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Evaluation of the target fishing mortality utilized for the sustainability of the austral sardine (*Sprattus fuegensis*) fishery in Patagonian waters of Chile.

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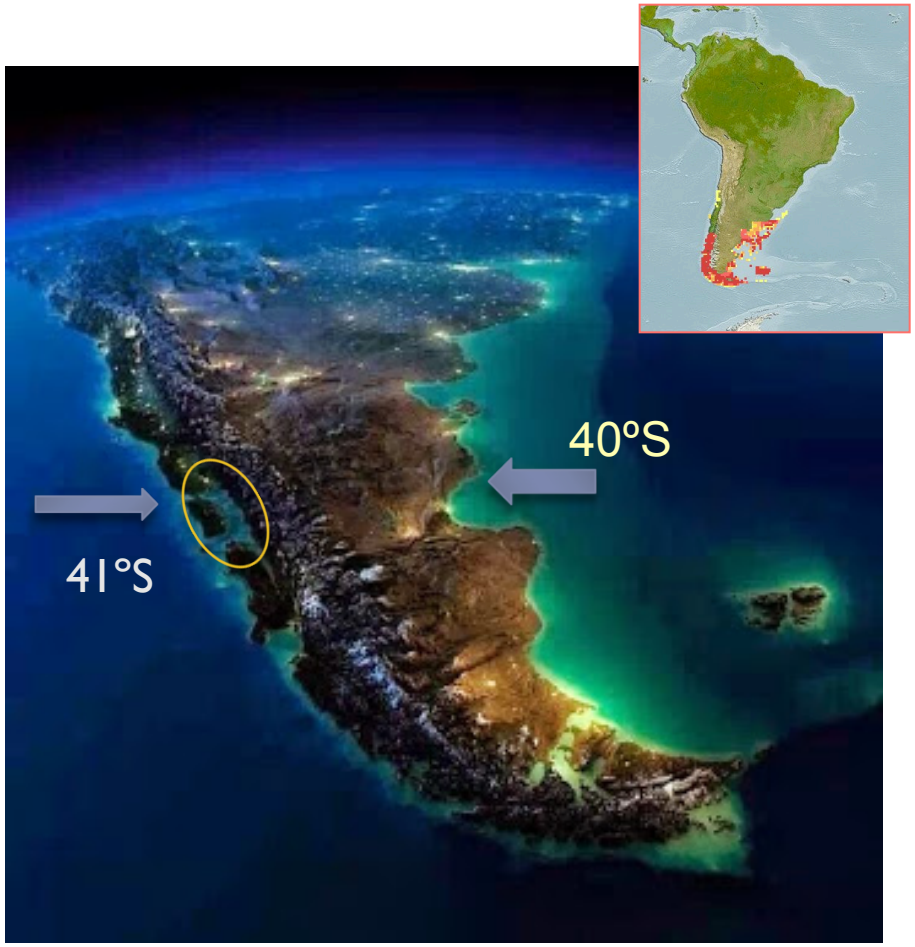
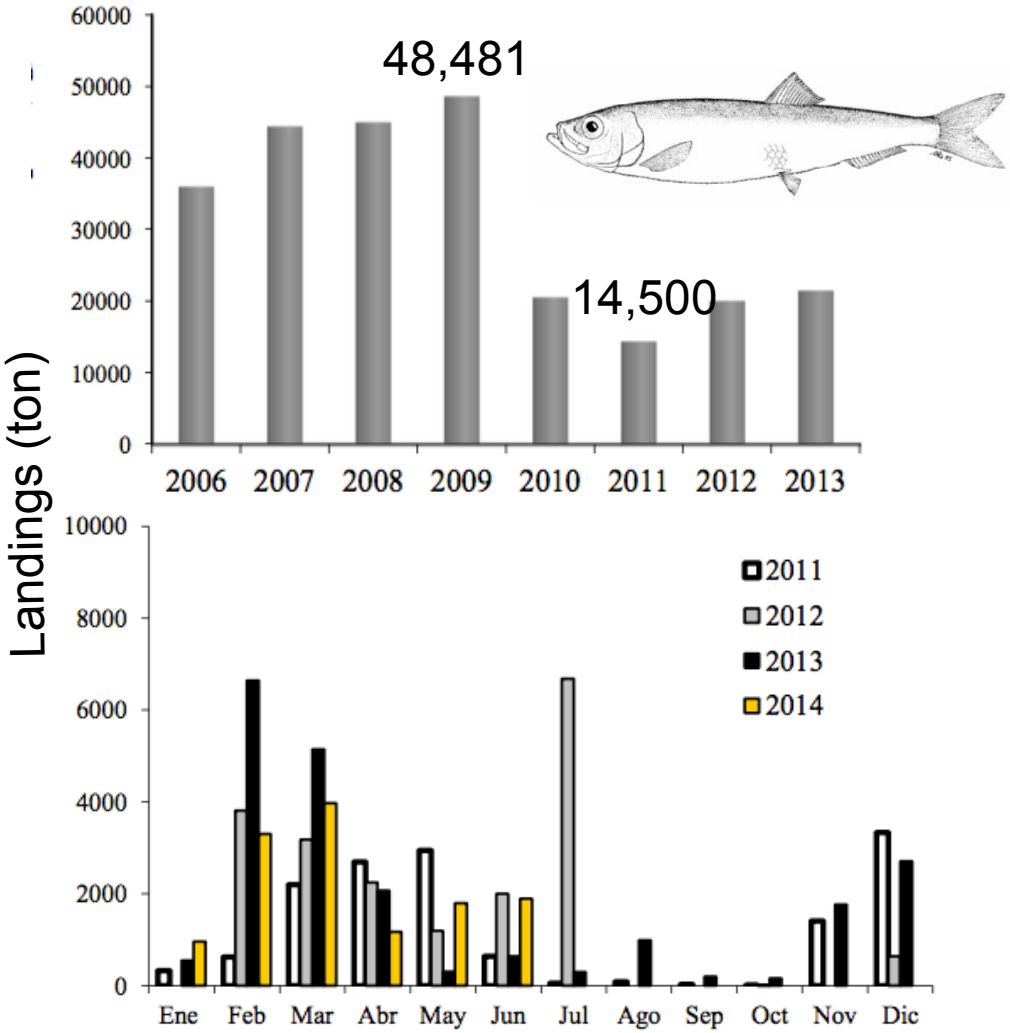
The austral sardine fishery

Sprattus fuegensis



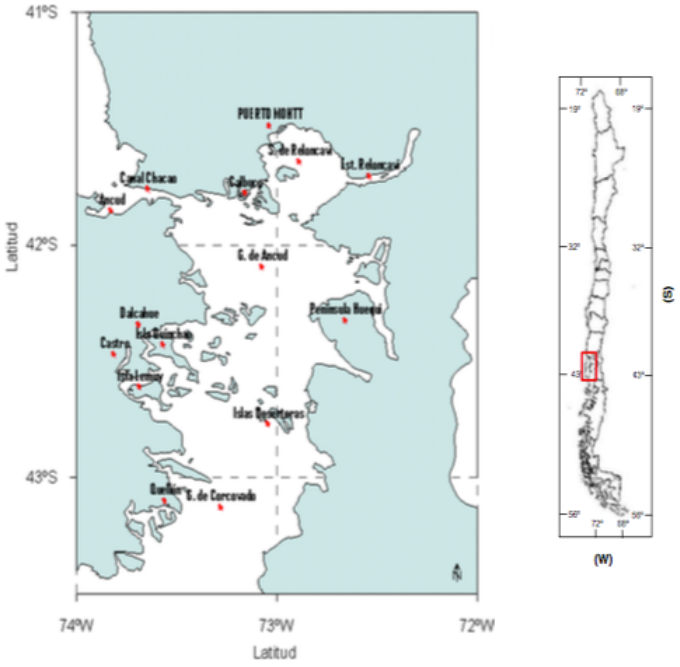
- Distribution in Patagonian waters of Chile and Argentina.
- The Chilean fishery is located in the inner waters of the Northern Patagonia (Los Lagos Region, Chile).
- The fishery started in 2006.
- The fishery is managed by setting a TAC, which is obtained from an Integrate Size-Structured Stock Assessment Model.

