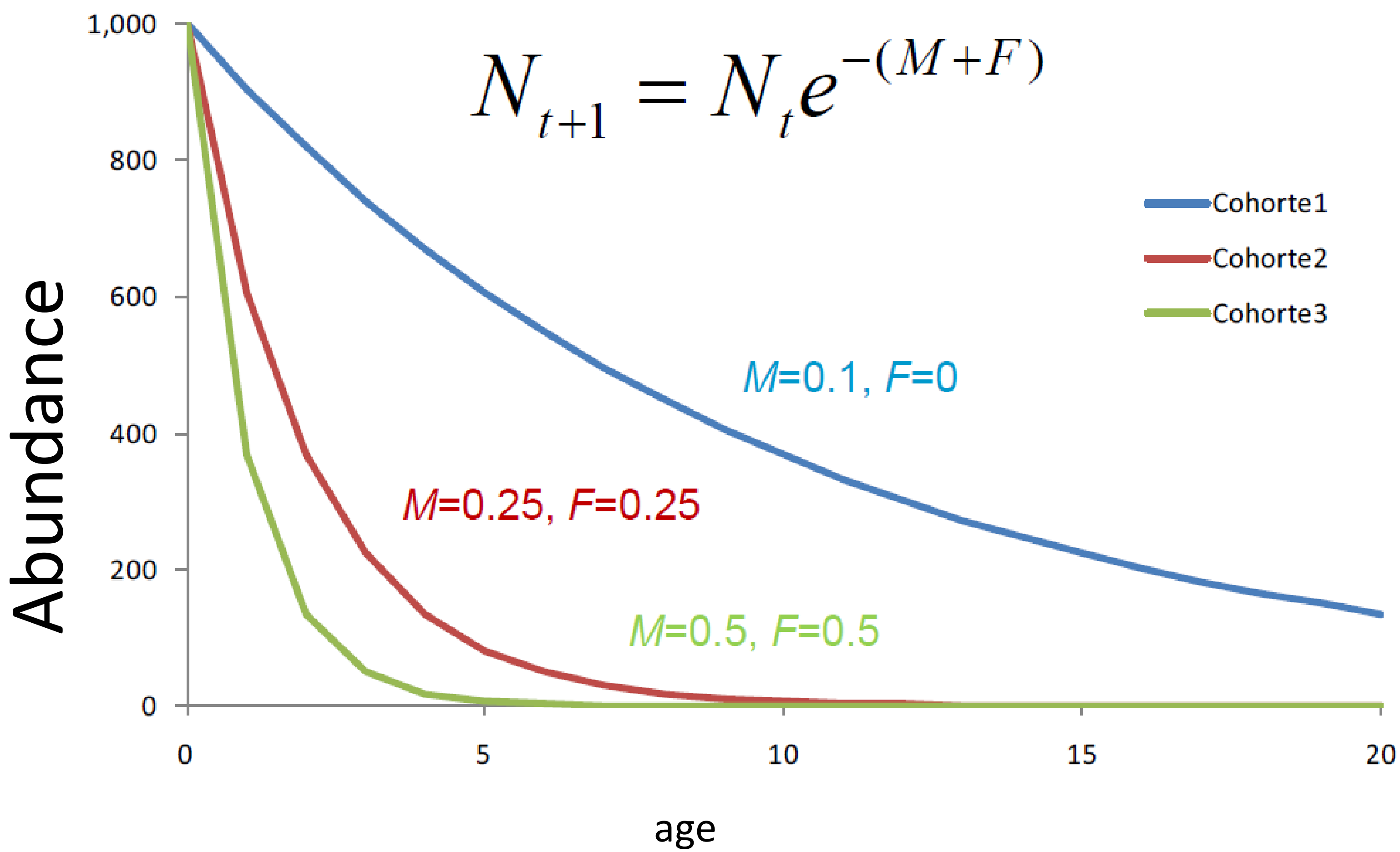
- We cannot capture the biomass dynamics unless we take into account the recruitment deviations
  - However ASPMdev is only able to estimate the relative scale
  - Even when the recruitment estimates are provided, the model ASPMfix cannot estimate the same scale as the IM
- Fitting one index at a time allows to estimate a scale when recruitment deviations are estimated (ASPMdev)
  - The biomass is lower than what the IM predict
  - The uncertainty around estimates are high

Catch-curve analysis

The trajectory of one cohort



The trajectory of one cohort



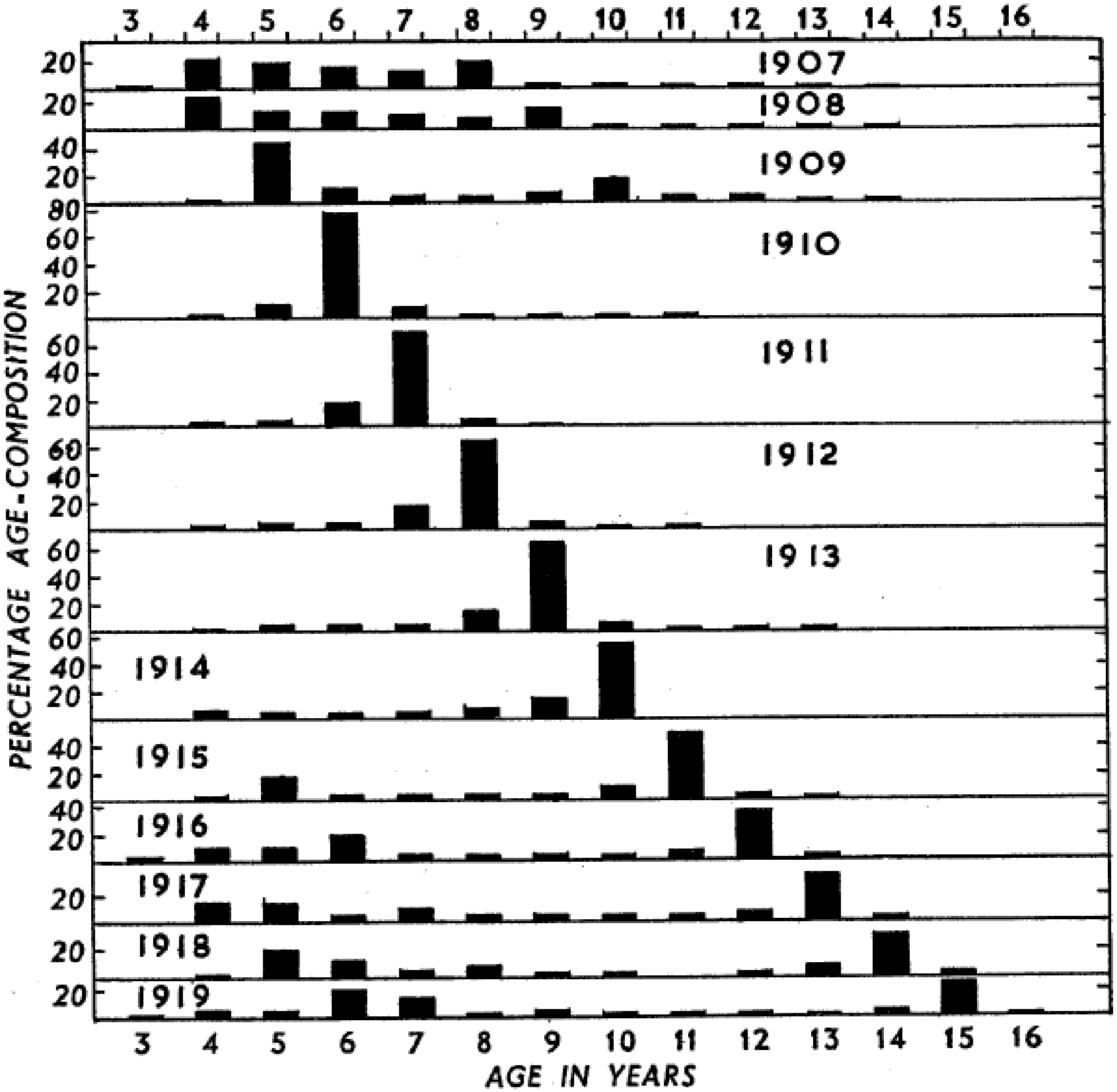
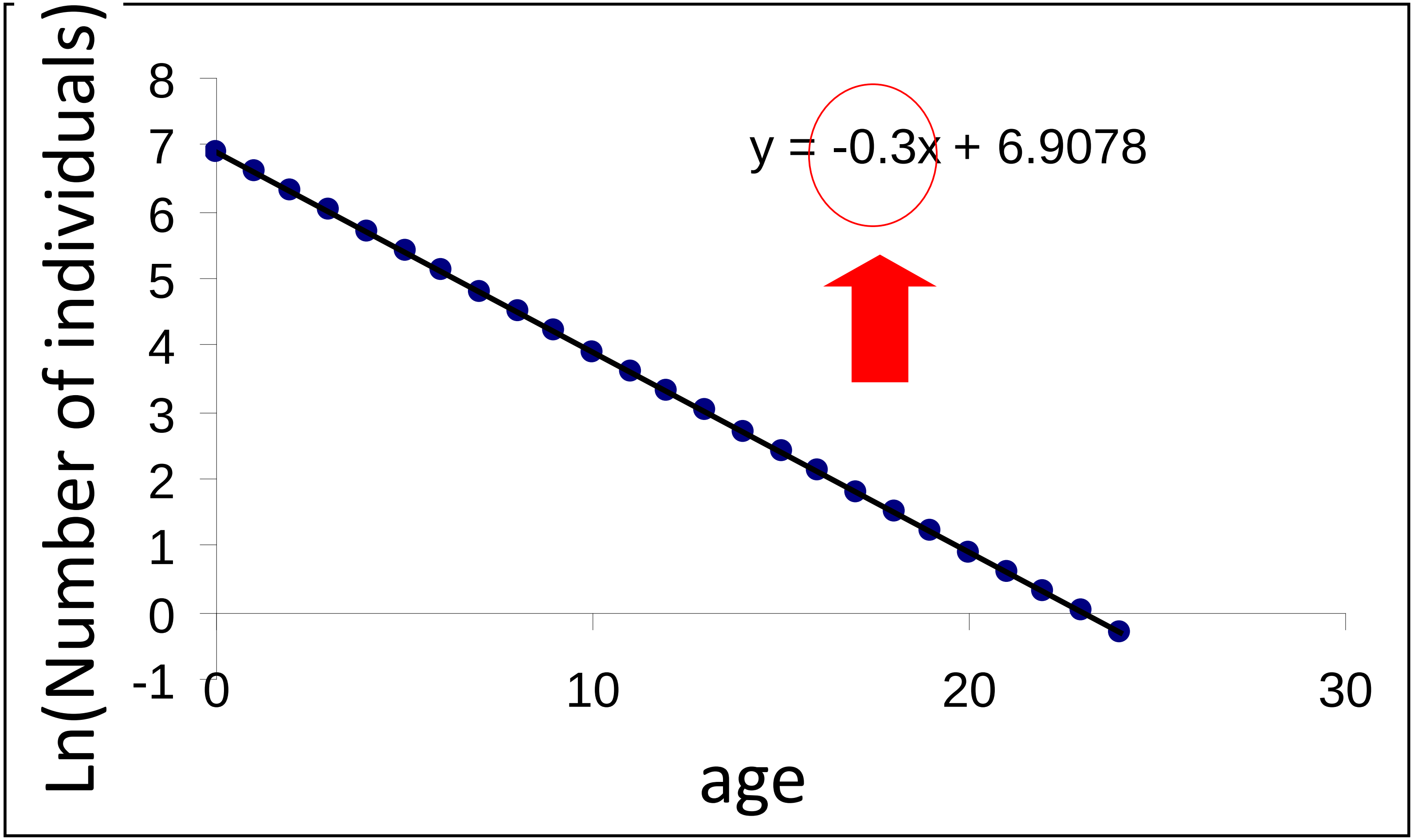


