Empirical selectivity

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Virtual workshop on Model Diagnostics in Integrated Stock Assessments

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Introduction

- Selectivity:
  - Assigning selectivity curves is one of the most important steps in creating contemporary statistical fishery stock assessment models.
  - focus of the first CAPAM workshop in 2013 and the associated special issue in Fisheries Research.
- Selectivity curves in stock assessment models:
  - represent a combination of contact gear selectivity, and
  - availability (e.g. due to the fish behavior of the fish or characteristics of the habitat),
  - this may result in complex selectivity shapes.
  - this is especially true when spatial processes of the dynamic are not modelled in an explicitly spatial model but are rather approximated using an area-as-fleet model.
  - Splines have been used to model selectivities with complex shapes
  - Splines are flexible but complicated to set up

Importance of correctly specifying selectivity

- An incorrectly specified selectivity curve can substantially bias the estimates of
  - estimate of absolute abundance,
  - estimate of fishing mortality,
  - and the consequently result in poor management advice.
- Therefore, it is important to ensure an appropriate selectivity curve is used.
- This is particularly true for the selectivity of old fish:
  - modelling as asymptotic or dome shape can have strong consequences in estimates.

Empirical selectivity

- The “empirical” selectivity diagnostic was recently developed at IATTC (e.g. Mauder et al 2020, Minte-Vera et al 2020, Xu et al 2020)
- Goals:
  - focus on the misfit of composition data for old fish that are more influential, but less abundant in the composition data,
  - used as a weighting metric in the newly developed Risk Analysis

Empirical selectivity

- The empirical selectivity (*Ta,t)* is simply the proportion at length *l* (or proportion at age *a*) in the catch divided by the proportion at length (or proportion at age) in the population

At length

$$T_{l,t} = \frac{\frac{Cl.t}{\sum_l^L Cl.t}}{\frac{Nl,t}{\sum_l^L Nl.t}}$$

At age

$$T_{a,t} = \frac{\frac{Ca.t}{\sum_a^A Ca.t}}{\frac{Na,t}{\sum_a^A Na.t}}$$

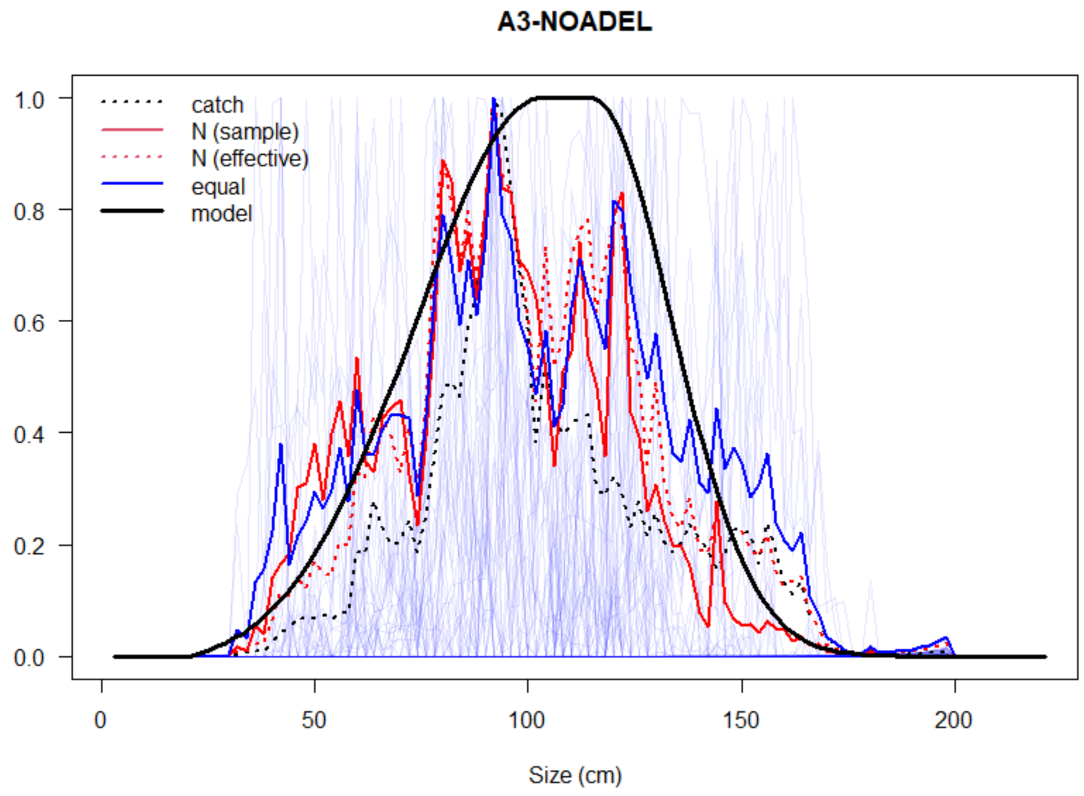
- Proportion in the catch comes from samples
- Proportion in the population comes from a preliminary integrated model fit set up with