The fishery of the austral sardine



Purse-seine fishing fleet

Estrato de CB (m^3)	2006	2007	2008	2009	2010	2011	2012
15-30	3	1	1	7	12	12	12
31 - 45	7	5	5	5	4	4	5
46-60	8	11	13	8	8	6	8
61-80	9	10	16	17	15	14	13
Total	27	27	35	37	39	36	38

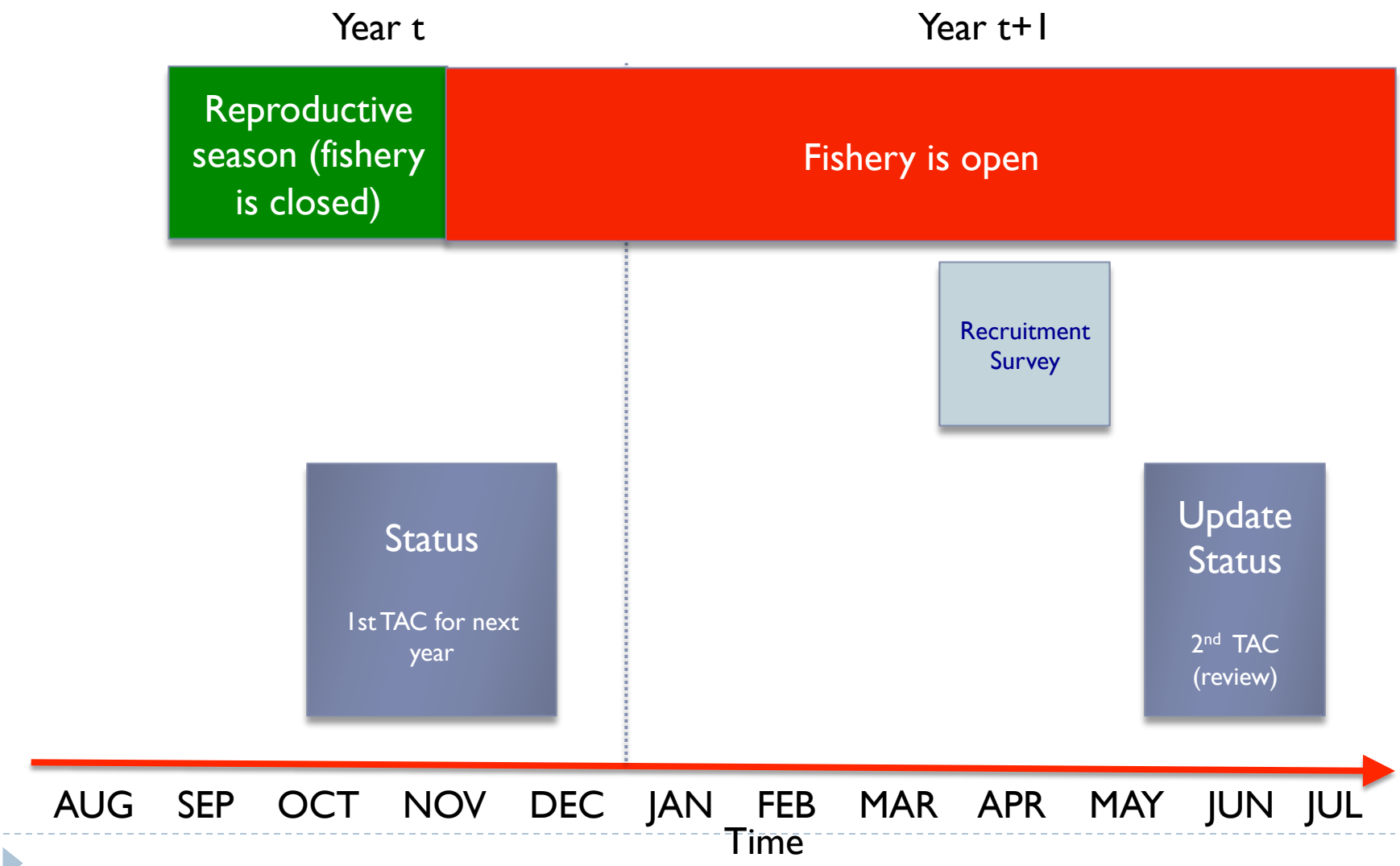


- Aranis et al. (2012). IFOP Technical Report.

The current management

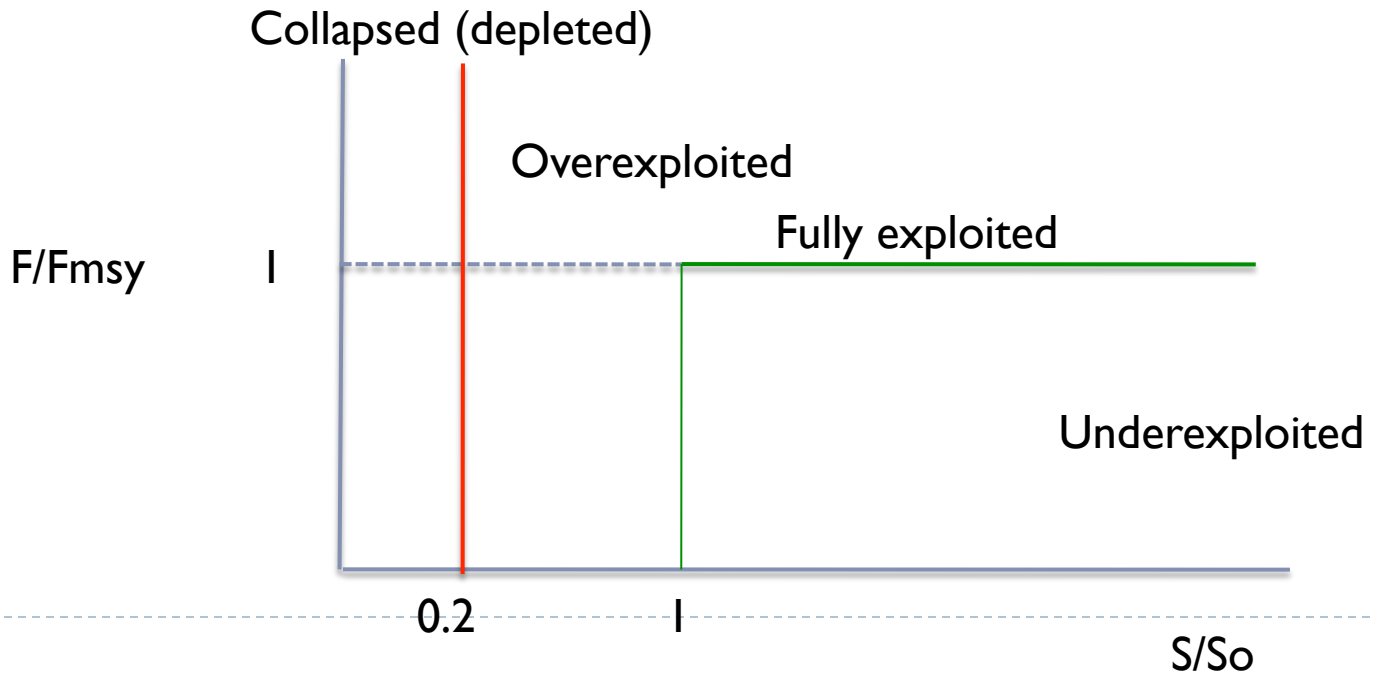
- On the basis of "the best" stock assessment model (a single-species model), which is used to:
- a) To evaluate the current status of the stock.
- b) To estimate a "total allowable catch" (TAC), by applying a target biological reference point (a constant fishing mortality rate, F60%)
- c) The status of the stock is updated with new data and the magnitude of the TAC is reviewed once the Autumn acoustic recruitment survey have finished.