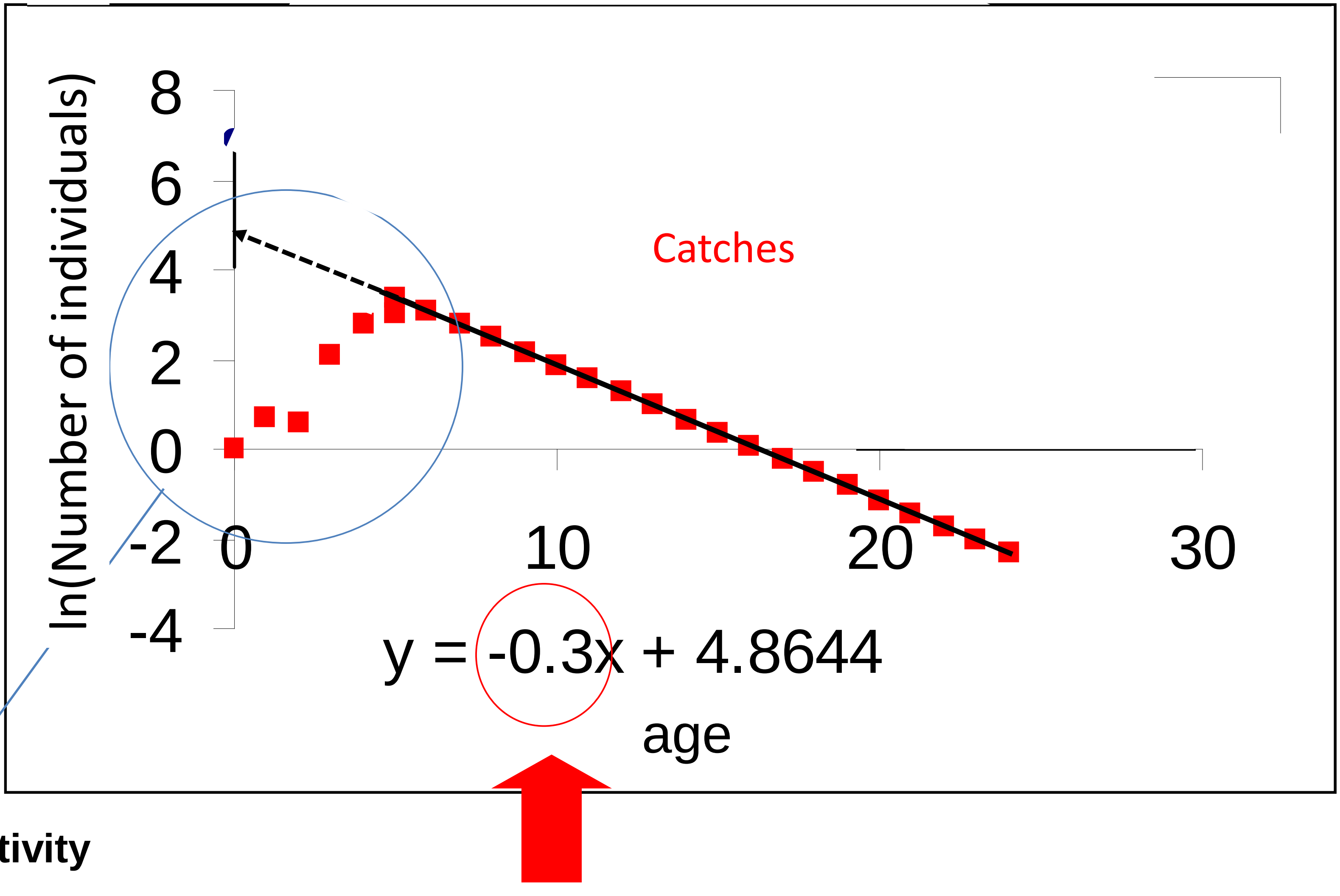
FIG. VI.14.—A PREDOMINANT YEAR-CLASS.

Percentage age composition of Norwegian herring in successive years of observation. (*After* Hjort, 1926)