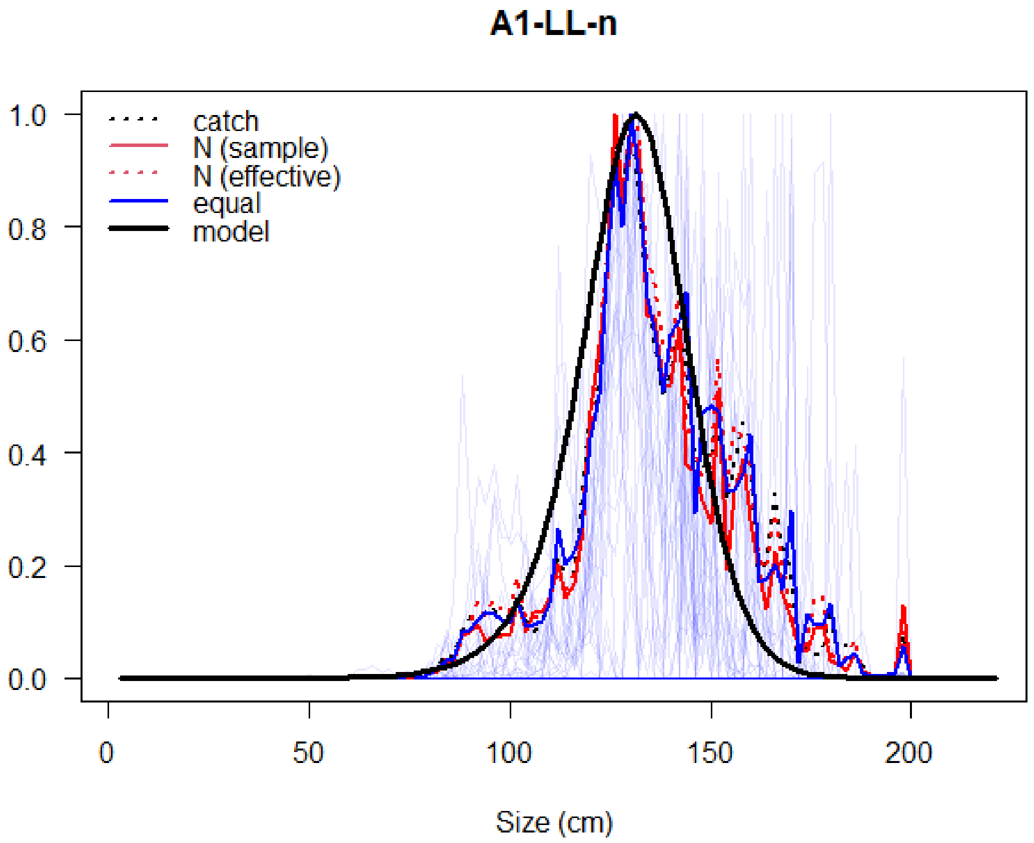
Empirical selectivity

- computed for each time step in the model where there is composition data,
- averaged by period or for the whole time series.
- weighted average:
    - weighted by the composition sample size,
    - weighted by the catches or
    - not weighted
- Implemented in the R package ***empirical.selectivity*** (Oliveros-Ramos 2021)

Empirical selectivity

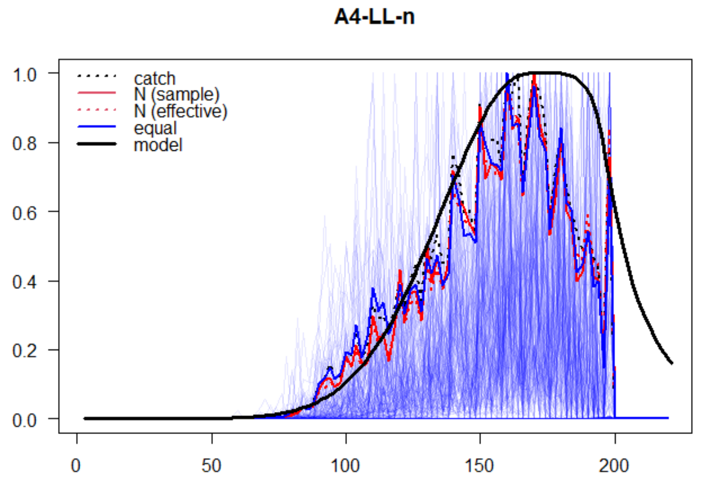
remotes::install_github("roliveros-ramos/fks")
remotes::install_github("roliveros-ramos/empirical.selectivity")

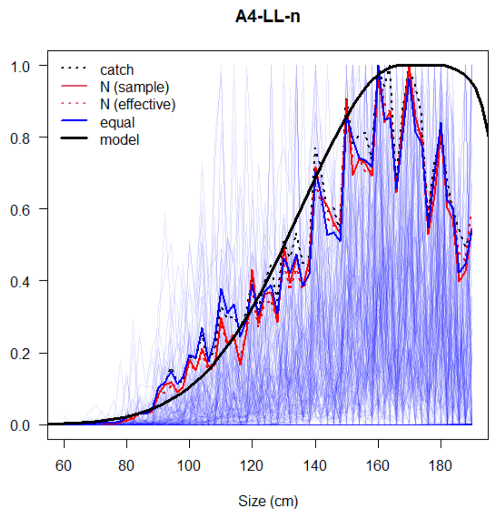


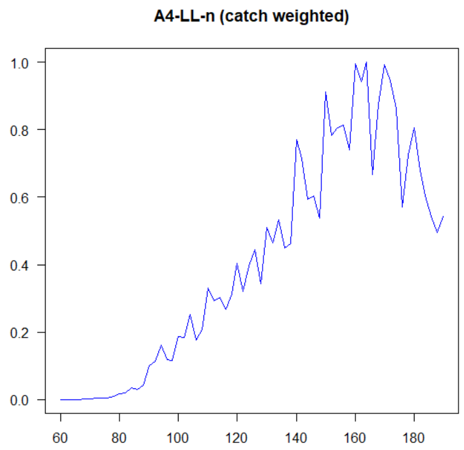


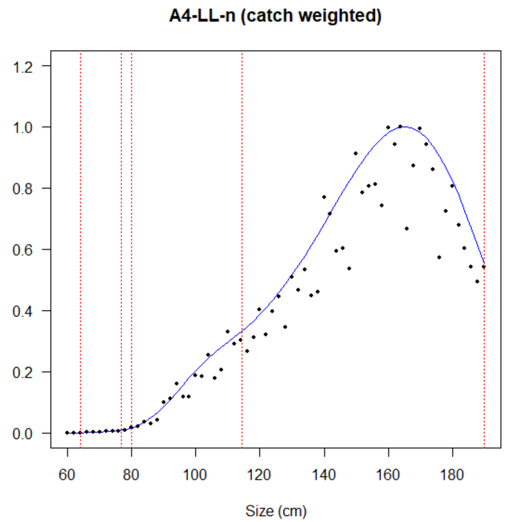
Empirical selectivity for model development

- facilitates the choice of the number and position of nodes, by fitting splines to empirical selectivities.
- allows for the choice of meaningful starting values for the spline parameters.










```
# A4-LL-n Length Selex
  0    0    0    0    0    0    -99  0    0    0    0    0.5  0    0    # SizeSpline_Code_A4-LL-n(1)
  -0.01  1    0.658   0    0.001   1    3    0    0    0    0    0.5  0    0    # SizeSpline_GradLo_A4-LL-n(1)
  -1   0.01    -0.052  0    0.001   1    3    0    0    0    0    0.5  0    0    # SizeSpline_GradHi_A4-LL-n(1)
  60   190  64   64   0    0    -99  0    0    0    0    0.5  0    0    # SizeSpline_Knot_1_A4-LL-n(1)
  60   190  76.748   76.7475911321447    0    0    -99  0    0    0    0    0.5  0    0    # SizeSpline_Knot_2_A4-LL-r
  60   190  80   80.0000655666902    0    0    -99  0    0    0    0.5  0    0    # SizeSpline_Knot_3_A4-LL-n(1)
  60   190  114.411  114.411292969612    0    0    -99  0    0    0    0    0.5  0    0    # SizeSpline_Knot_4_A4-LL-r
  60   190  190  190  0    0    -99  0    0    0    0    0.5  0    0    # SizeSpline_Knot_5_A4-LL-n(1)
  -9   7    -8.026   0    1    1    -2   0    0    0    0    0.5  0    0    # SizeSpline_Val_1_A4-LL-n(1)
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  -9   7    -0.732   0    1    1    -2   0    0    0    0    0.5  0    0    # SizeSpline_Val_5_A4-LL-n(1)
```