The sequence of events:



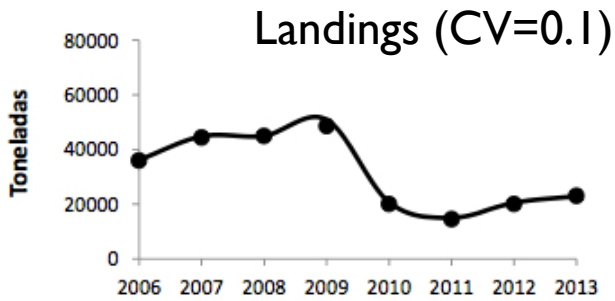
Chilean fishing law of 2013:

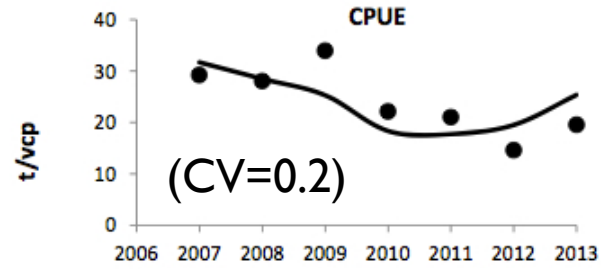
- Maximum Sustainable Yield (MSY) is the goal for fishery management, i.e., the higher average catch under current environmental conditions.
- A recovery plan must be applied for overexploited stocks.

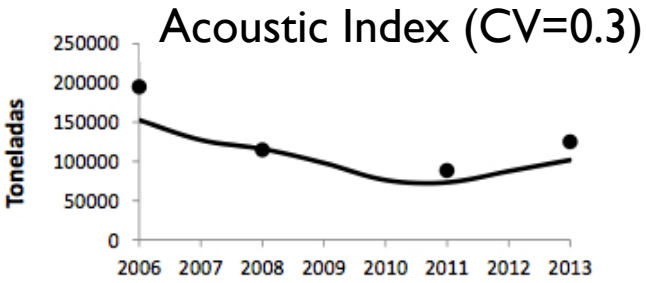


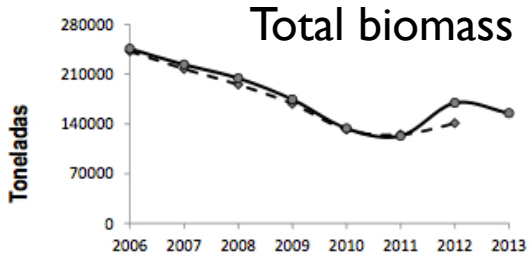
Integrated Size-Structured SAM

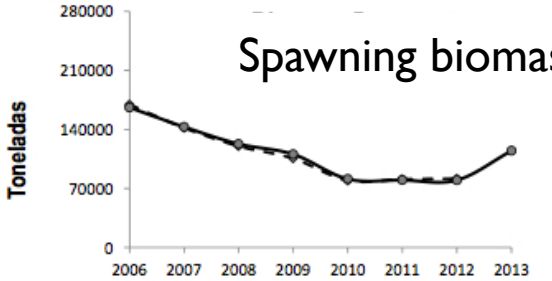
$$N_{i,l} = G_{l,l'} N_{i-1,l} e^{-Z_{i-1,l}} + R_i p_l$$

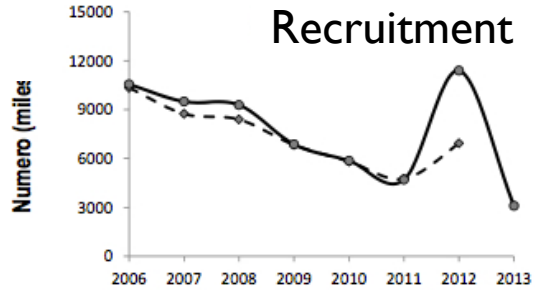










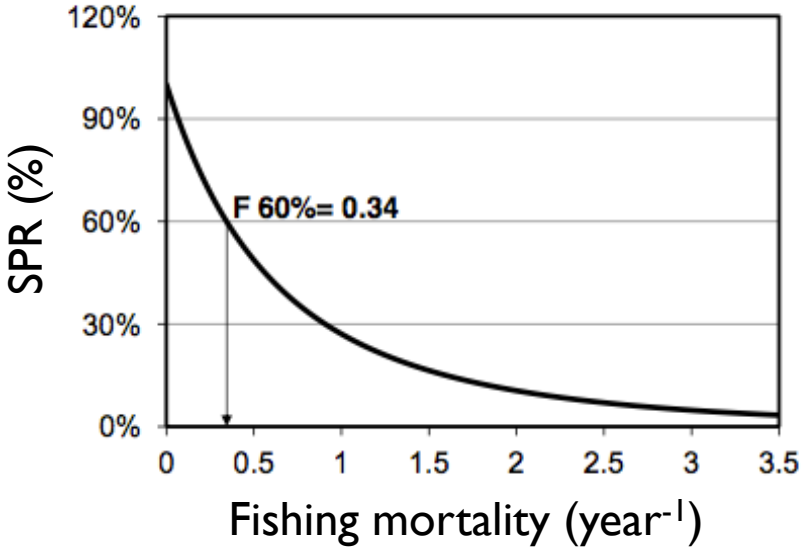


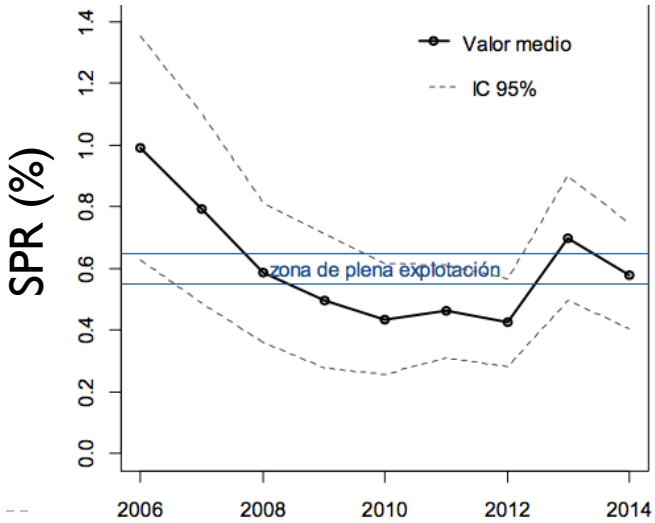
- M=0.83
- Logistic selectivity
- Effective number for multinomial:
  n=200 (Catch size composition)
- n=70 (Survey size composition)

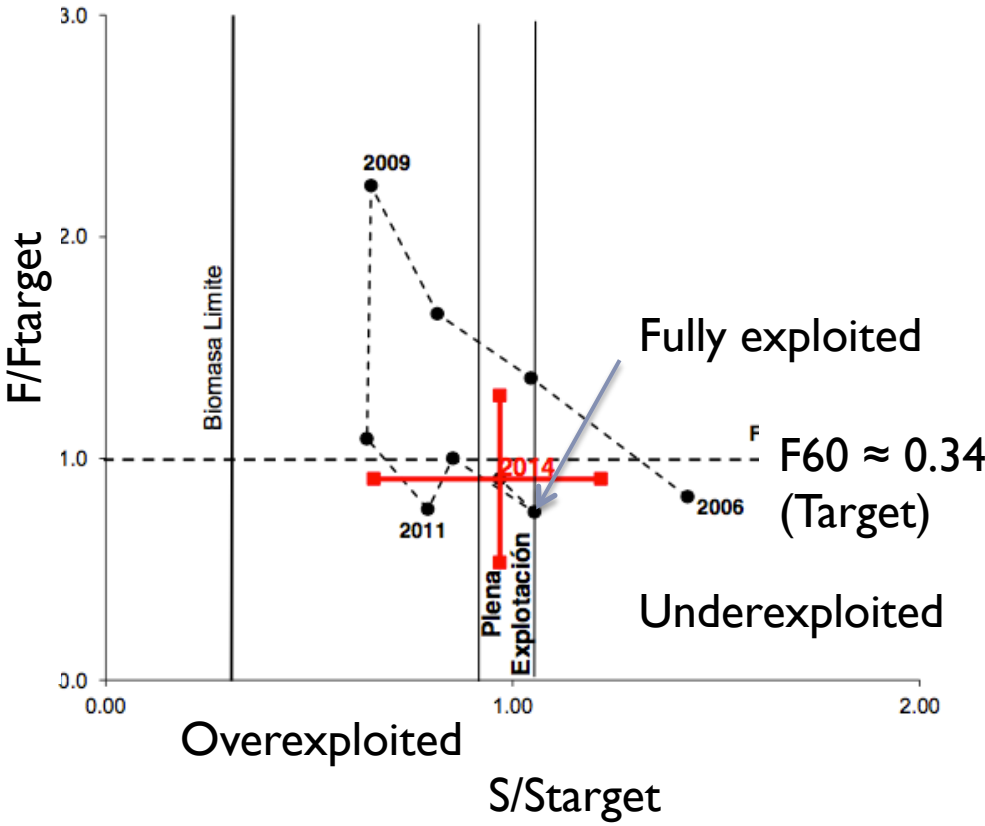
Prior for acoustic survey, growth parameters, and survey catchability