The trajectory of one cohort

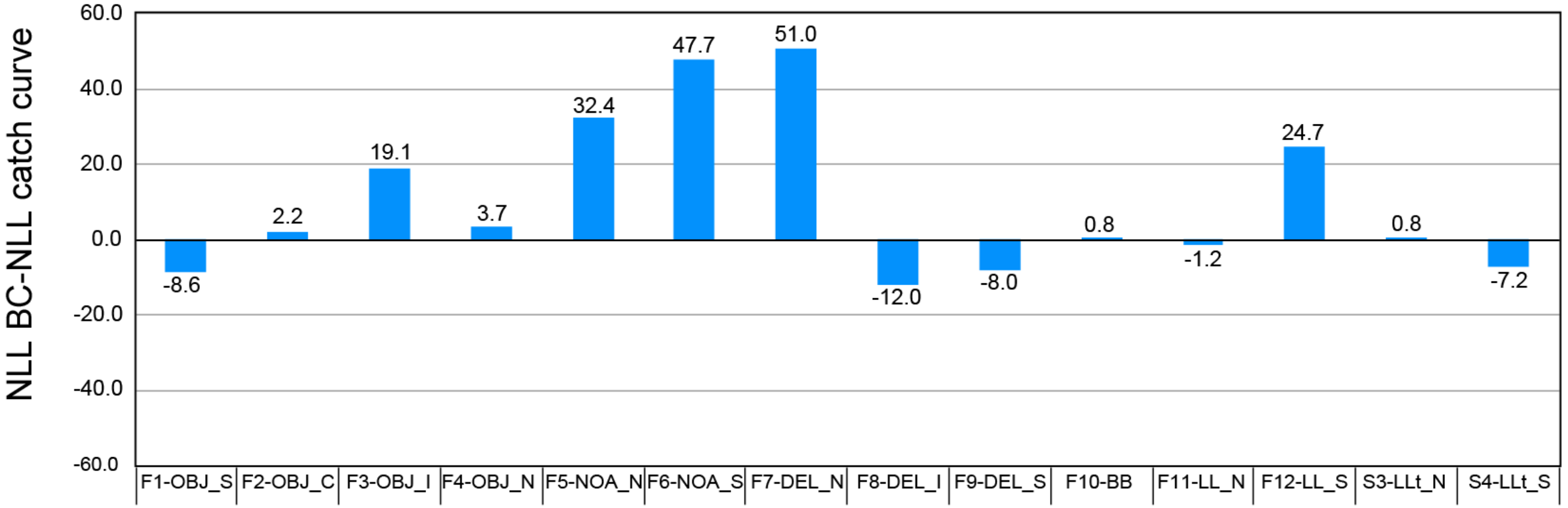


Catch curves

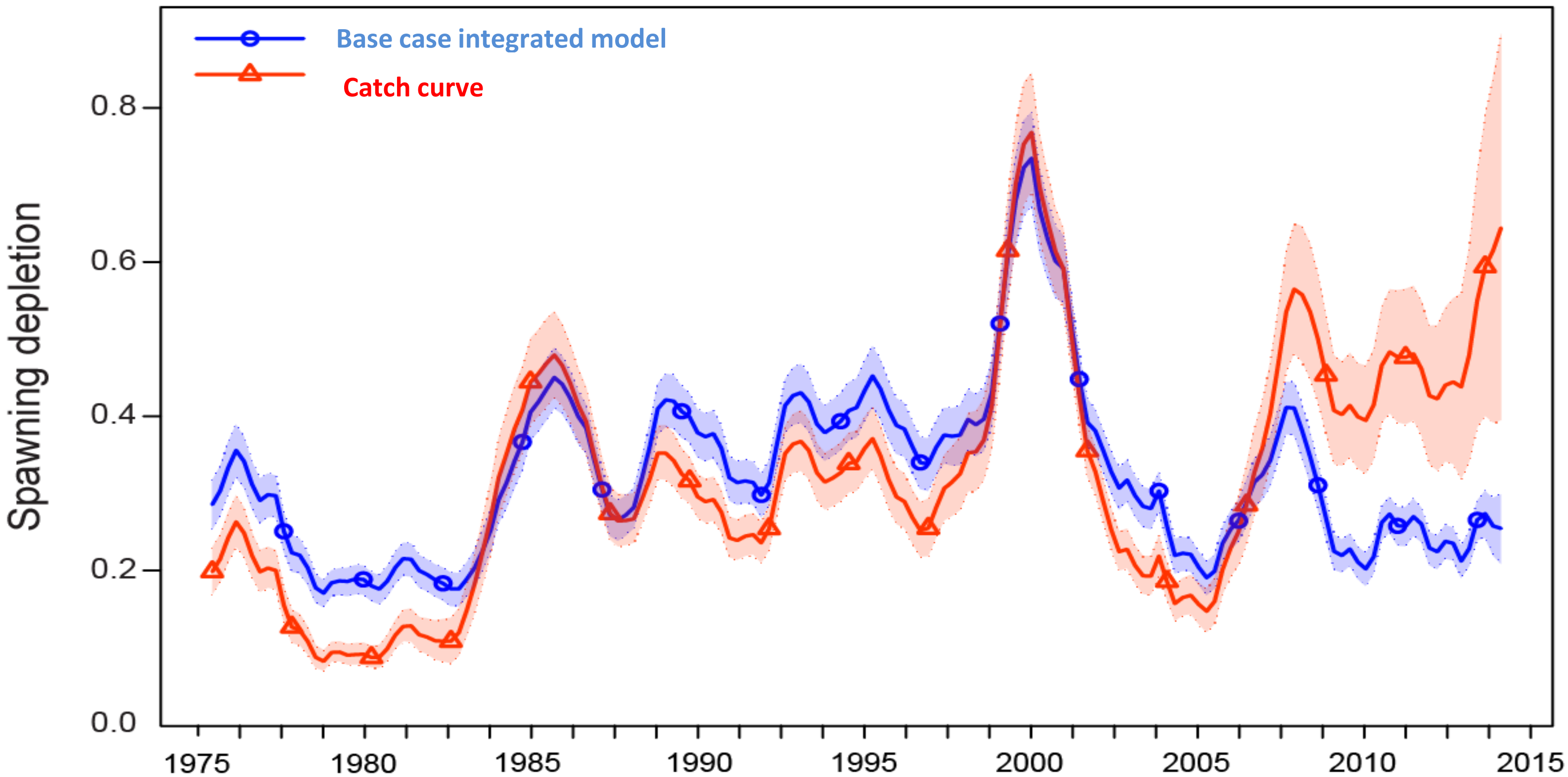


selectivity

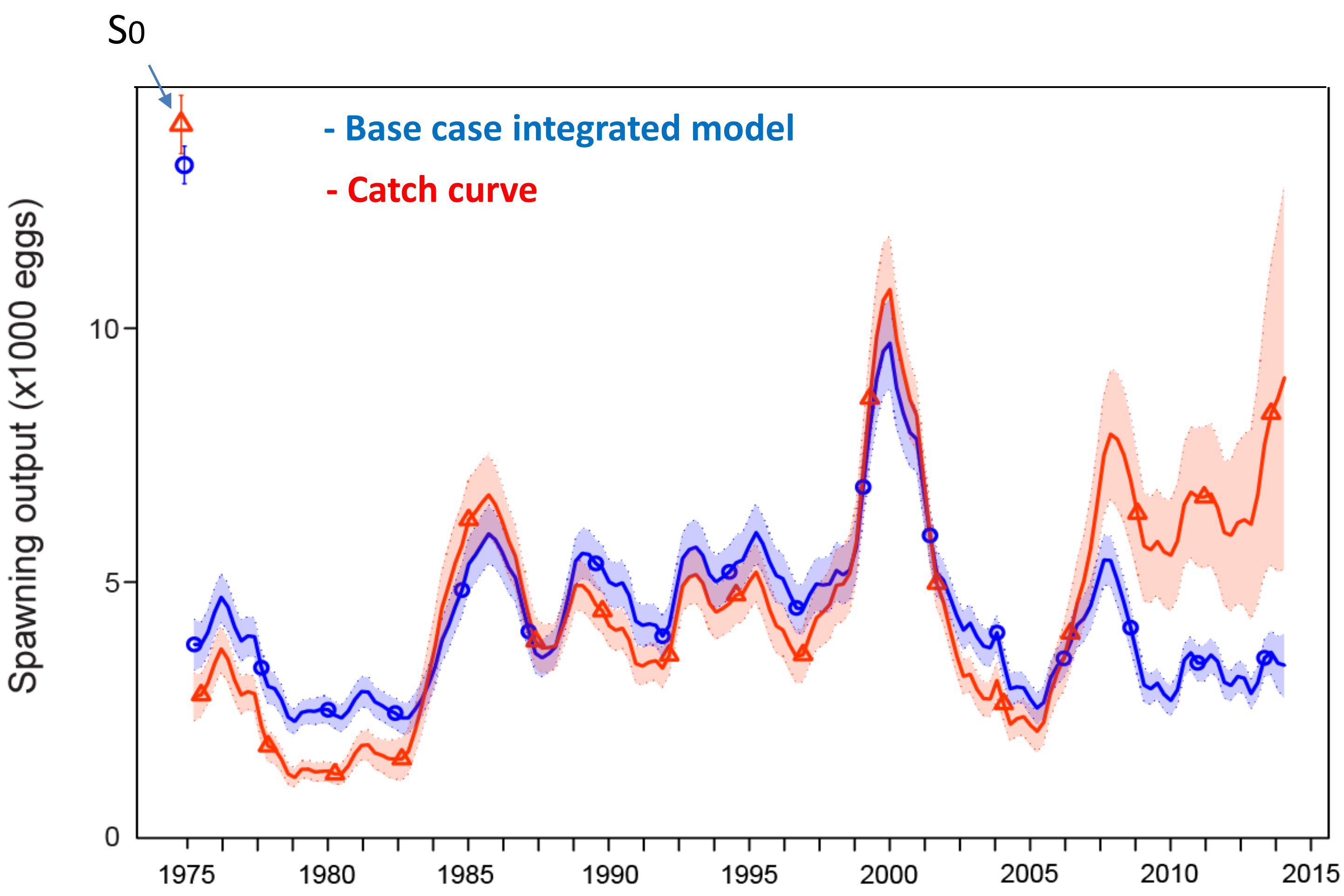
Results catch curve fits to length-frequency data