27
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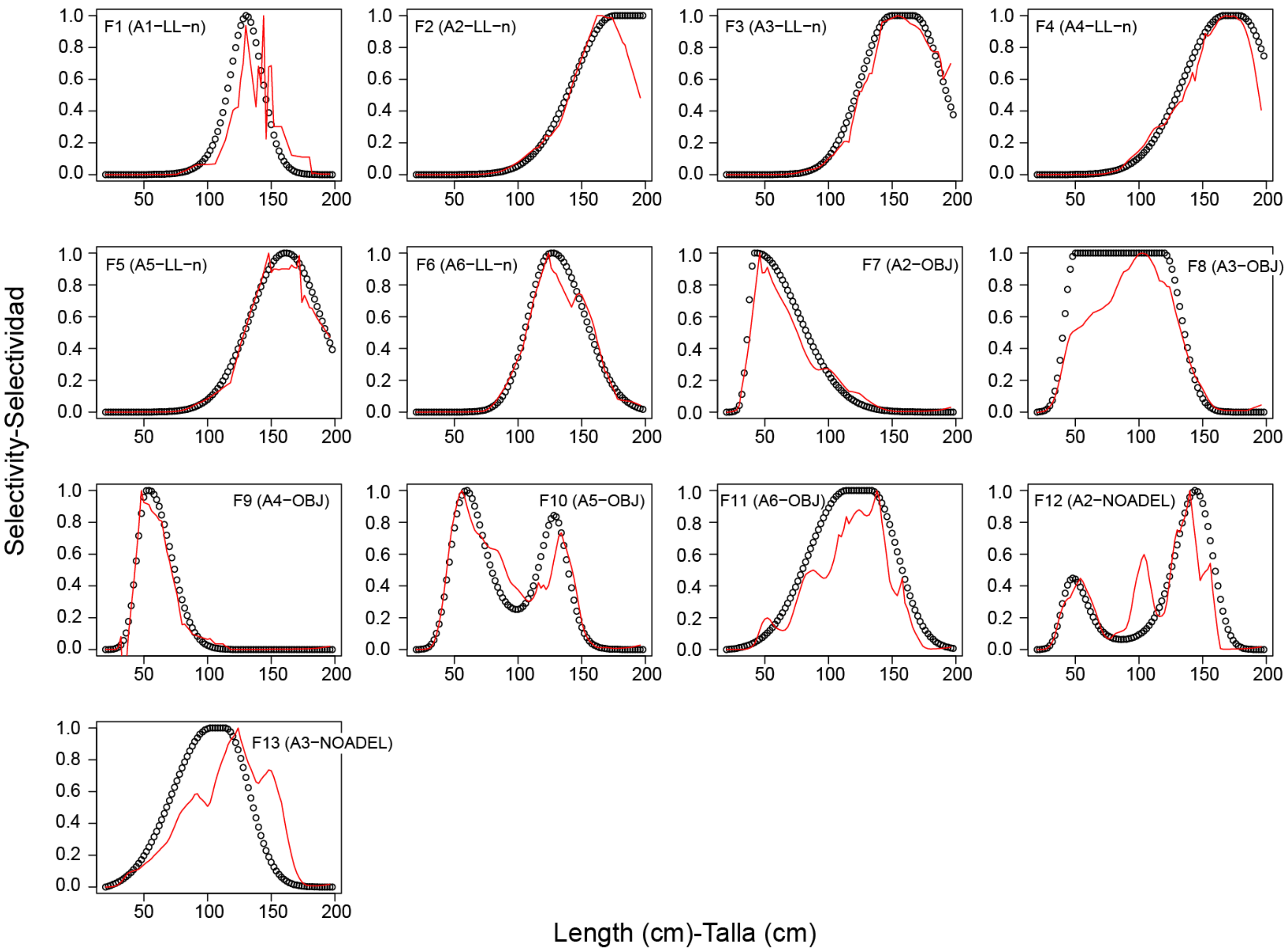
Example: Bigeye tuna in the Eastern Pacific Ocean