- Leal et al. (2014) IFOP Technical Report

Biological Reference Points & Status

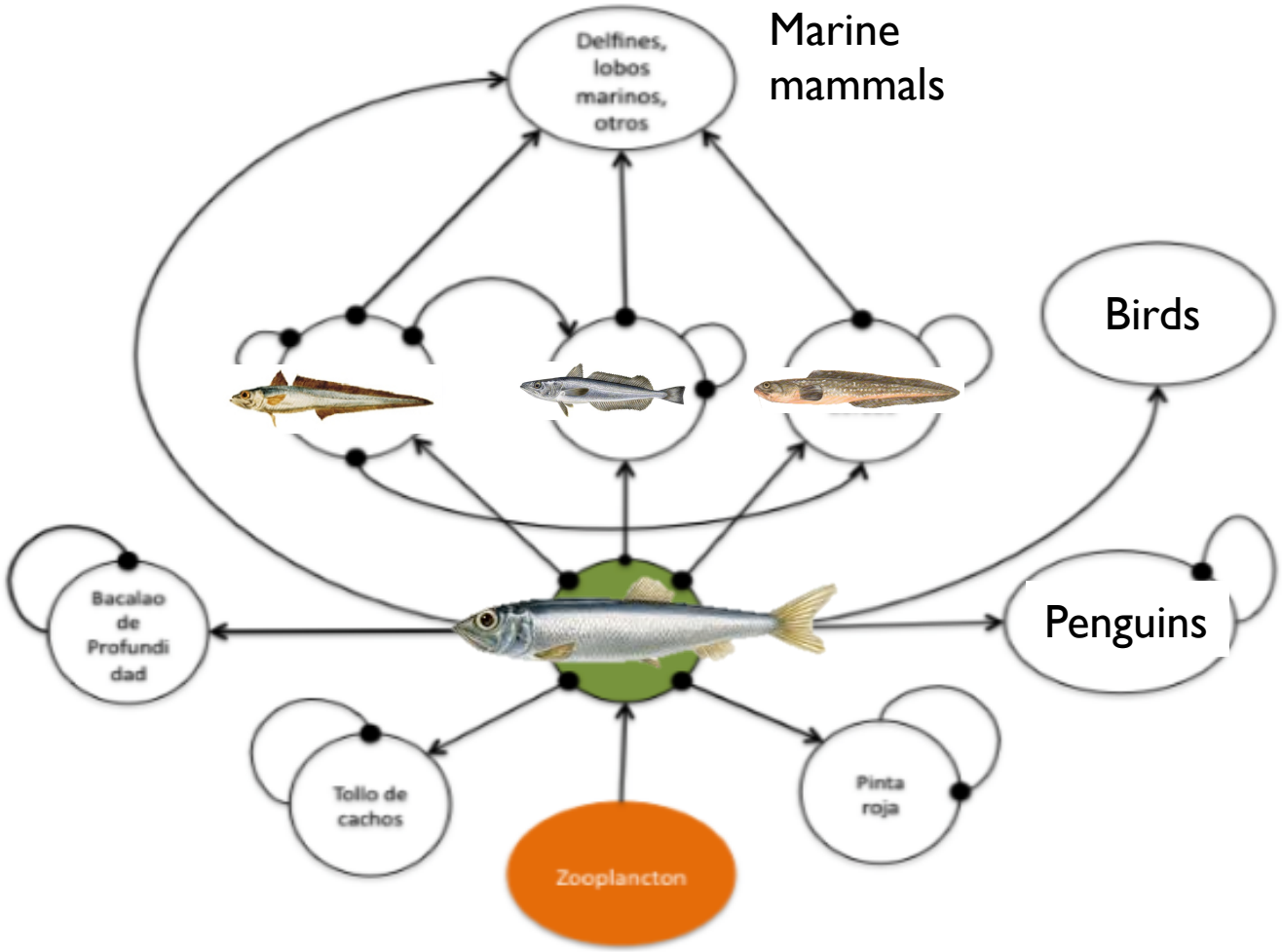






- Leal et al. (2014) IFOP Technical Report

The austral sardine as a forage low trophic level species



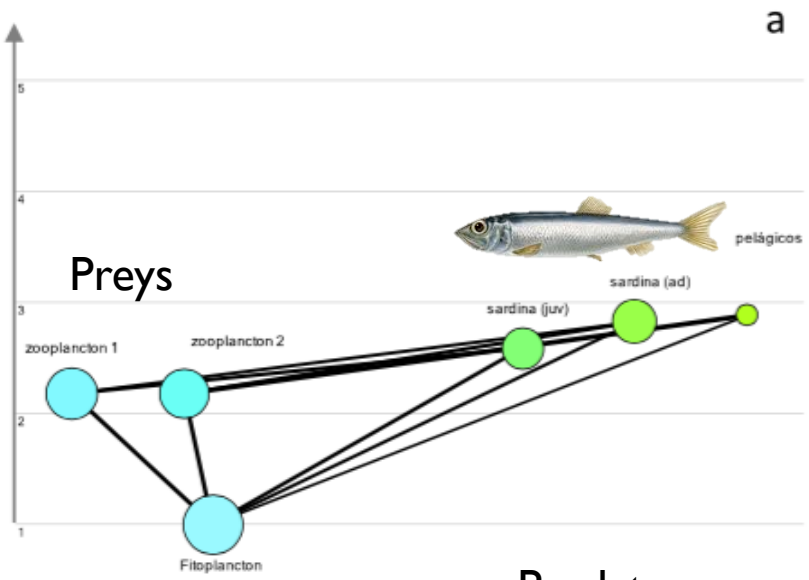
- Zuleta and Rubilar (2010) CEPES Techn. Rep.

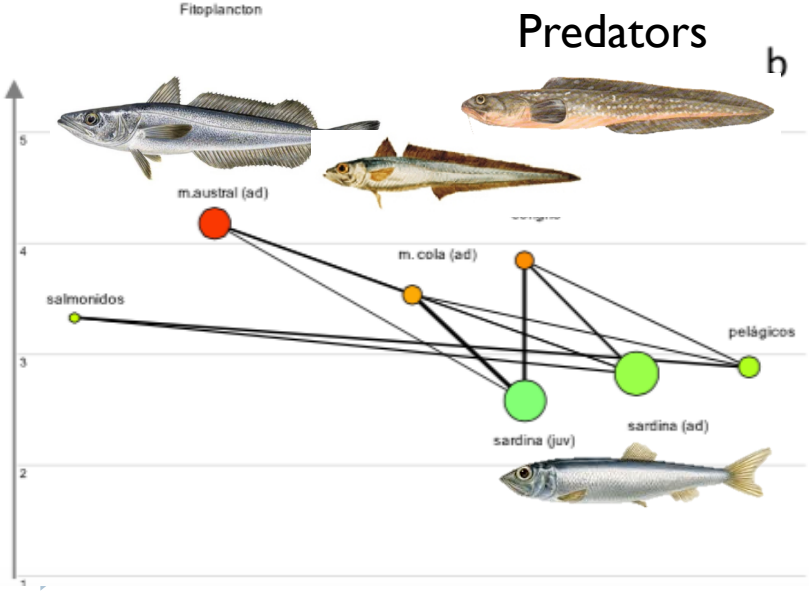
Objetive

- To evaluate the performance of the current target for long-term fishery sustainability of the austral sardine, taking into account the trophic links.