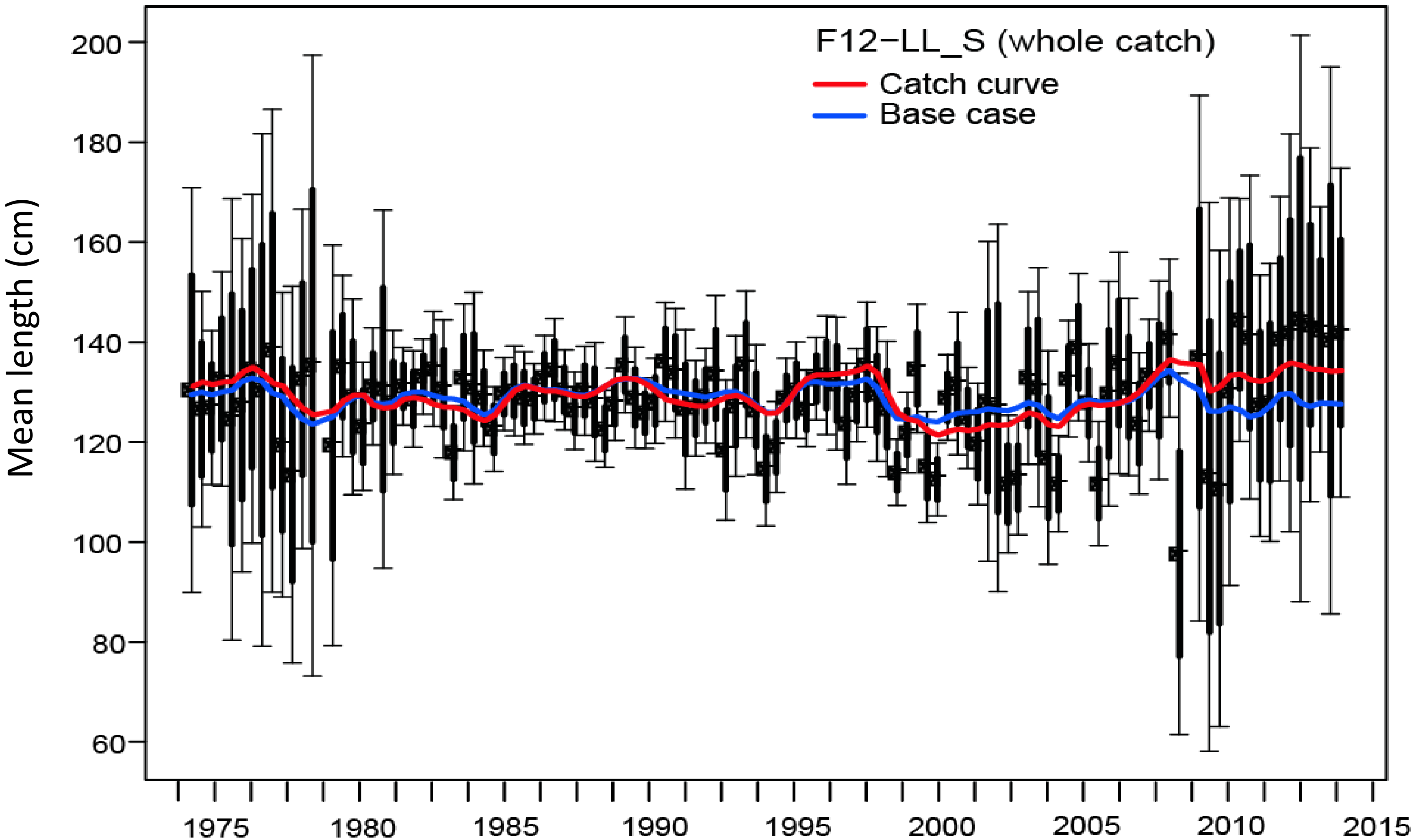


Results catch curve: relative abundance

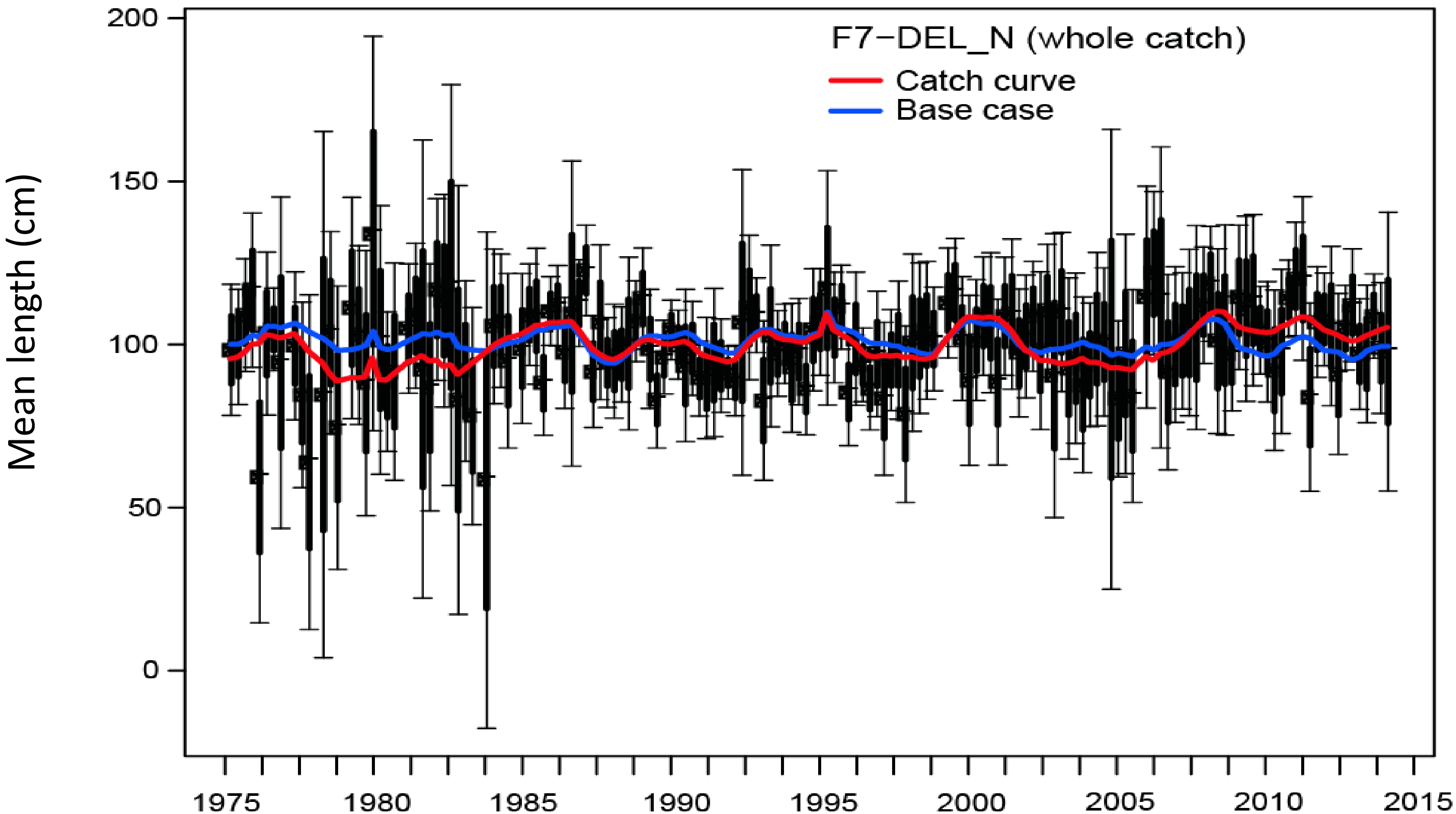


Results catch curve: absolute abundance

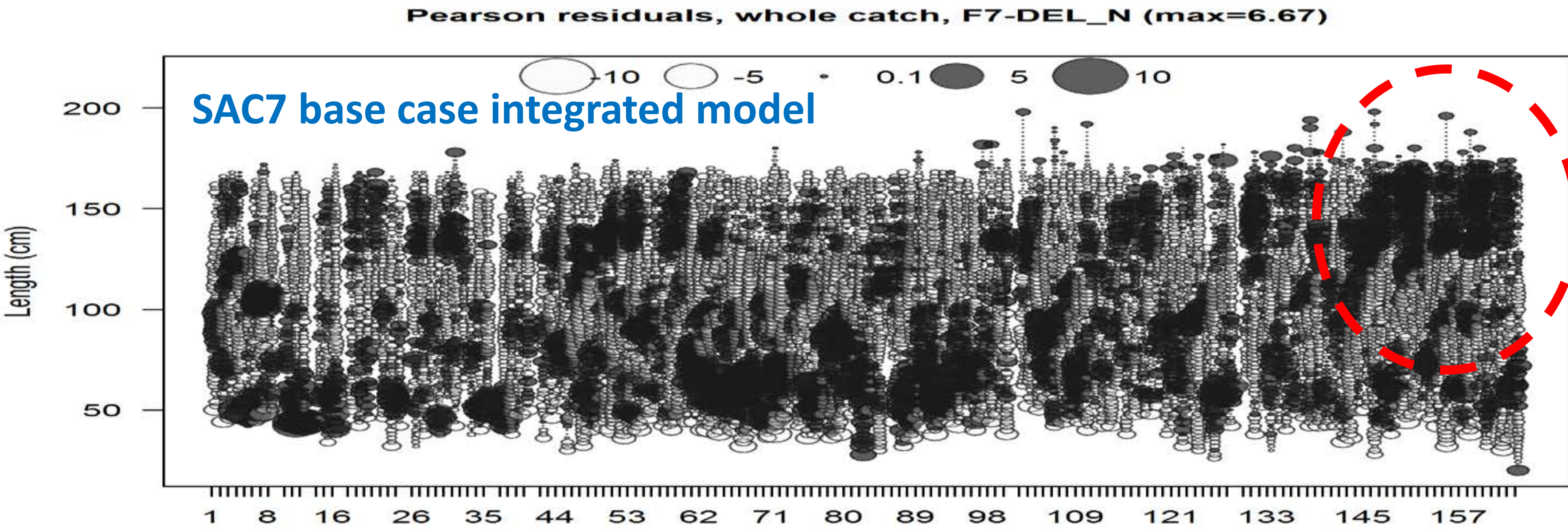


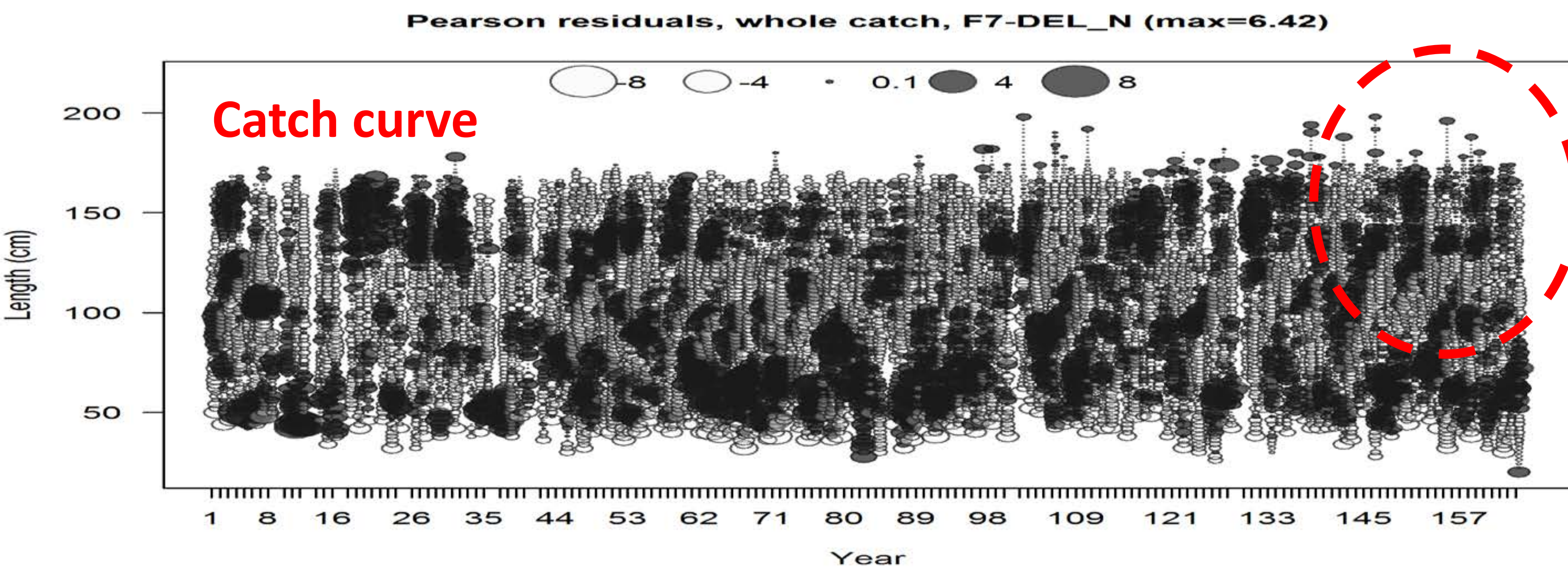


F12−LL_S (whole catch)
Catch curve
Base case
Mean length (cm)
200
180
160
140
120
100
80
60
1975
1980
1985
1990
1995
2000
2005
2010
2015