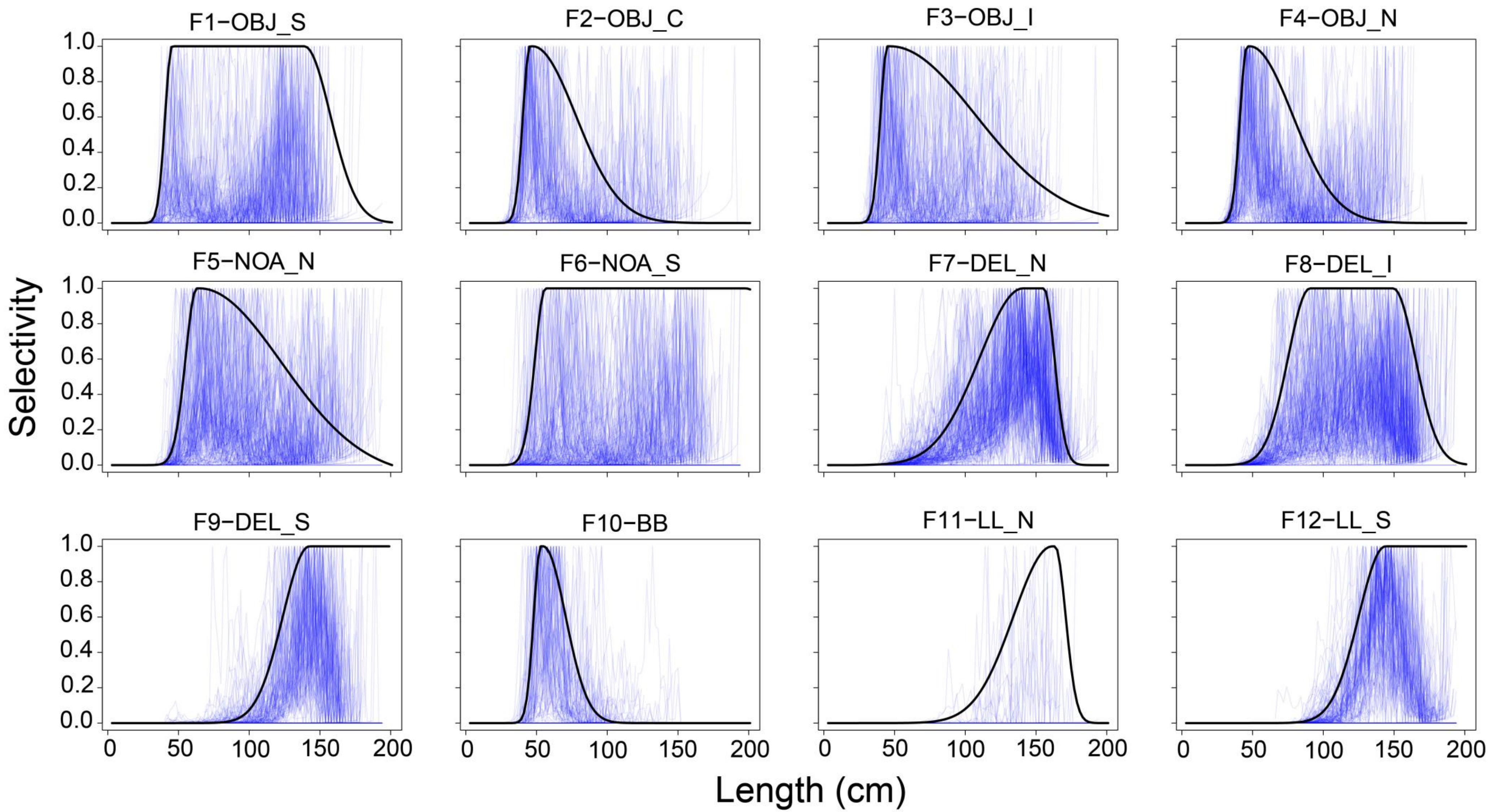


o Estimated selectivity

__ Empirical selectivity

Application: Yellowfin tuna in the Eastern Pacific Ocean

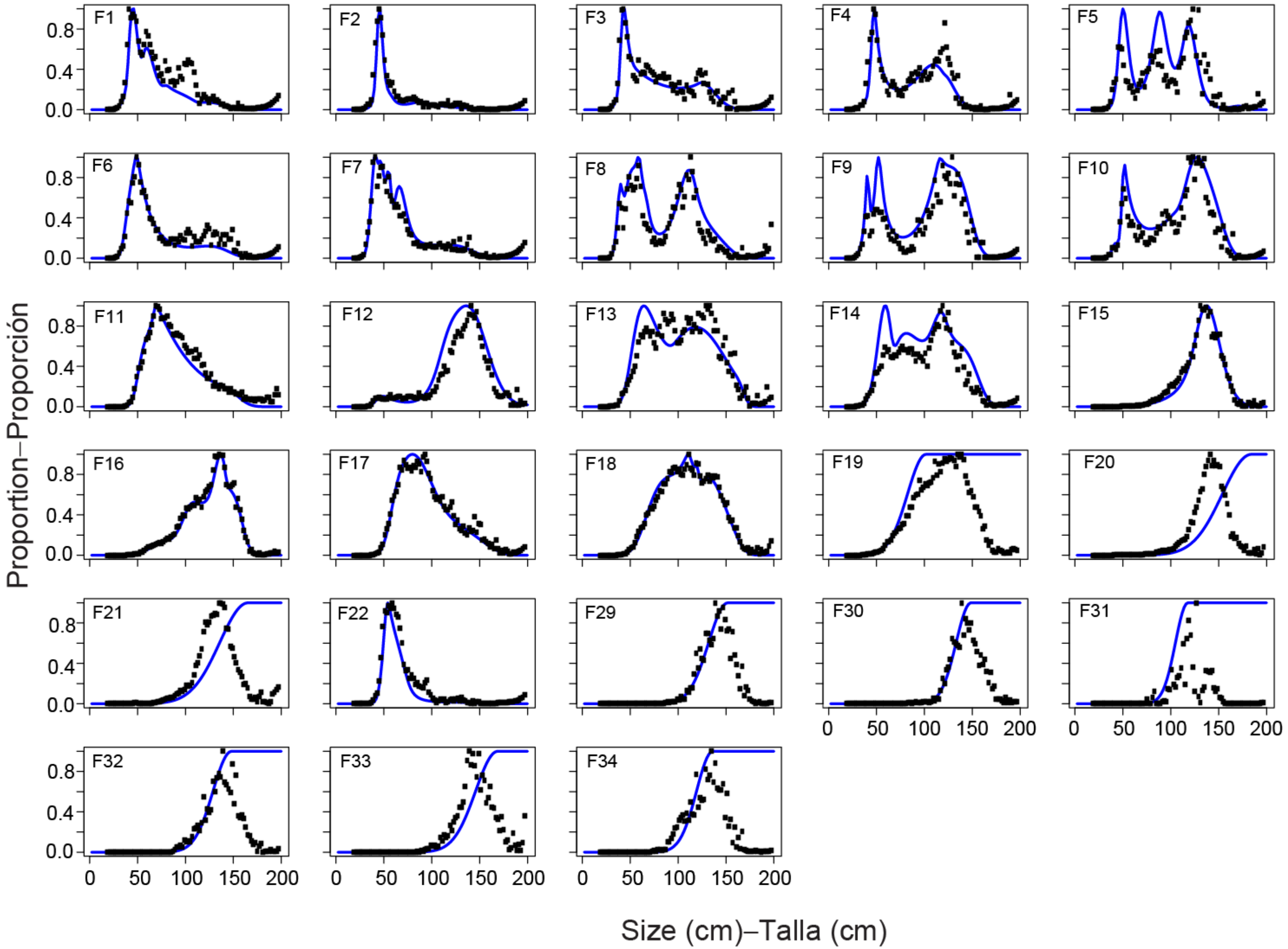
Old model



Application: Yellowfin tuna in the Eastern Pacific Ocean

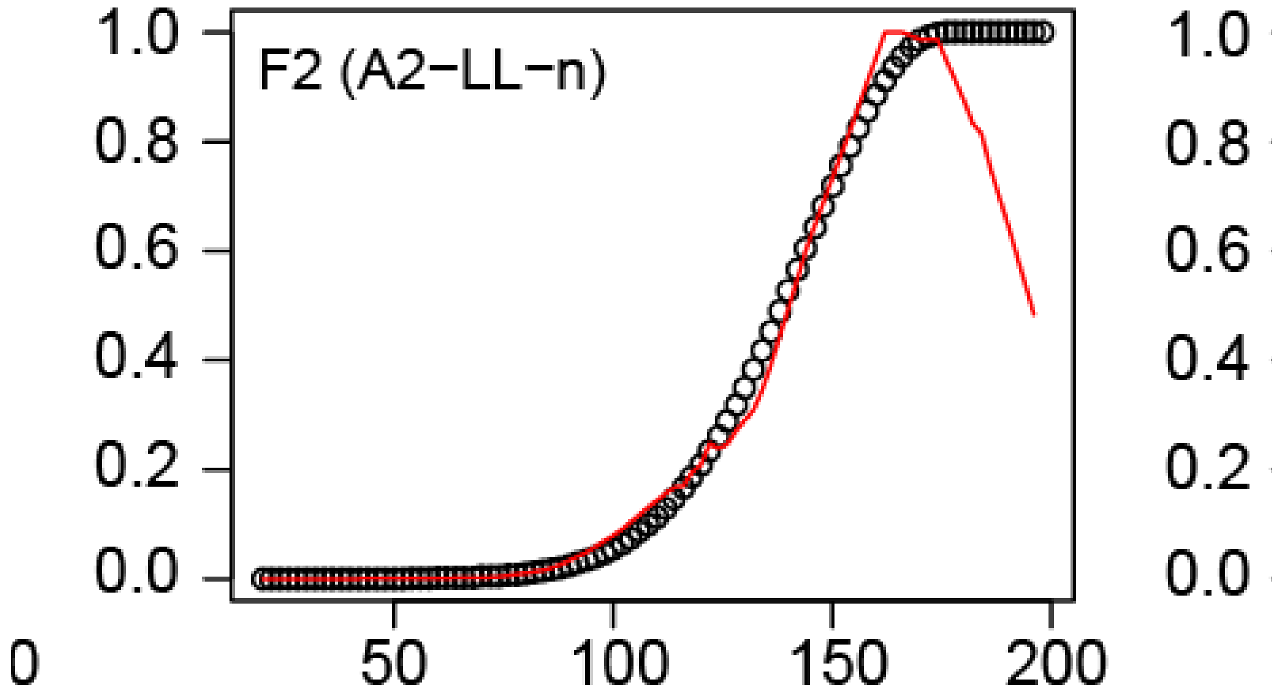
New model

Extensive use of splines



Empirical selectivity used as diagnostic