- APPROACHES:
- 1) To evaluate potential predator responses to changes in fishing mortality (ECOPATH with ECOSIM)
- 2) Management strategy evaluation of the current target through closed-loop.

Ecopath with Ecosim





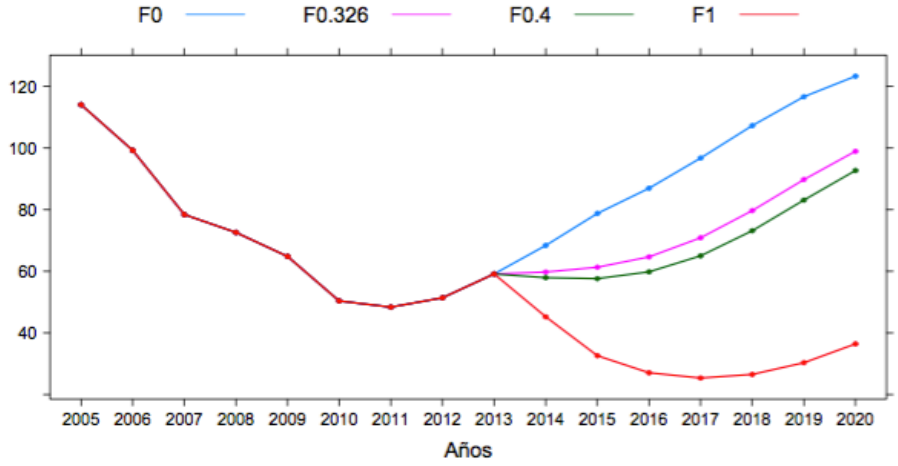
ECOPATH with ECOSIM:
-Trophic control

Projection: 7 yrs

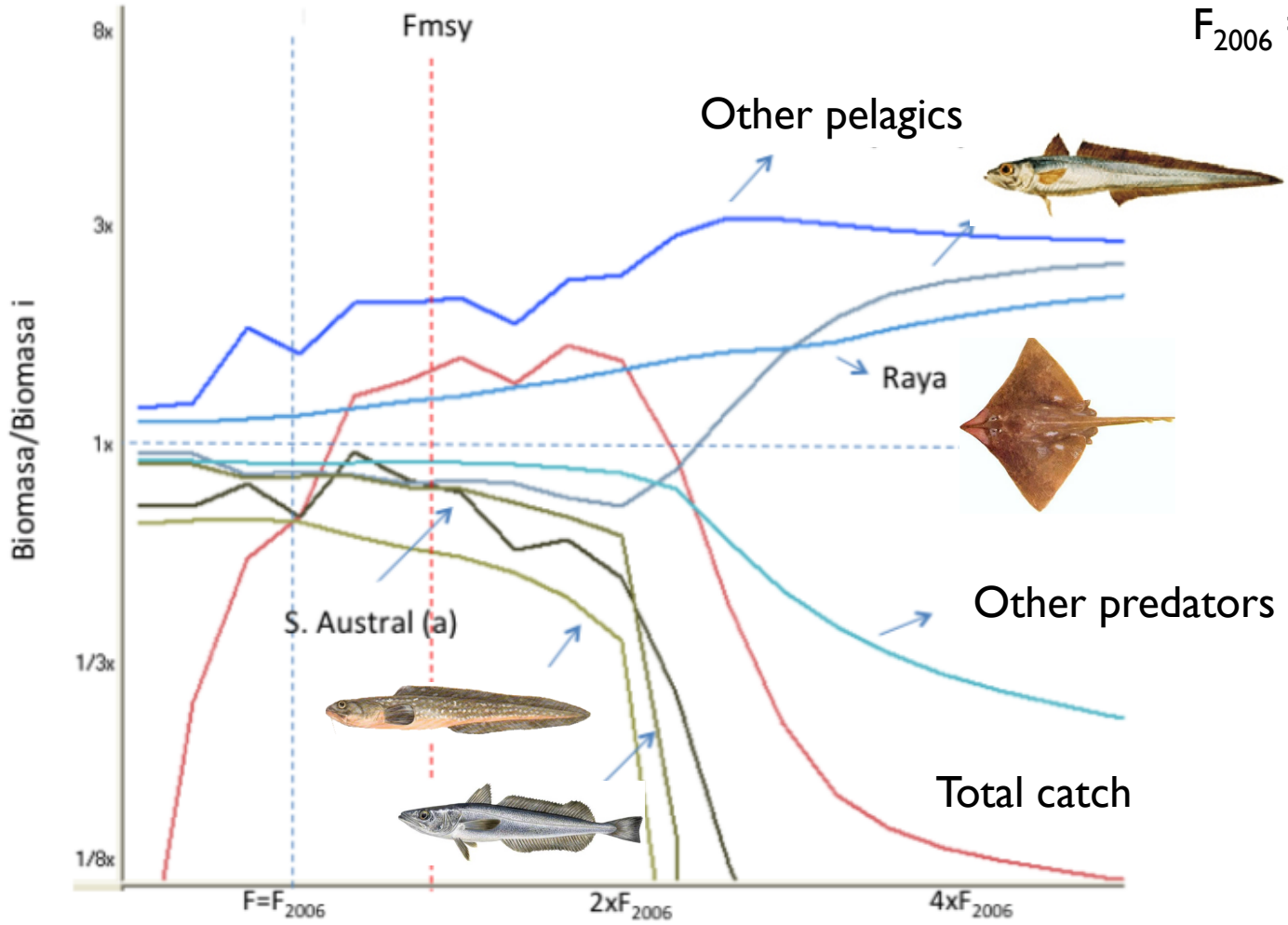
Biomass

Predator Response Prediction

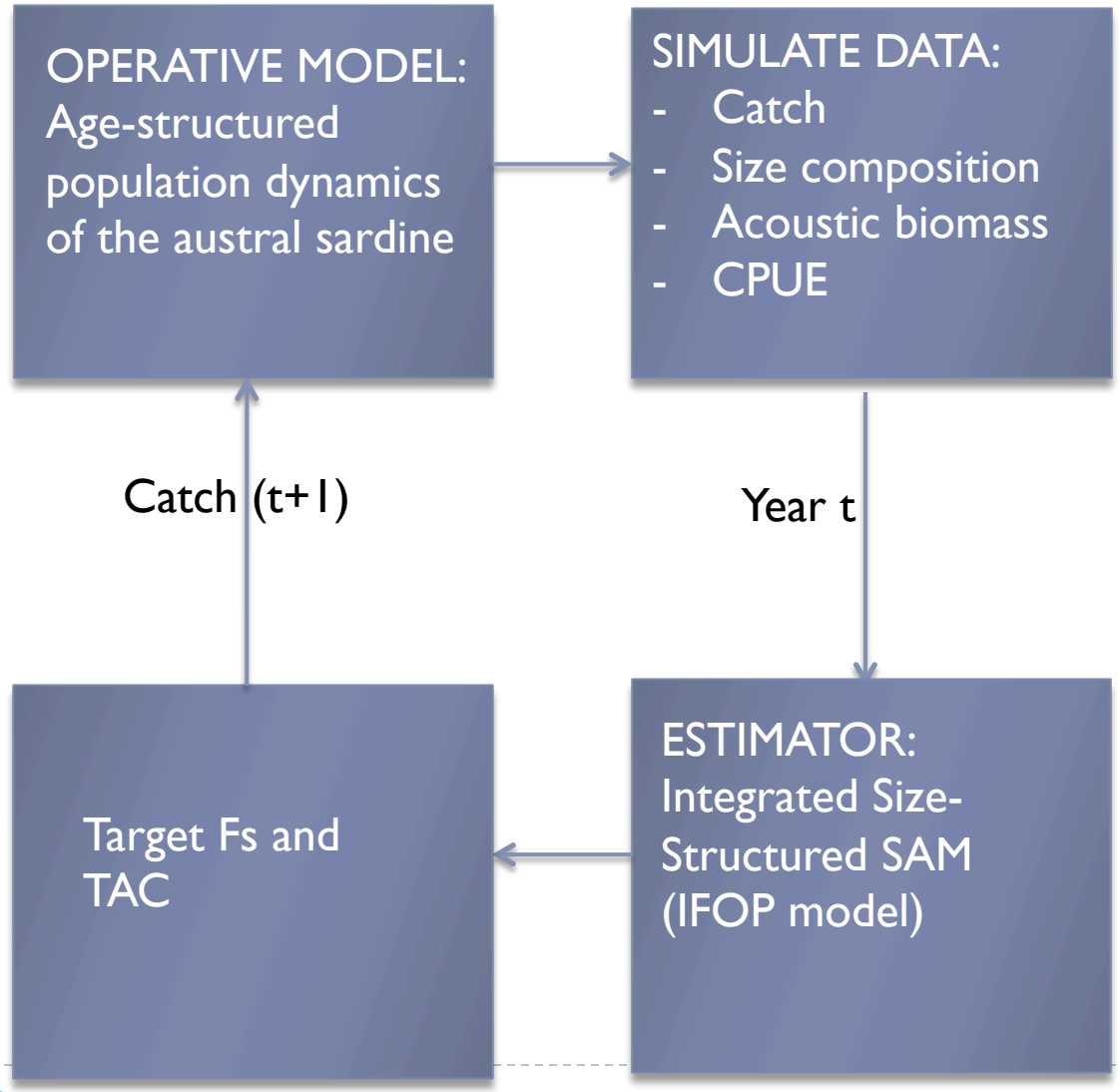
Projected biomass ('000 t) of the austral sardine