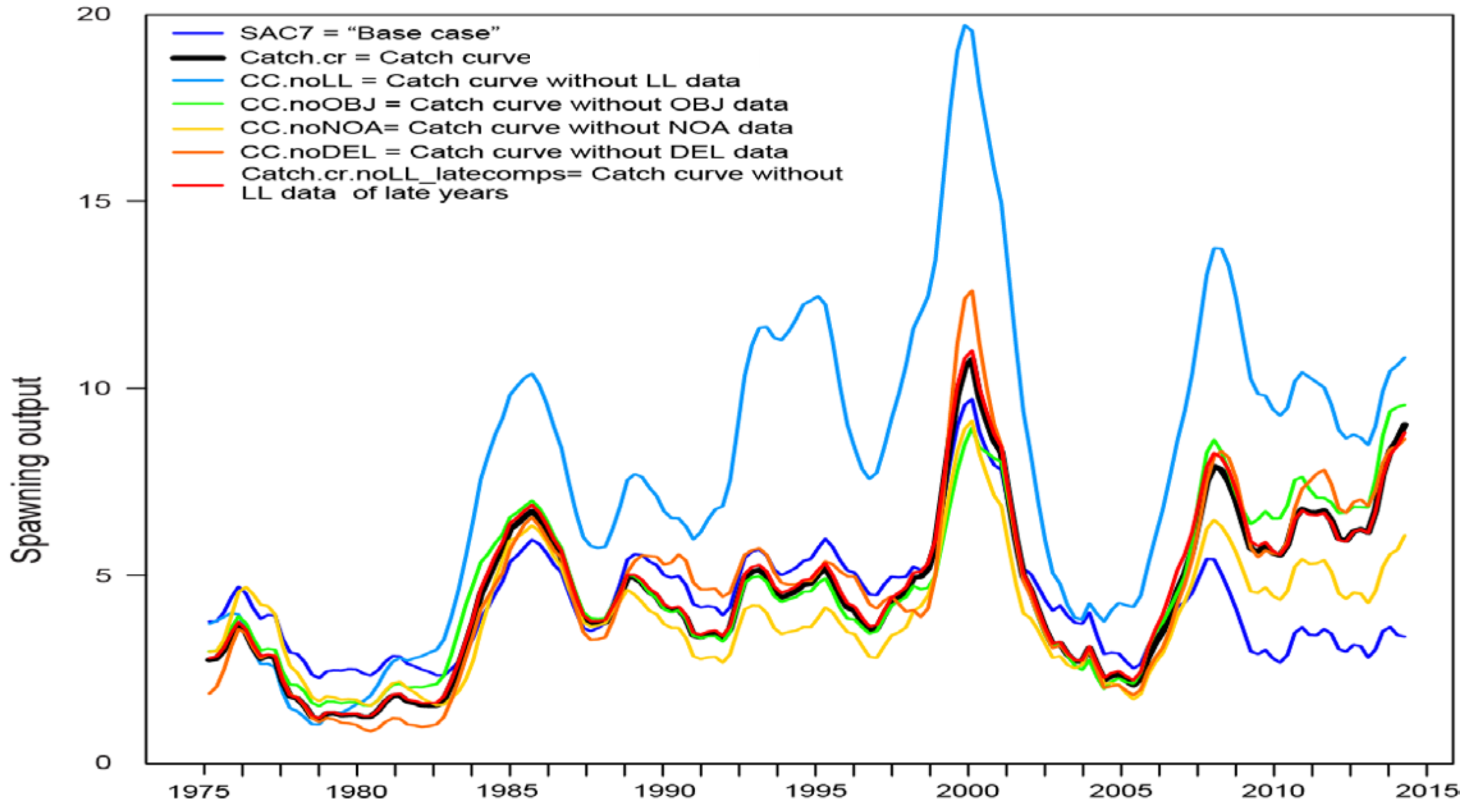


F7−DEL_N (whole catch)
Catch curve
Base case
Mean length (cm)
200
150
100
50
0
1975
1980
1985
1990
1995
2000
2005
2010
2015


Pearson residuals, whole catch, F7-DEL_N (max=6.67)
-10
-5
0.1
5
10
SAC7 base case integrated model
Length (cm)
200
150
100
50
1 8 16 26 35 44 53 62 71 80 89 98 109 121 133 145 157


Pearson residuals, whole catch, F7-DEL_N (max=6.42)
-8
-4
0.1
4
8
Catch curve
Length (cm)
200
150
100
50
1 8 16 26 35 44 53 62 71 80 89 98 109 121 133 145 157
Year

Catch curve: sensitivity to data sets



Results catch curve

- The absolute biomass estimates from the catch-curve are similar to those of the base-case model for most of the series
- At the end of the series there is an indication model misspecification at the end of the time-series
- The length-frequency of LL_S fleet is in the most influent in the catch-curve results

Depletion model

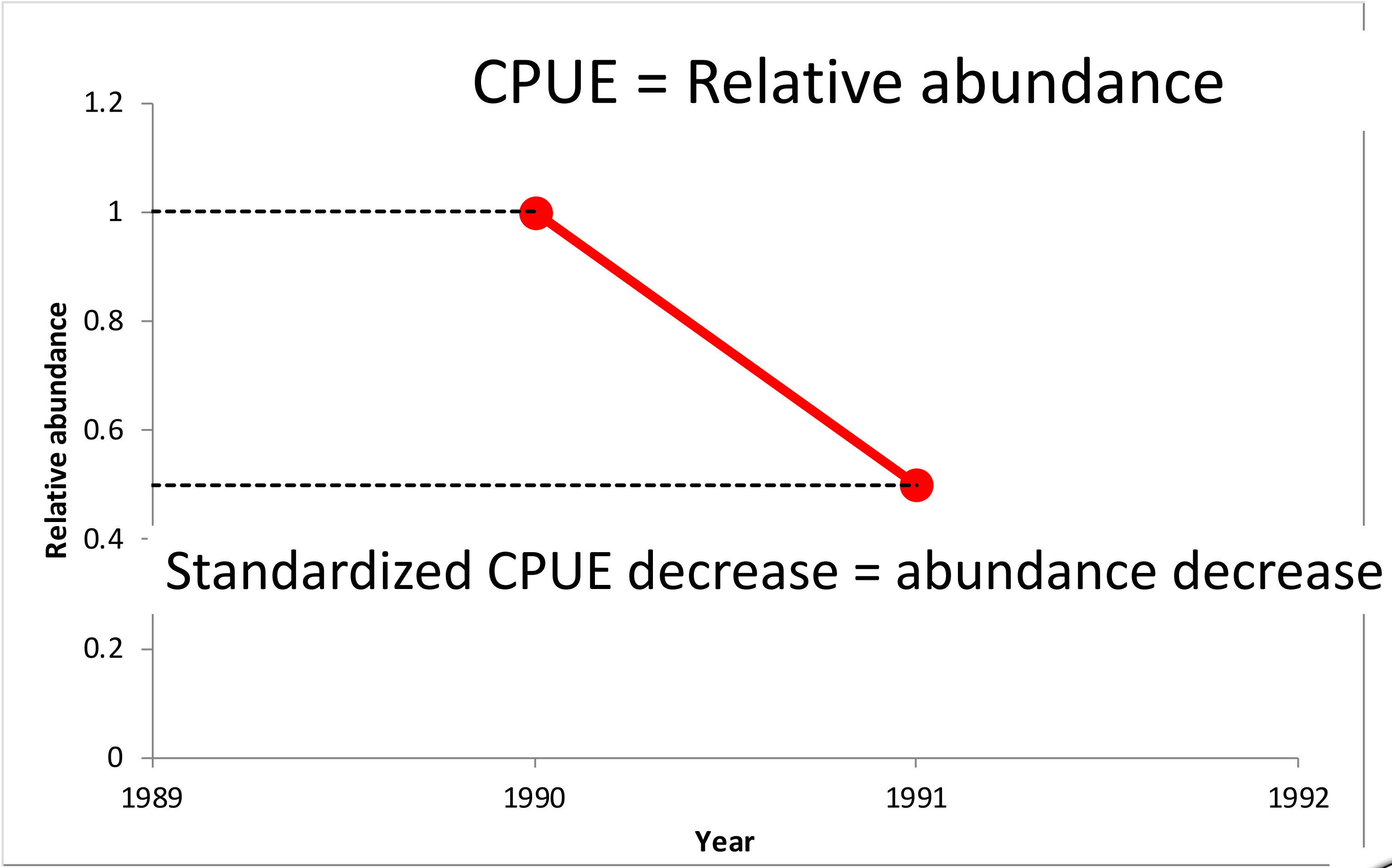
CPUE

$$C_t = q \times E_t \times B_t$$

$$C_t / E_t = q \times B_t$$

- C_t / E_t is the “catch per unit of effort” (CPUE)
- CPUE is proportional to the biomass of the stock B_t
- The proportionality constant is **q (catchability)**