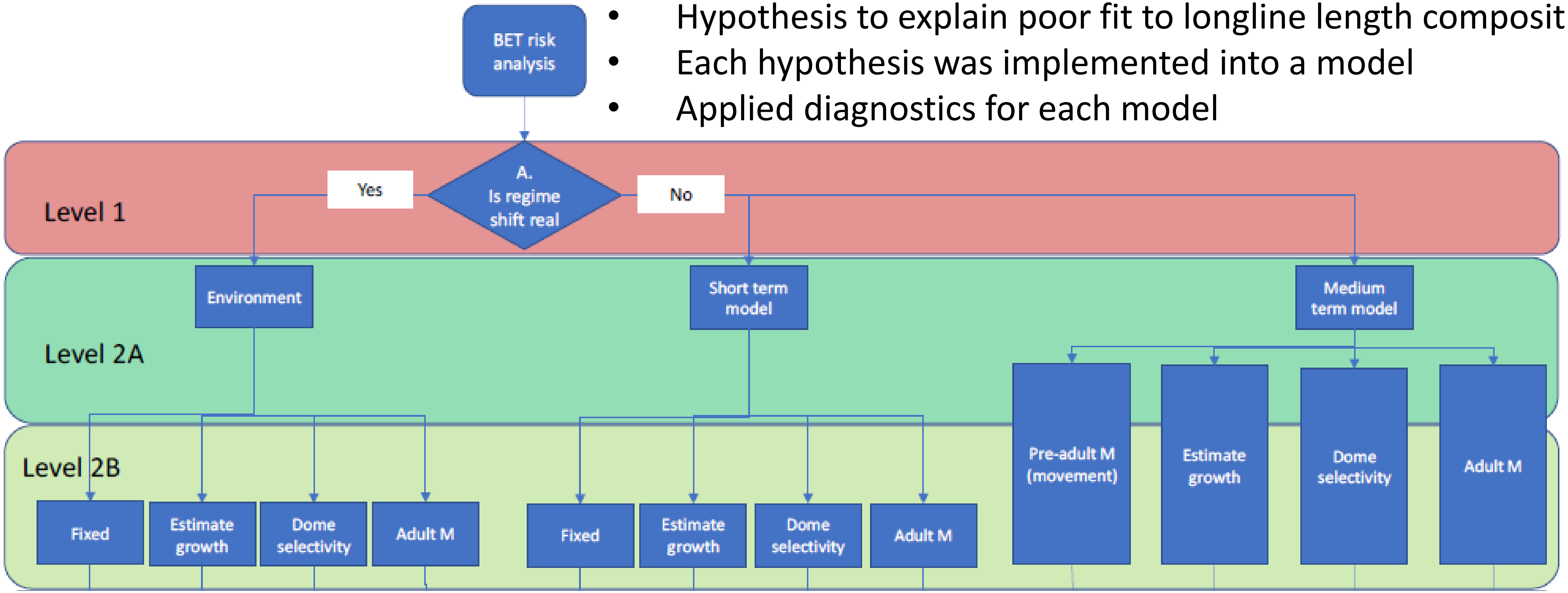
Example: Bigeye tuna in the Eastern Pacific Ocean



- Fishery A2-LL-n is the longline fishery that has catches the highest proportion **of large bigeye**
- It is therefore assumed in a reference model to have **asymptotic selectivity**
- However, the **empirical selectivity suggests** the selectivity of A2-LL-n is **dome-shaped**