Potential changes in predators



MSE: closed-loop



Performance:

- Spawning biomass relative to the unexploited level (St/So ratio)
- Potential Predator response prediction (PREP)

Predator response prediction

- PREP equation for teleosts:

Table 6.2

Group-specific parameter estimates for the PREP equation $R = \rho D^{\alpha}\left(1-\frac{B}{B_0}\right)^{\beta}$

The numbers in parentheses are 1 standard error. The final row lists the percentage of variance explained (approximate R^2 values).

Par.	All	Teleosts	Birds	Mammals	Elasmobranchs	Invertebrates
α	0.62 (0.01)	0.58 (0.01)	0.74 (0.03)	0.68 (0.03)	0.76 (0.02)	0.99 (0.05)
β	0.91 (0.01)	0.83 (0.02)	0.88 (0.03)	0.85 (0.04)	0.91 (0.03)	0.99 (0.06)
$\ln(\rho)$	4.49 (0.04)	4.30 (0.05)	4.92 (0.08)	4.44 (0.10)	4.93 (0.09)	5.32 (0.22)
R^2	0.62	0.60	0.85	0.58	0.81	0.75

From: "Lenfest Forage Fish Task Force" (LFFTF):
http://oceancon.server265.com/foragefish/press/mangel.html

Operative model

- Age-structured SAM, by considering:

A1: S-R Beverton-Holt and M=1 (Base-case: without error)

A2: Base-case with process and observation errors.

B1: S-R Ricker and M=1, without error

B2: B1 with process and observation errors.

- Coded in ADMB and conditioned to:

- Catch, size-composition, cpue, acoustic biomass, and EwE biomass as an indice (2006-2013).

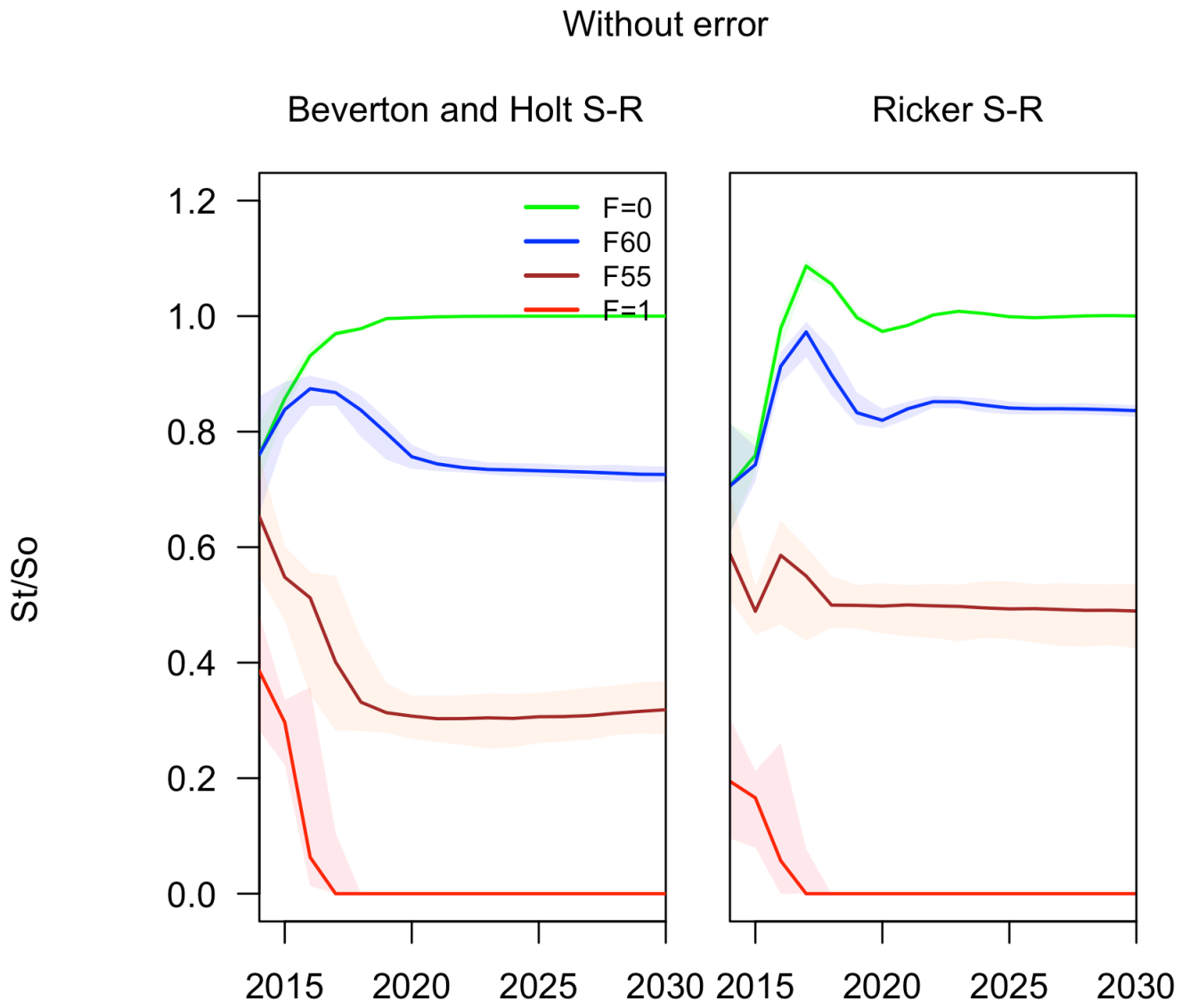
- Time-invariant growth, maturity, natural mortality, selectivity and steepness (h=0.8).