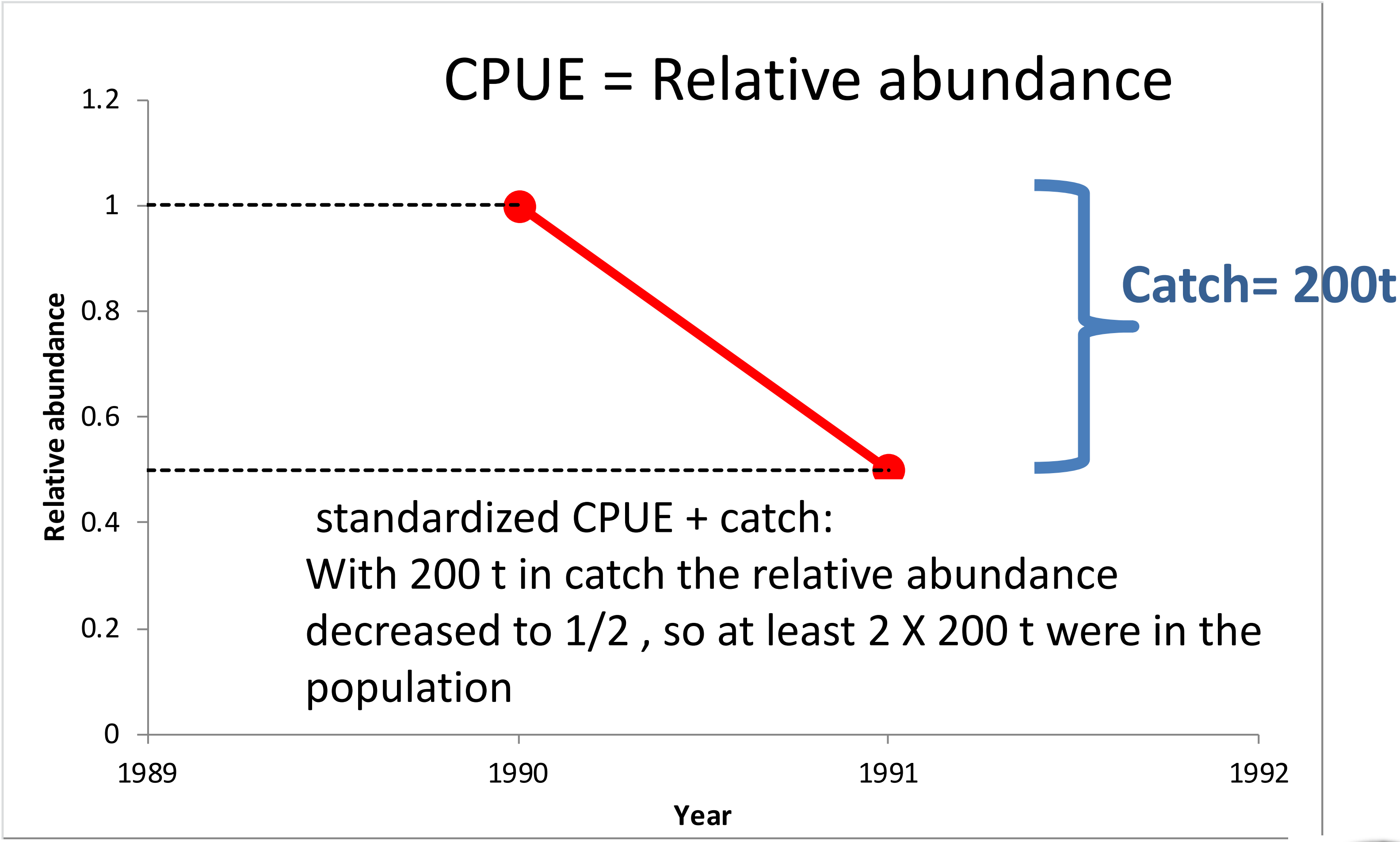
CPUE: why use it



Maunder (2016)

CPUE: why use it

CPUE decreased by 1/2



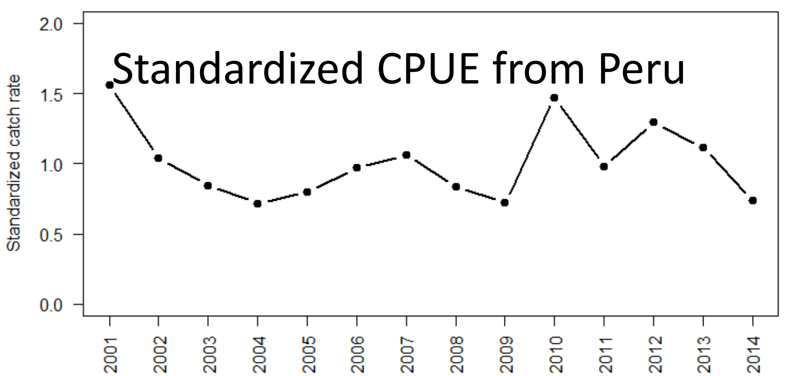
Maunder (2016)

CIAT IATTC

CPUE: what scale? Dorado work

Annual cpue

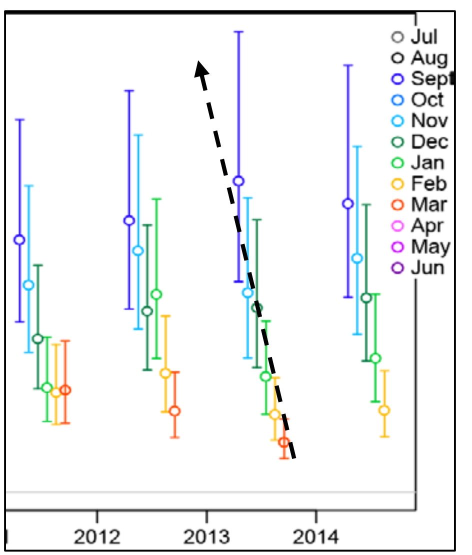
- Low information content
- Constant



Torrejón – Magallanes y Oliveros – Ramos (2015)

Monthly cpue

- High information content
- Fast growth
- High mortality rate



Standardized CPUE from Ecuador

Aires-da-Silva et al (2016)

Managing Data-Poor Fisheries: Case Studies, Models & Solutions 1:251–258, 2010
Copyright: California Sea Grant College Program 2010
ISBN number 978-1-888691-23-8

A Depletion Estimator for Within-Season Management of Yellowfin Tuna

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mmaunder@iattc.org

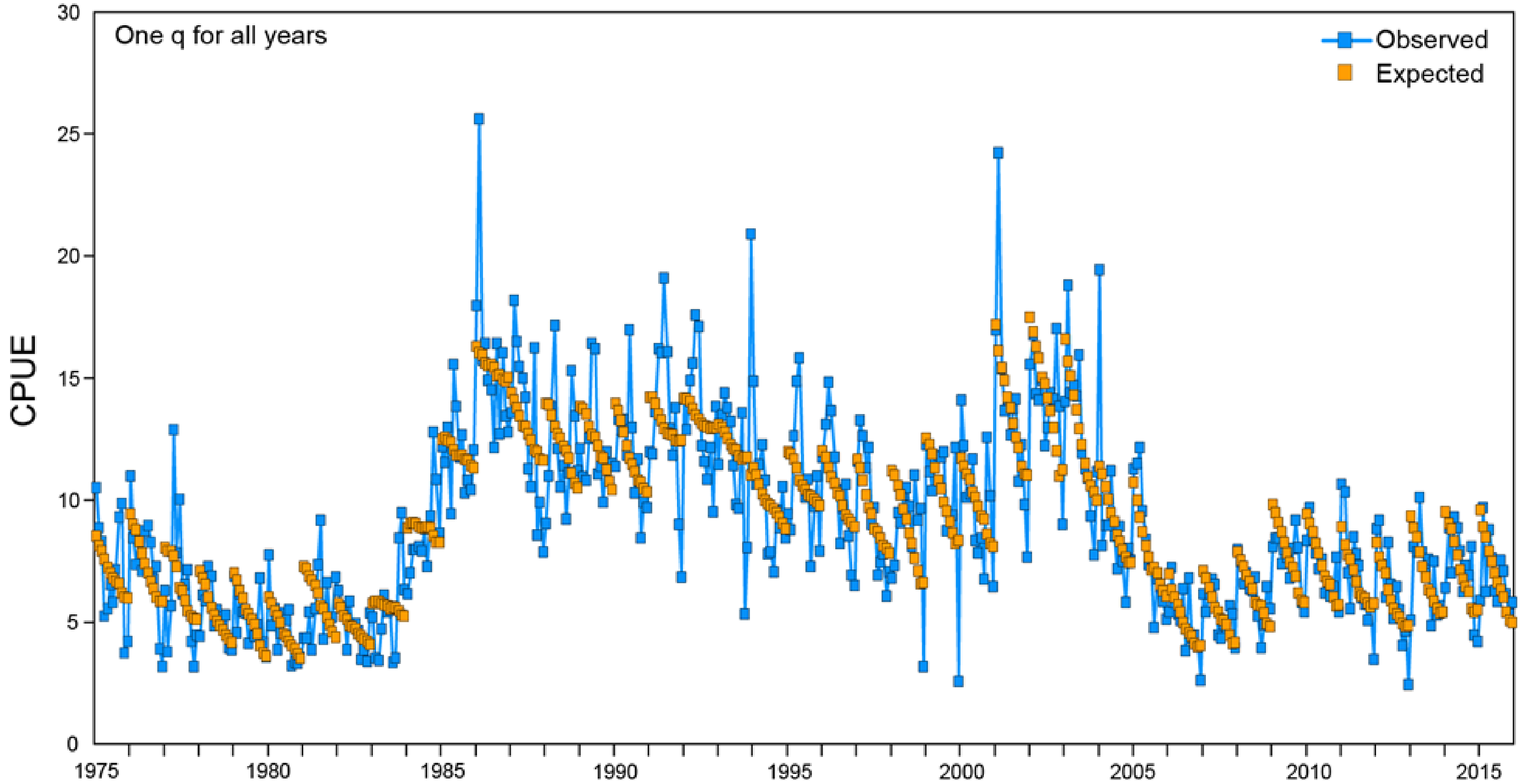
$$B_{y,w+1} = B_{y,w}\left(1 + G\right)S + R - C_{y,w}$$