Empirical selectivity used as diagnostic

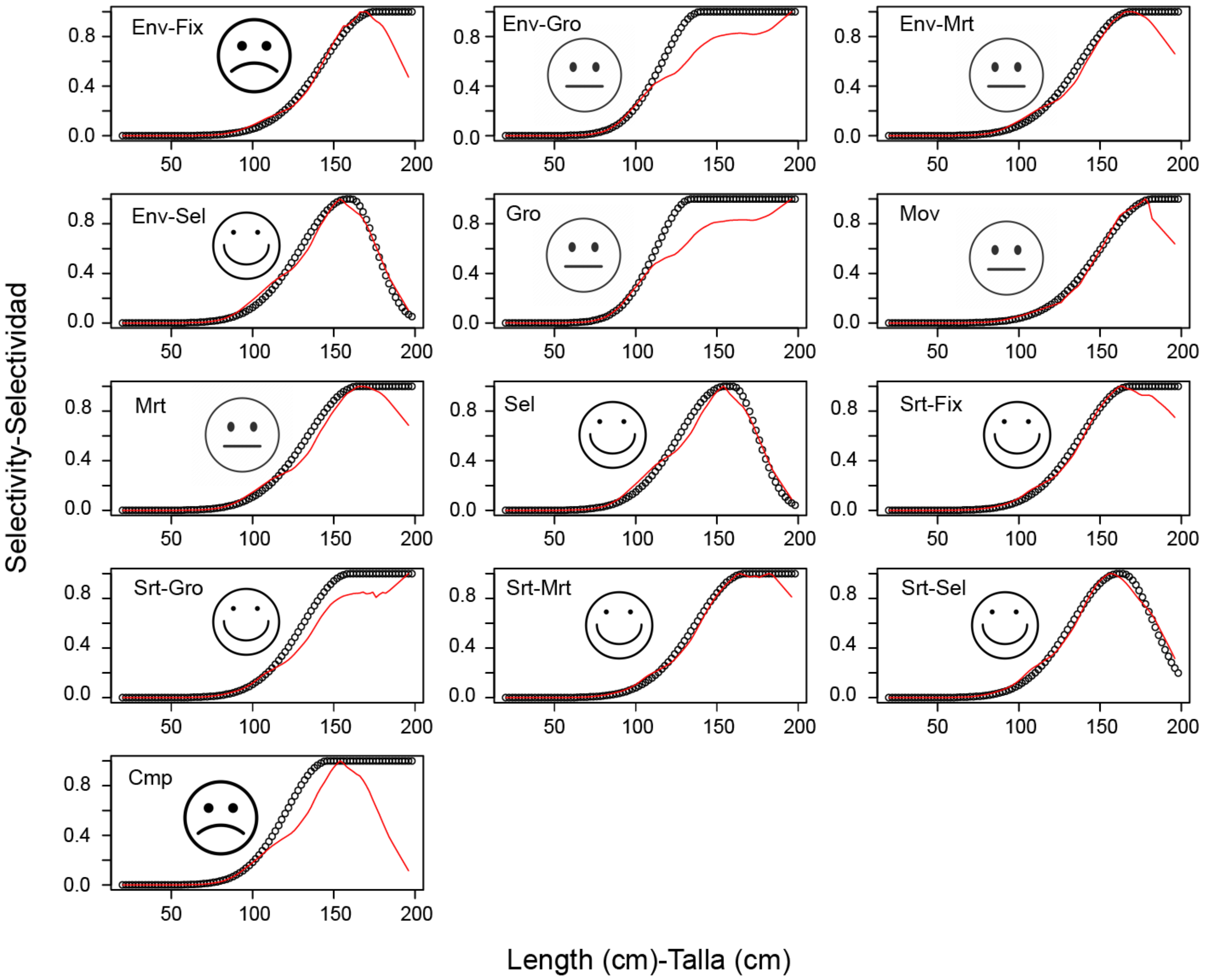
- Hypothesis to explain poor fit to longline length composition
- Each hypothesis was implemented into a model
- Applied diagnostics for each model



Hypotheses for the poor fit of longline compositions

- Random error in observations (**Fixed** – fix growth and natural mortality)
- Growth is mis-specified (**Estimate growth** – estimate the Richards growth curve and its variability)
- Longline selectivity is dome-shaped (**Dome selectivity** – use the double-normal selectivity curve)
- Adult natural mortality is mis-specified (**Adult M** – estimate the natural mortality of age 26+ quarters)
- longline compositions are unrepresentative (not shown) – down-weight longline compositions

Empirical selectivity used as diagnostic



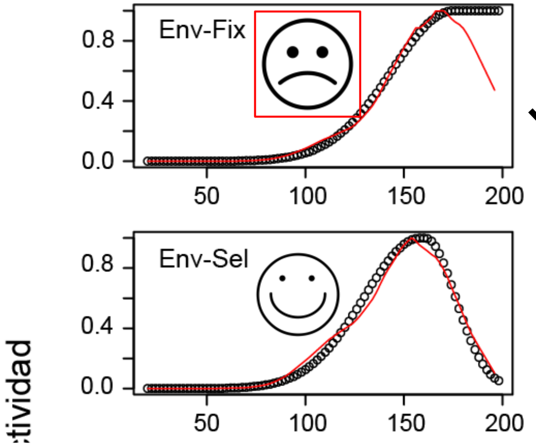
Bigeye tuna in the Eastern Pacific Ocean

Comparison the difference across reference models

Estimated selectivity vs. empirical selectivity

for fishery A2-LL-n

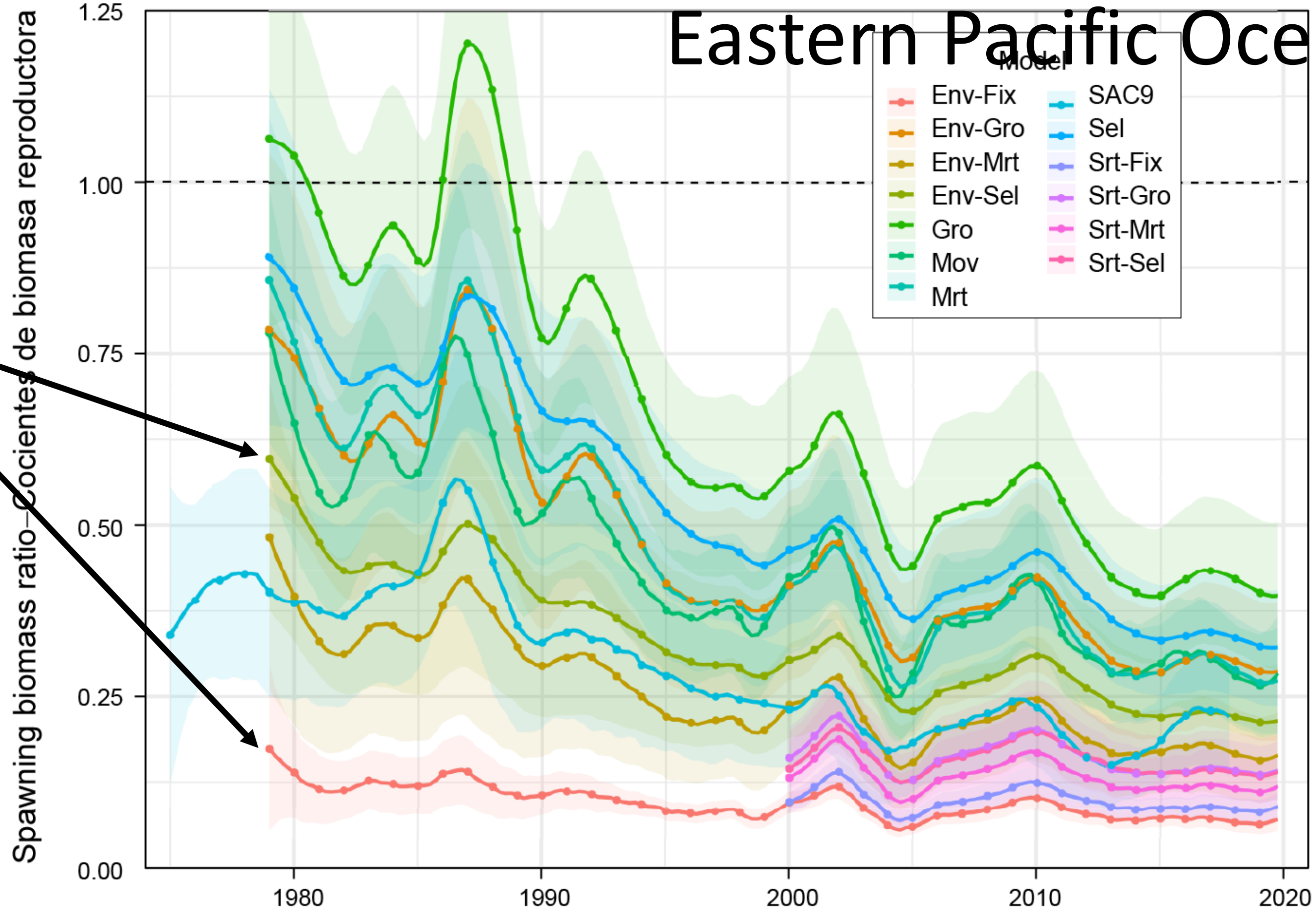
Stock status is very sensitive to selectivity assumption