Objective and harvest control rule

- BRP: Maximum sustainable yield will occur when spawning stock biomass will be 60% of the unexploited spawning biomass (proxy)
- Constant fishing mortality and catch less than 50 thousand ton.
- F target: F60%=0.326
- Threshold for overexploitation: F55%=0.4
- Fcrash = 1 $year^{-1}$ (according to EwE)
- Healthy status: Pr(St/So>60%So)
- Collapse or depletion: Pr(St/So<20%So)

MSE was based on 100 samples of parameters obtained from 10.000 MCMC for each fishing mortality rate, during 17 year (from 2014 to 2030)

Spawning biomass ratio (M=1)



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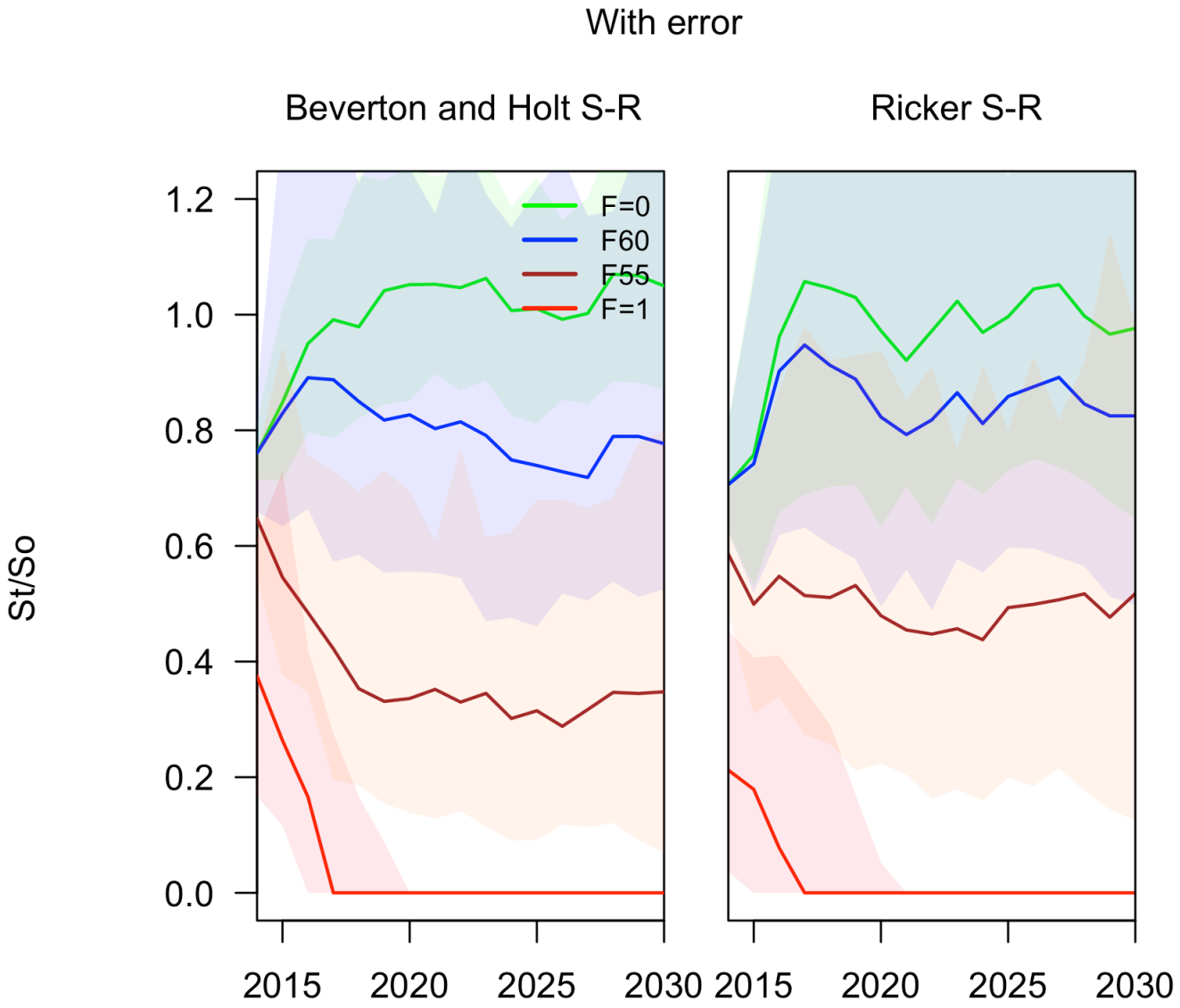
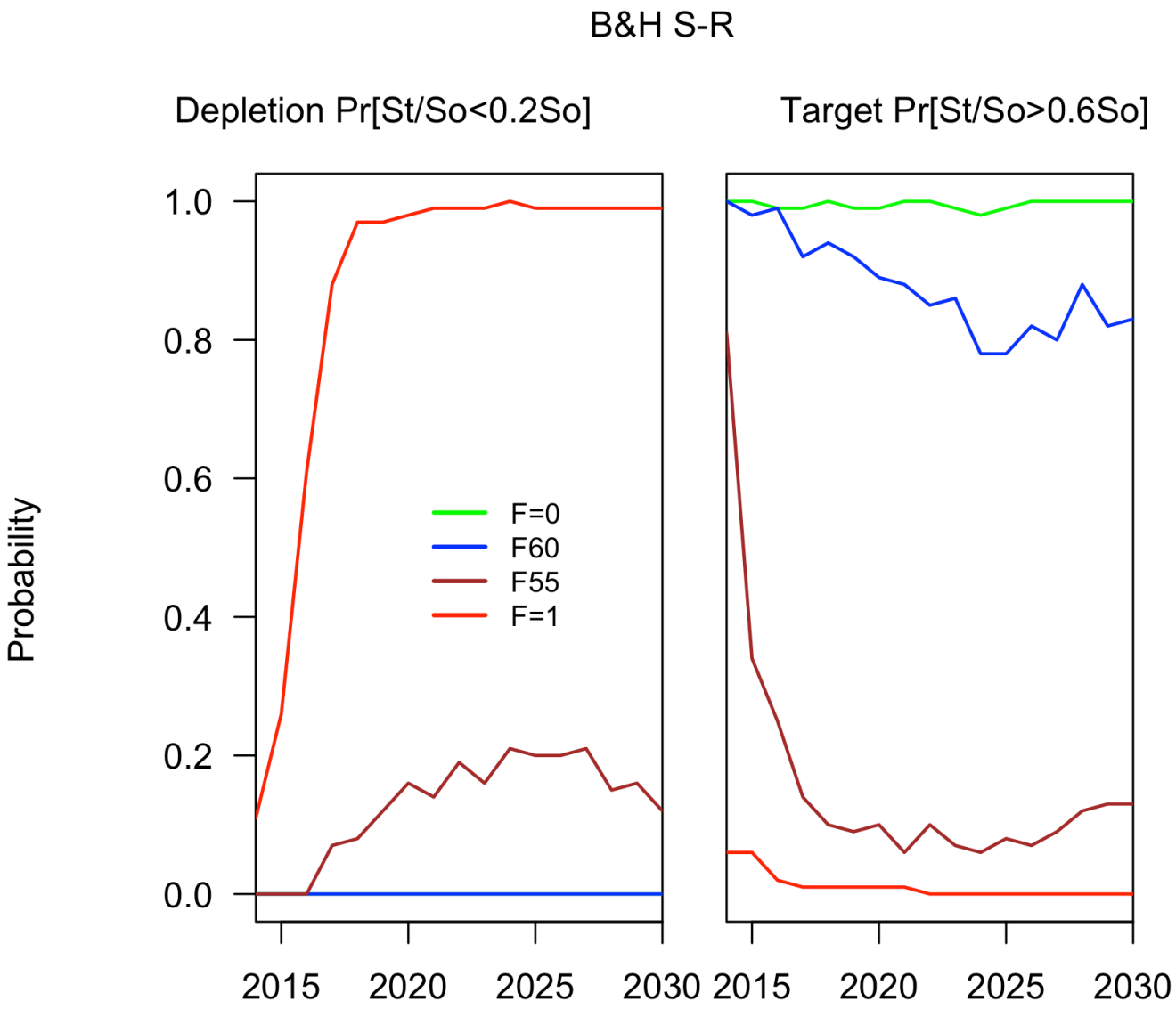
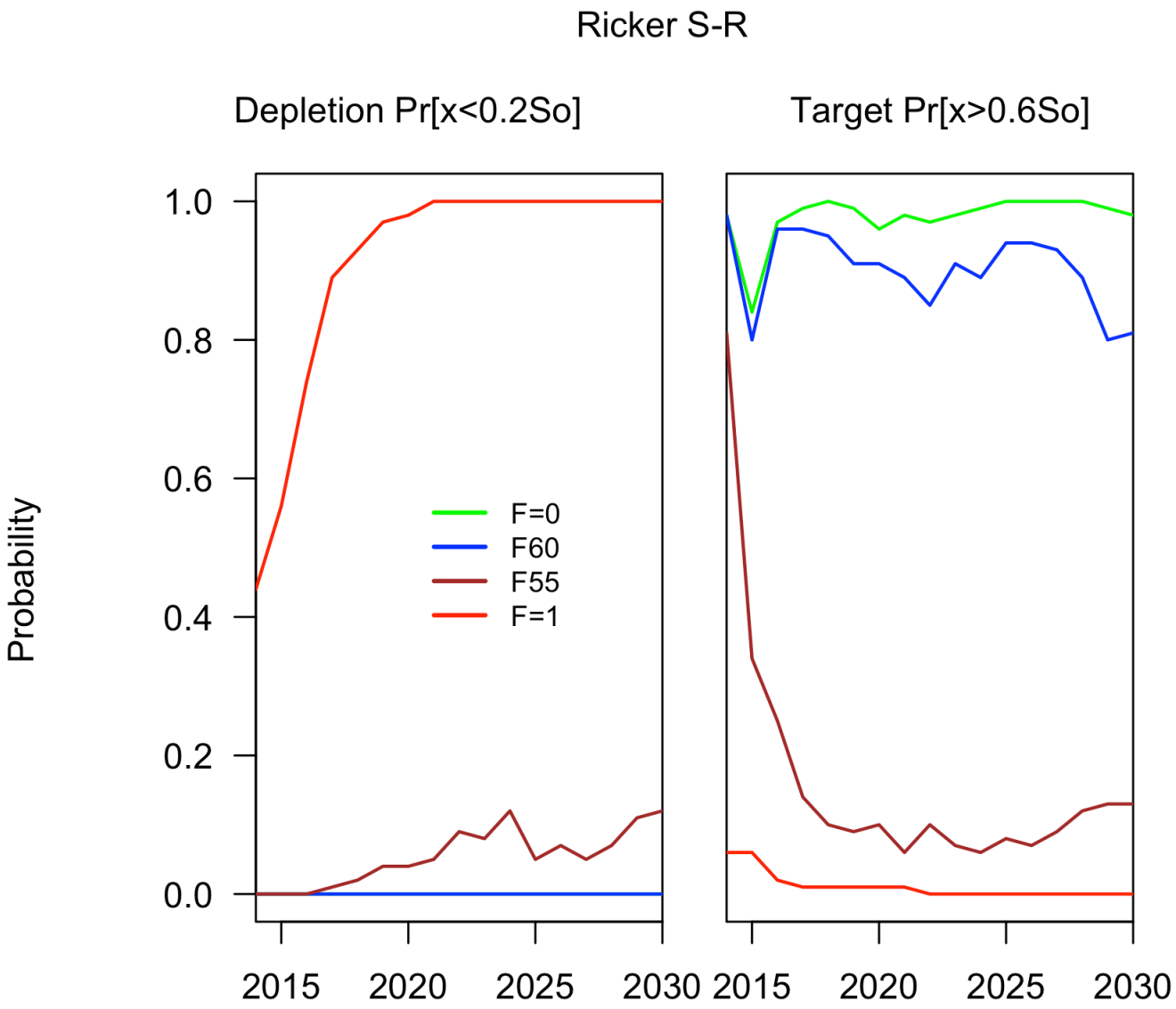