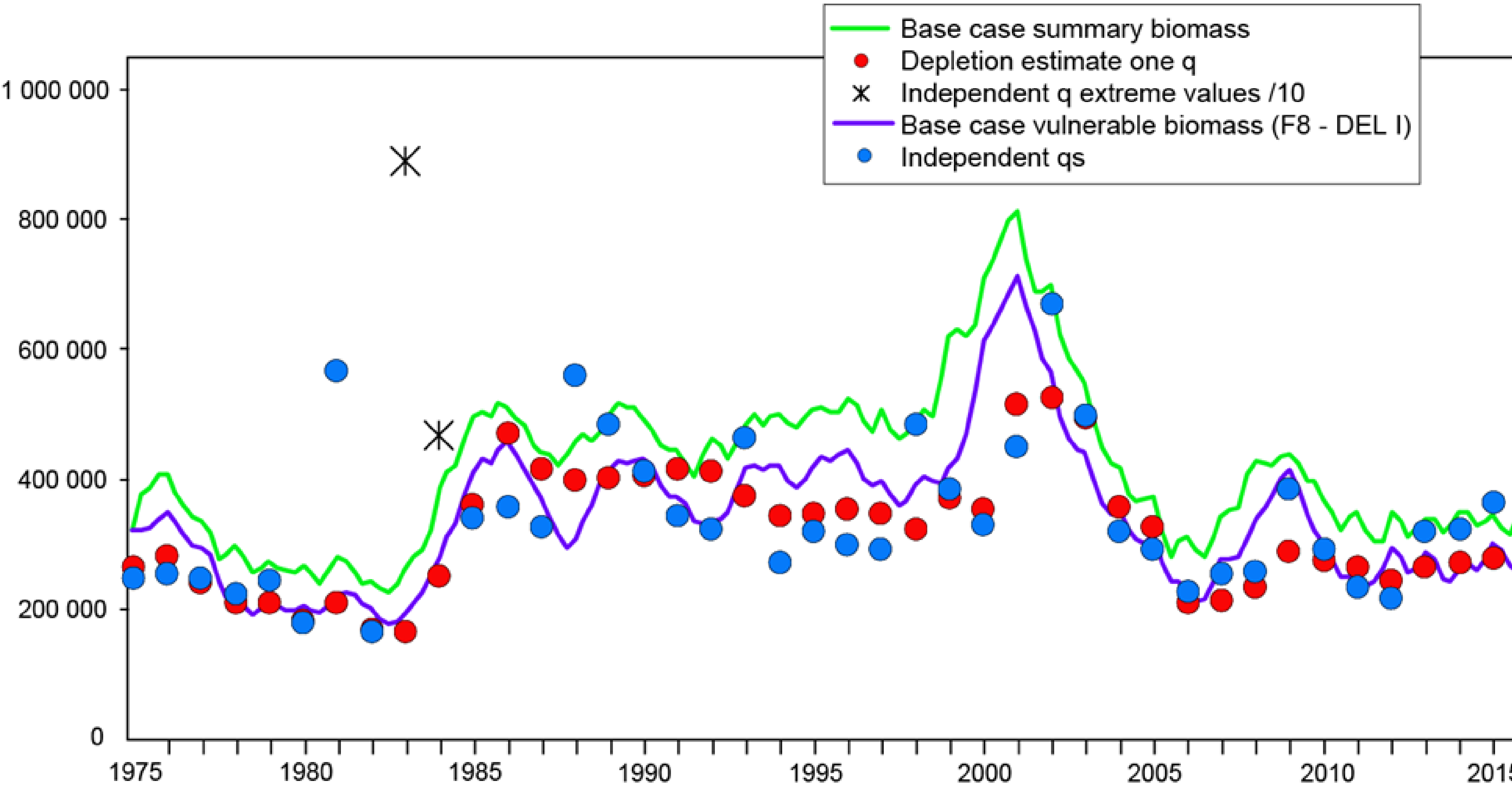
where $B_{y,w}$ is the biomass in week w of year y, and $C_{y,w}$ is the catch in week w of year y.

$$\text{CPUE} = q \times B_t$$

In this study we used a monthly time step
CPUE is purse-seine catch per day fished, regardless of set type

Results: fits to CPUE



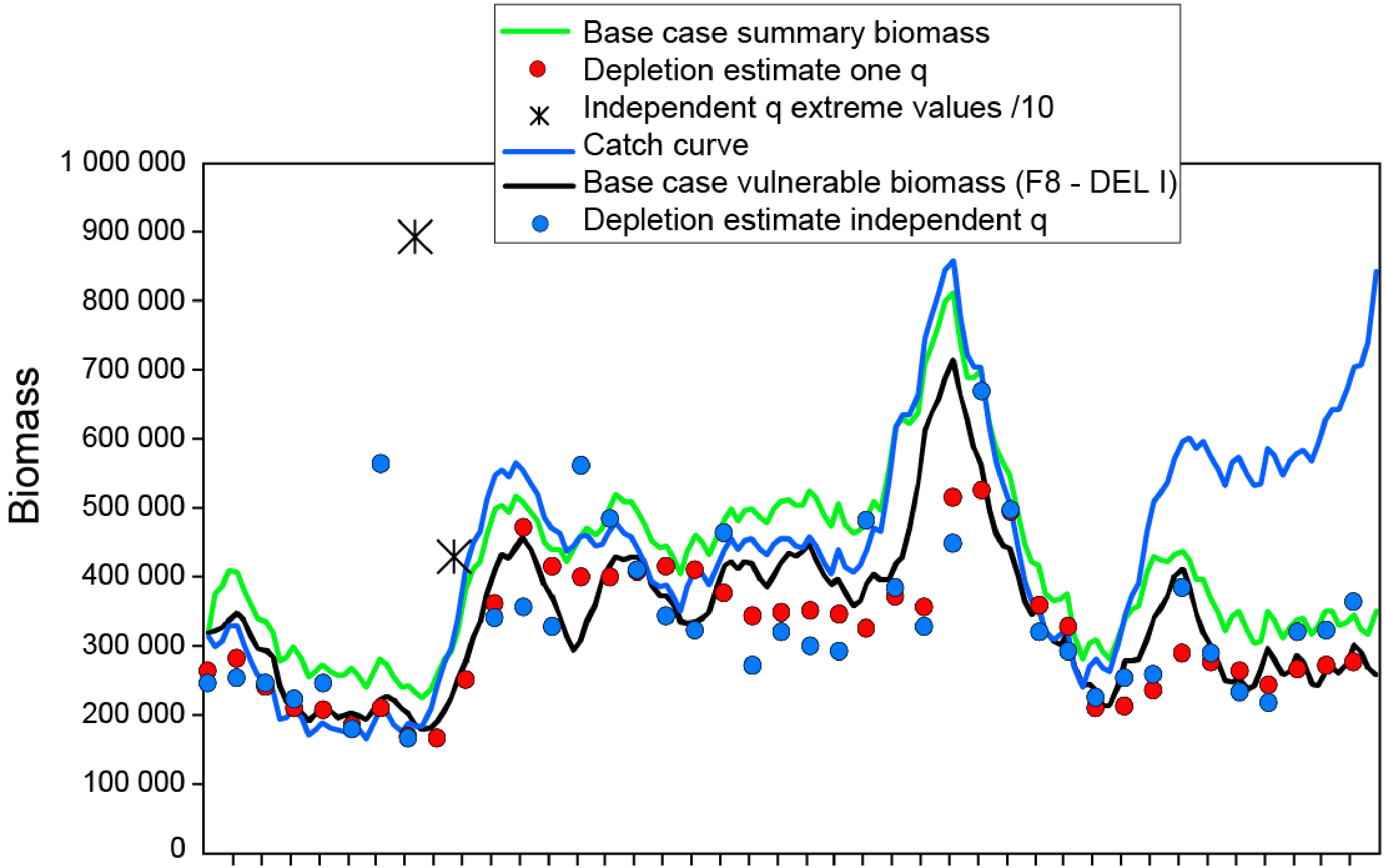

Base case summary biomass
Depletion estimate one q
Independent q extreme values /10
Base case vulnerable biomass (F8 - DEL I)
Independent qs
1 000 000
800 000
600 000
400 000
200 000
0
1975
1980
1985
1990
1995
2000
2005
2010
2015

Results depletion model

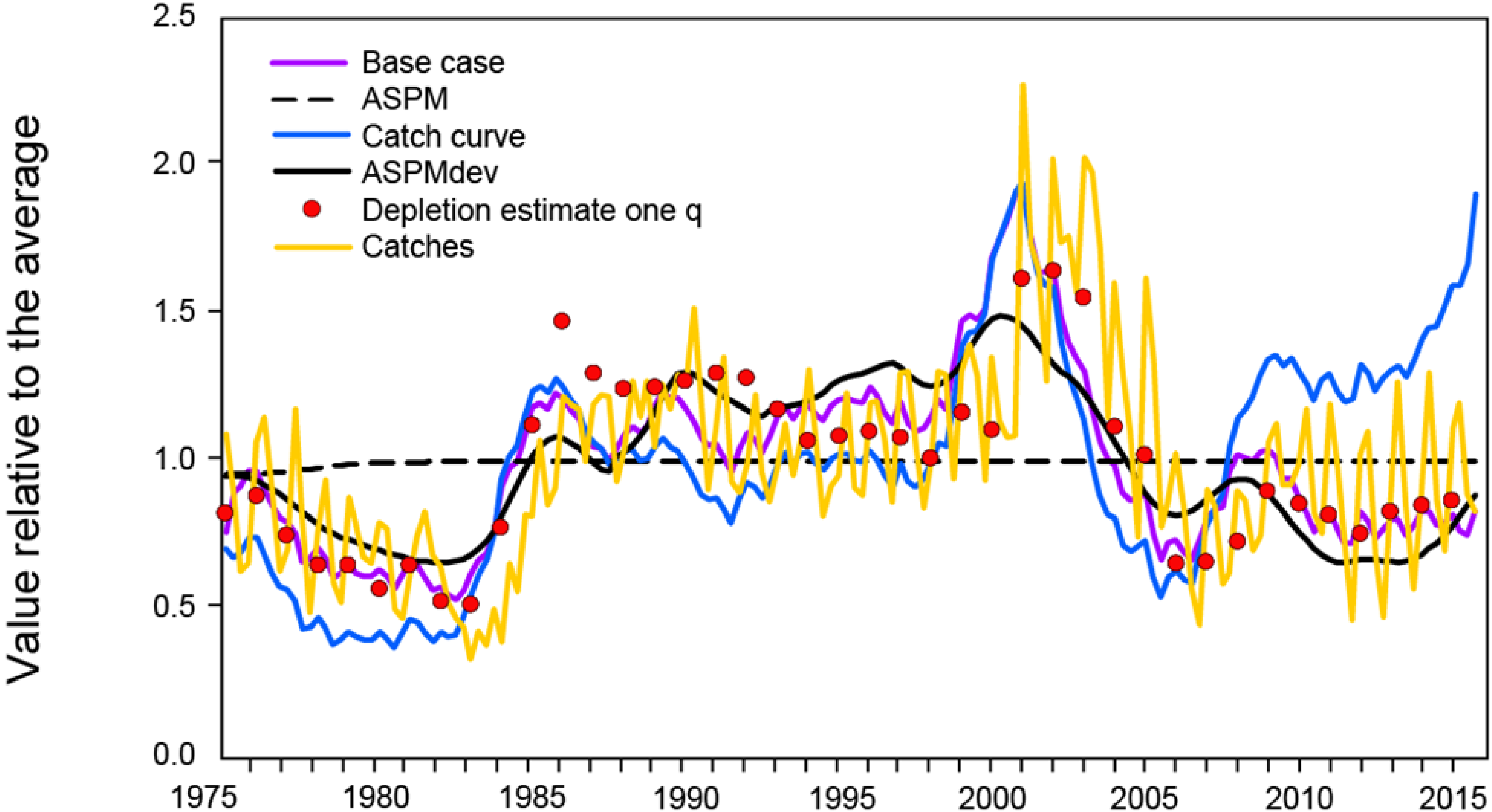
- The depletion estimator provided good fit to the data
- The depletion model was able to provide an estimate of the absolute abundance, which coincided with the base-case model, this increased our confidence on the integrated model
- This approach should investigated for improving the assessment, for example by changing to a monthly time step

Summary of results

Absolute abundance



Relative abundance



Conclusions

- The absolute scale cannot be estimated from the five indices of relative abundance (CPUE) alone within the age-structure production model, unless precise estimates of recruitment deviations are provided (ASPMfix)
- Only relative changes in abundance can be estimated from the five indices of relative abundance (CPUE) within a ASPMdev model
- The indices of relative abundance from LL are in contradiction to those from PS
- The LL index should be investigated for changes in the fishery that might have influenced its ability to represent relative abundance.