The only difference between the two models is in the selectivity assumption for A2-LL-n

Due to the high sensitivity of stock status to this selectivity assumption, the empirical selectivity diagnostics can have a large impact on ensemble mean through model weighting

Bigeye tuna in the Eastern Pacific Ocean



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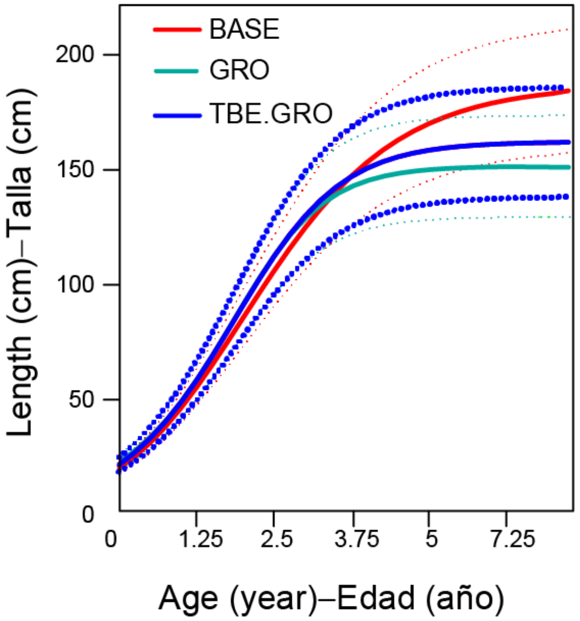
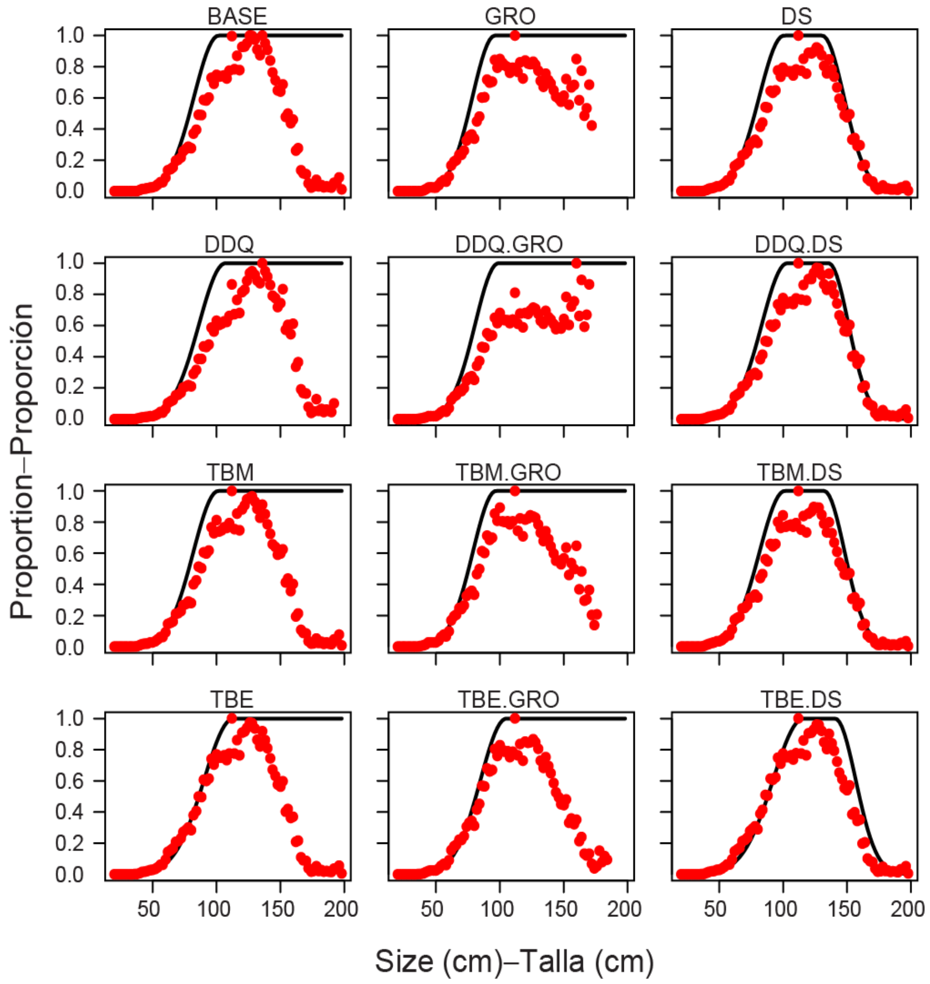
Empirical selectivity used for weighting models