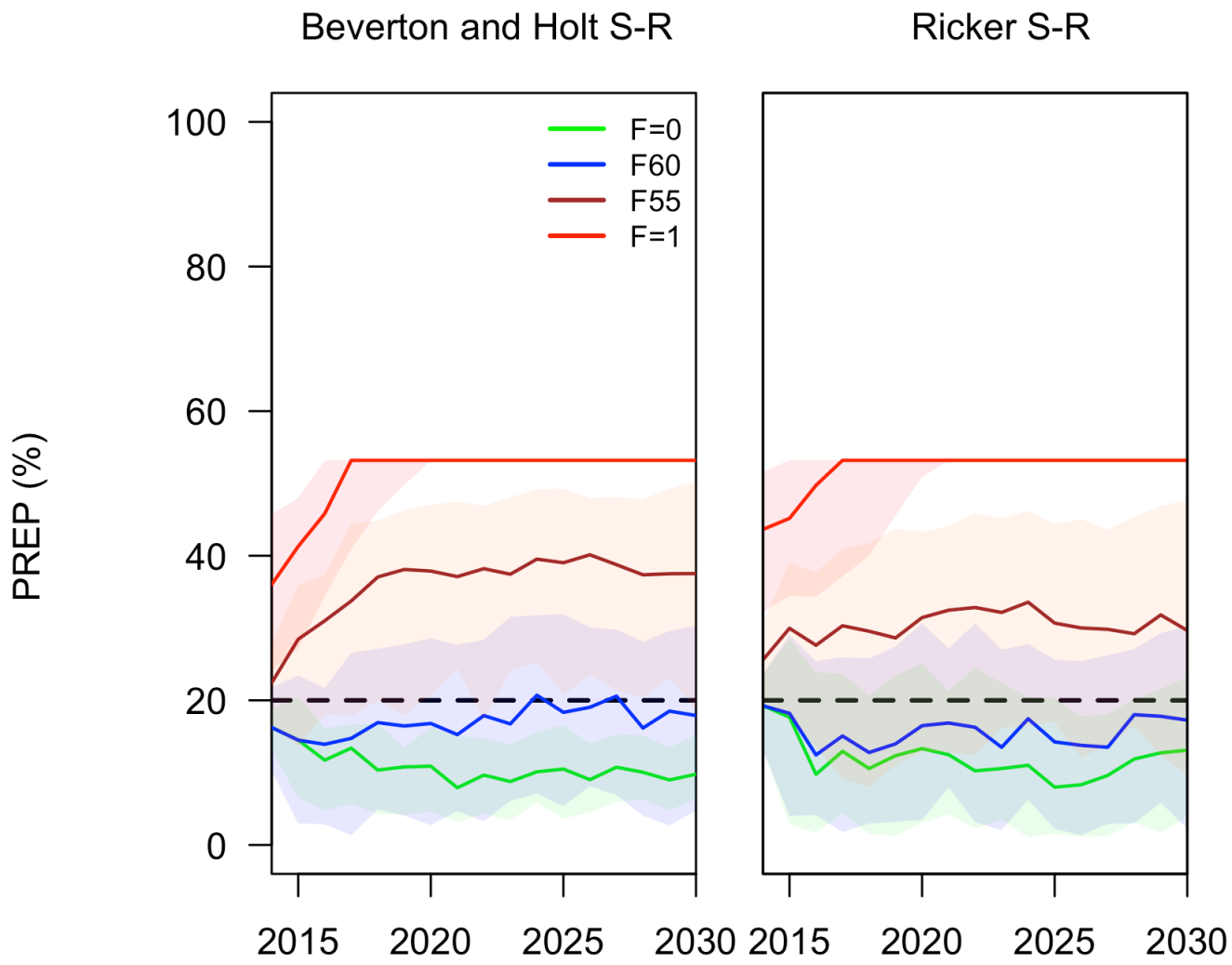
Probability of depletion & status



Probability of depletion: Ricker



PREP: hake (*Merluccius australis*)



Discussion y conclusion:

- Both the error of process (recruitment, CV≈0.4) and error of observation (indices) produce great interannual variation, which is determining risks of overexploitation and depletion for the austral sardine population dynamics (as conditioned by the operating model).
- F55%=0.4 had a bad performance as a thershold to define the boundary of full exploitation.
- F55% showed that a slight increment over the target (F60%=0.326) generates undesirable consequences for long-term sustainability of the austral sardine fishery.

Discussion and conclusion (cont.):

- The best performance of F60% was achieved when the OM considered a Ricker S-R.
- Although the F60% had pretty good performance, the probability of overexploitation was close to 20%, and a decline in a valuable predator close to 20% (PREP of austral hake).
- The performance of the size-structured stock assessment model must be evaluated as an estimator (convergence < 0.0001 ≈ 57.5 to 95%).
- From a precautionary point of view, F66% could be better for long term sustainability of the austral sardine fishery.

Acknowledgements

- To Program COPAS Sur-Austral (http://

- To EPOMAR (http://epomar.cl)

- To FIP (fisheries research fund of Chile) for grant FIP2012-15 (http:///www.fip.cl)