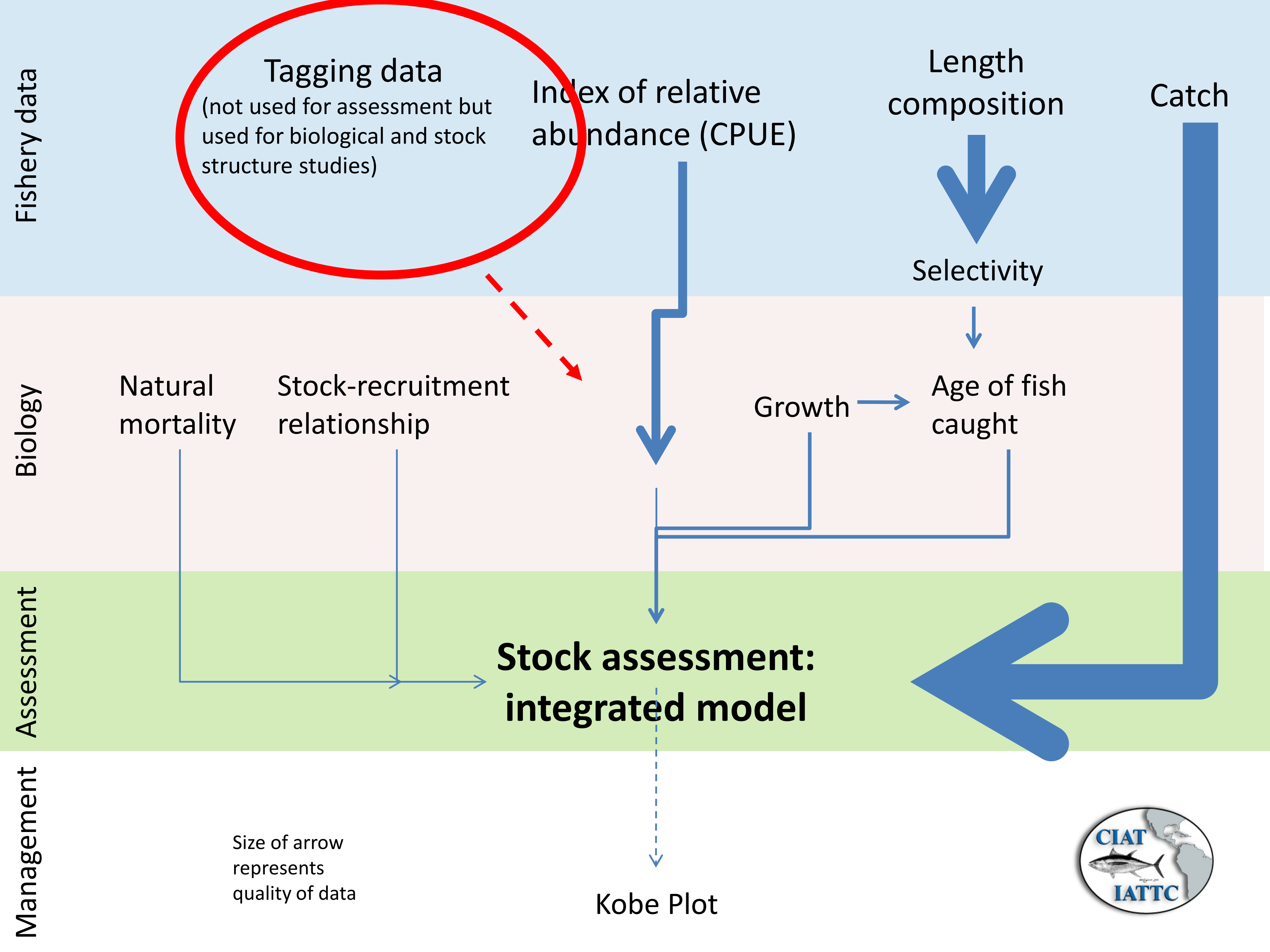
Conclusions

- The absolute biomass estimates from the catch-curve are similar to those of the base-case model, except at the end of the series, which might be an indication model misspecification at the end of the time-series

- The depletion estimator provided good fit to the data, was able to provide an estimate of the absolute abundance, which coincided with the base-case model, and increase our confidence in the stock assessment model.

- Given the good performance of the depletion model presented here and in Maunder (2010), suggests that the approach should investigated for improving the assessment, for example by changing to a monthly time step

- Also, the depletion model could provide “in-season” abundance estimates, important if catch quotas are used for management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Size of arrow represents quality of data
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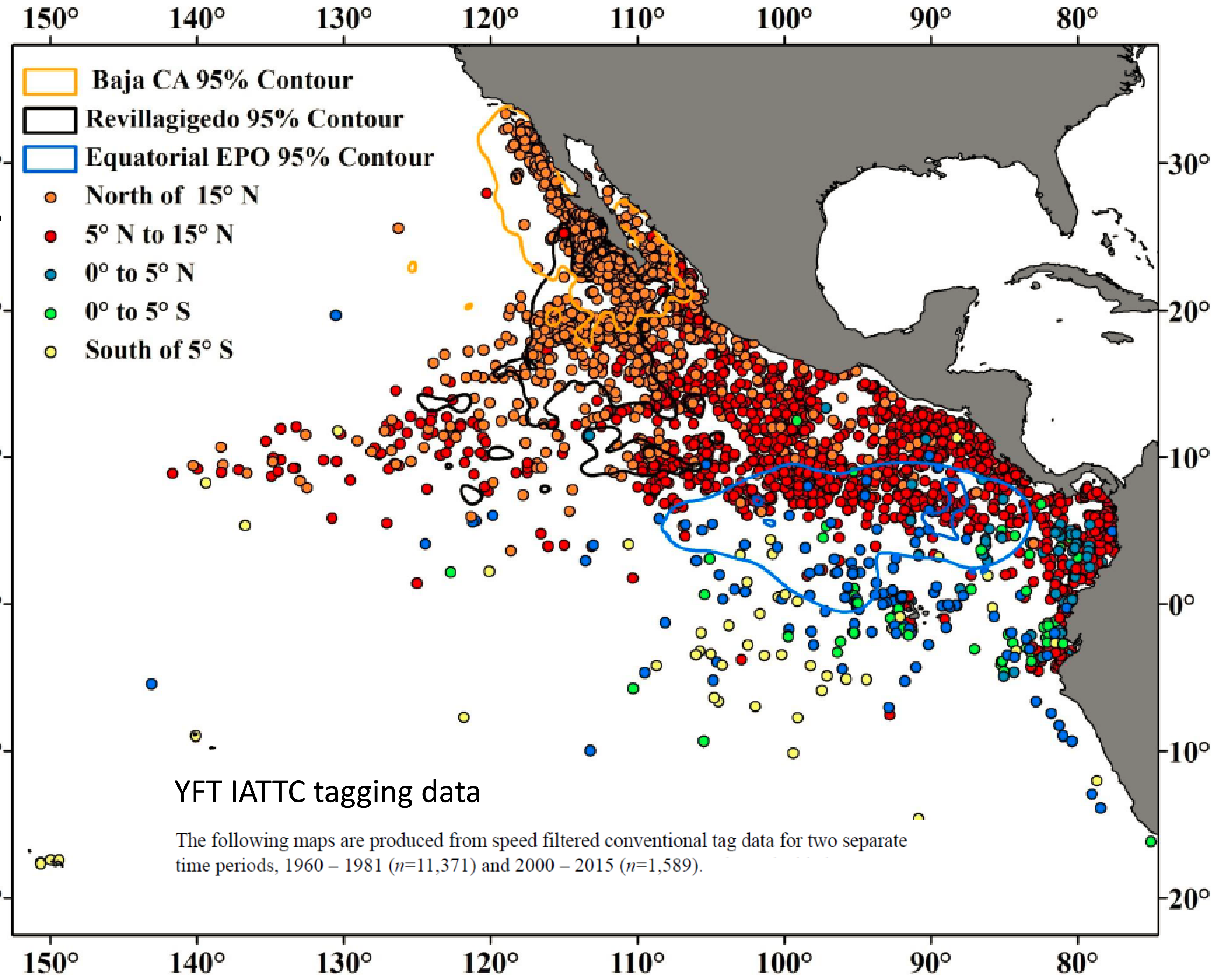
Release area



The following maps are produced from speed filtered conventional tag data for two separate time periods, 1960 – 1981 (n=11,371) and 2000 – 2015 (n=1,589).

Conclusions

- Tagging data could be another piece of information to be integrated into the models
- Tagging data provides information on biological (growth, natural mortality, movement and mixing rates) and fisheries process
- A large-scale tagging program can be used to estimate abundance

Thank you