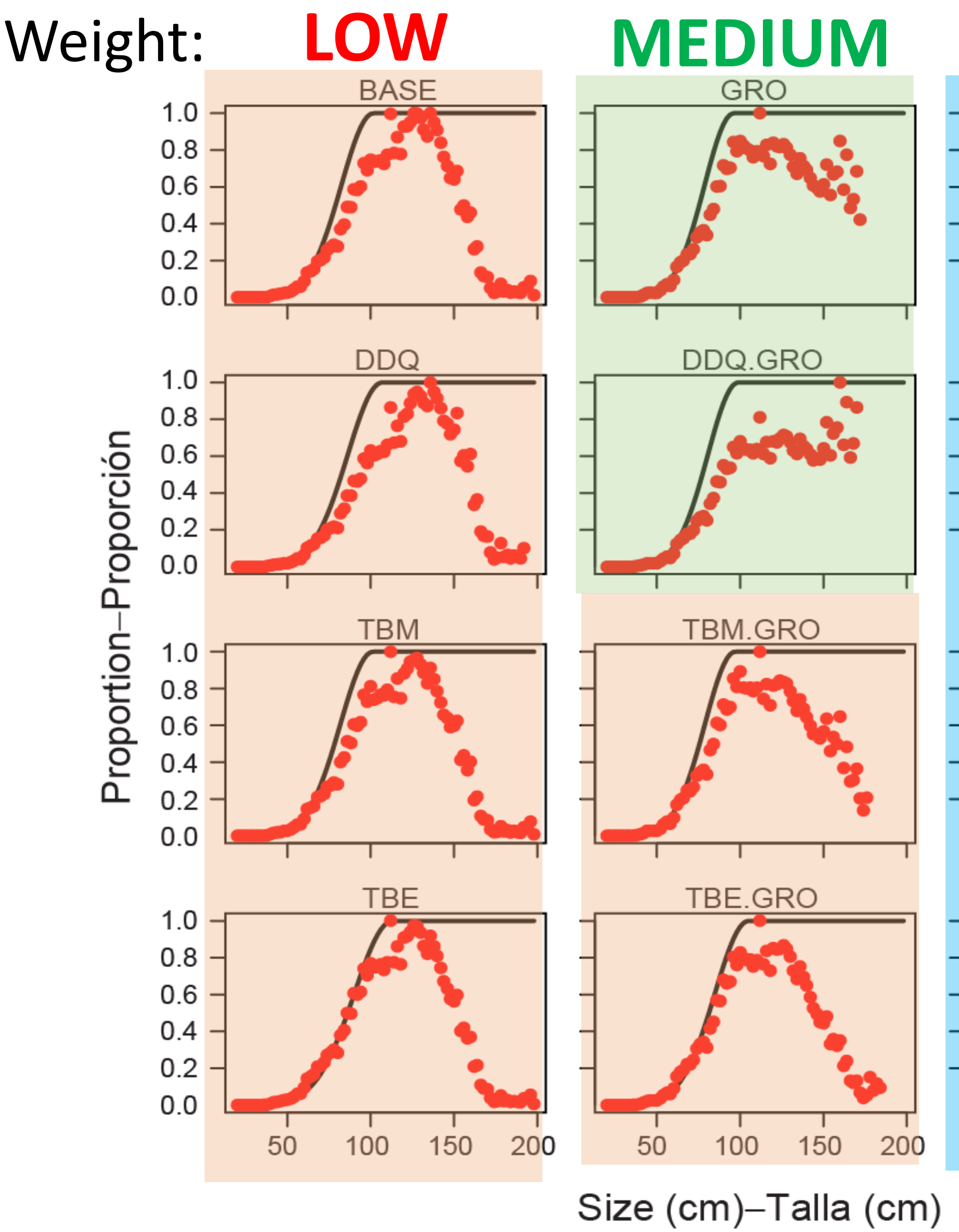
Example: Yellowfin tuna in the Eastern Pacific Ocean

- Hypothesis to explain poor fit to purse-seine sets on dolphin length composition
- Each hypothesis was implemented into a model
- Applied diagnostics for each model

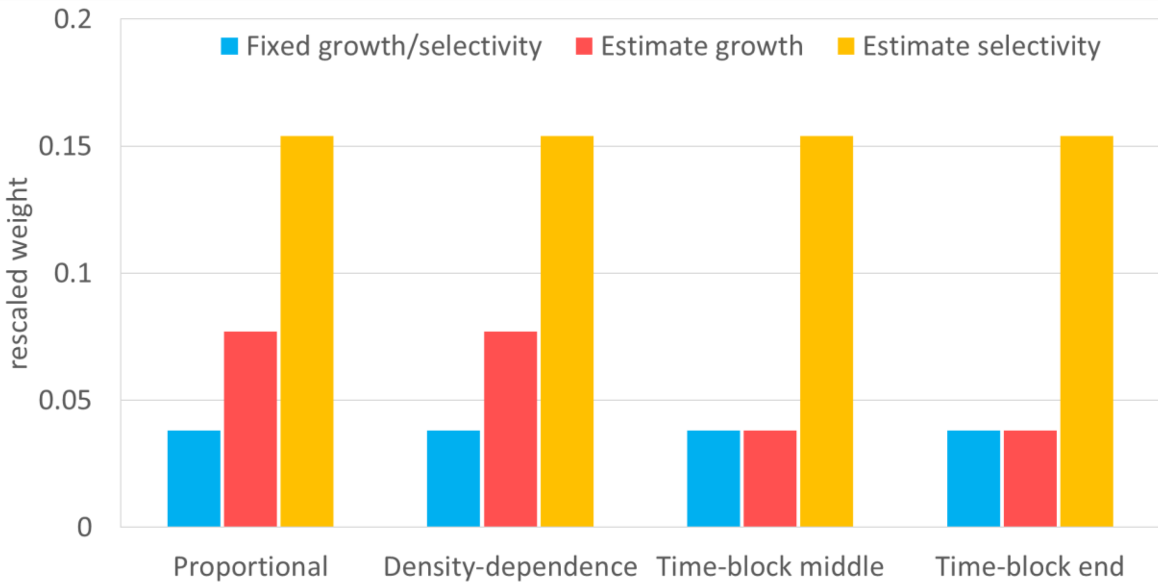




Empirical selectivity used for weighting models



Fishery F19-DEL_P



Empirical selectivity

For model development:

- Facilitate the implementation of complex selectivities
- Need the use of an external R library:
    - Compares selectivity functions
    - Optimally select number of knots and positions for splines
    - Provides initial values for selectivity parameters in correct SS3 format

For diagnostics/weighting models:

- Allows categorization of models by visual comparison
- Still subjective
- Needs quantitative metric :
    - to compare the fits of empirical selectivity
    - to compute impact of misfit

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Thank you