Progress towards implementing harvest strategies and MSE in the management of EPO tuna fisheries

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www.iattc.org

Inter-American Tropical Tuna Commission

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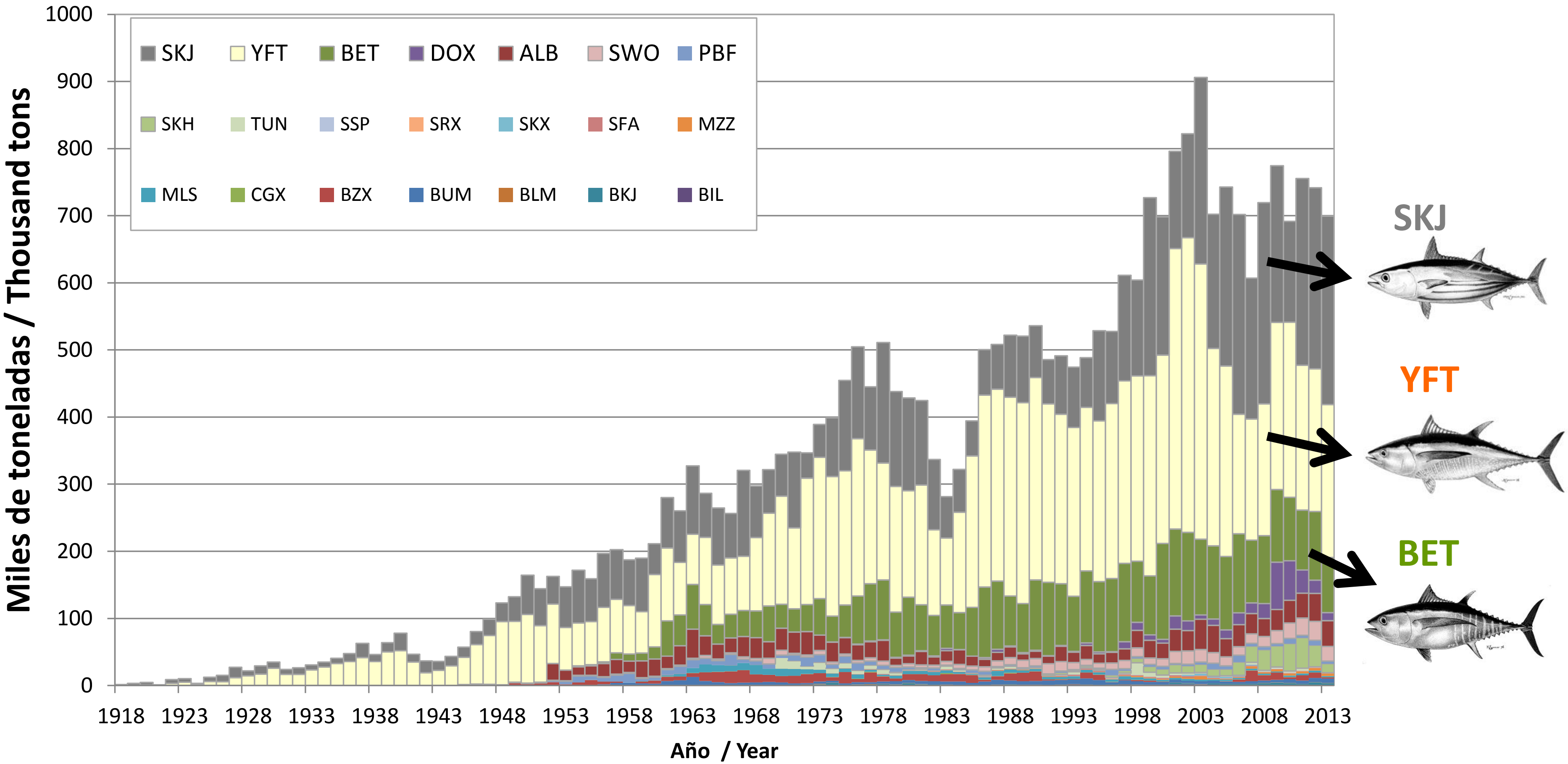
Topics

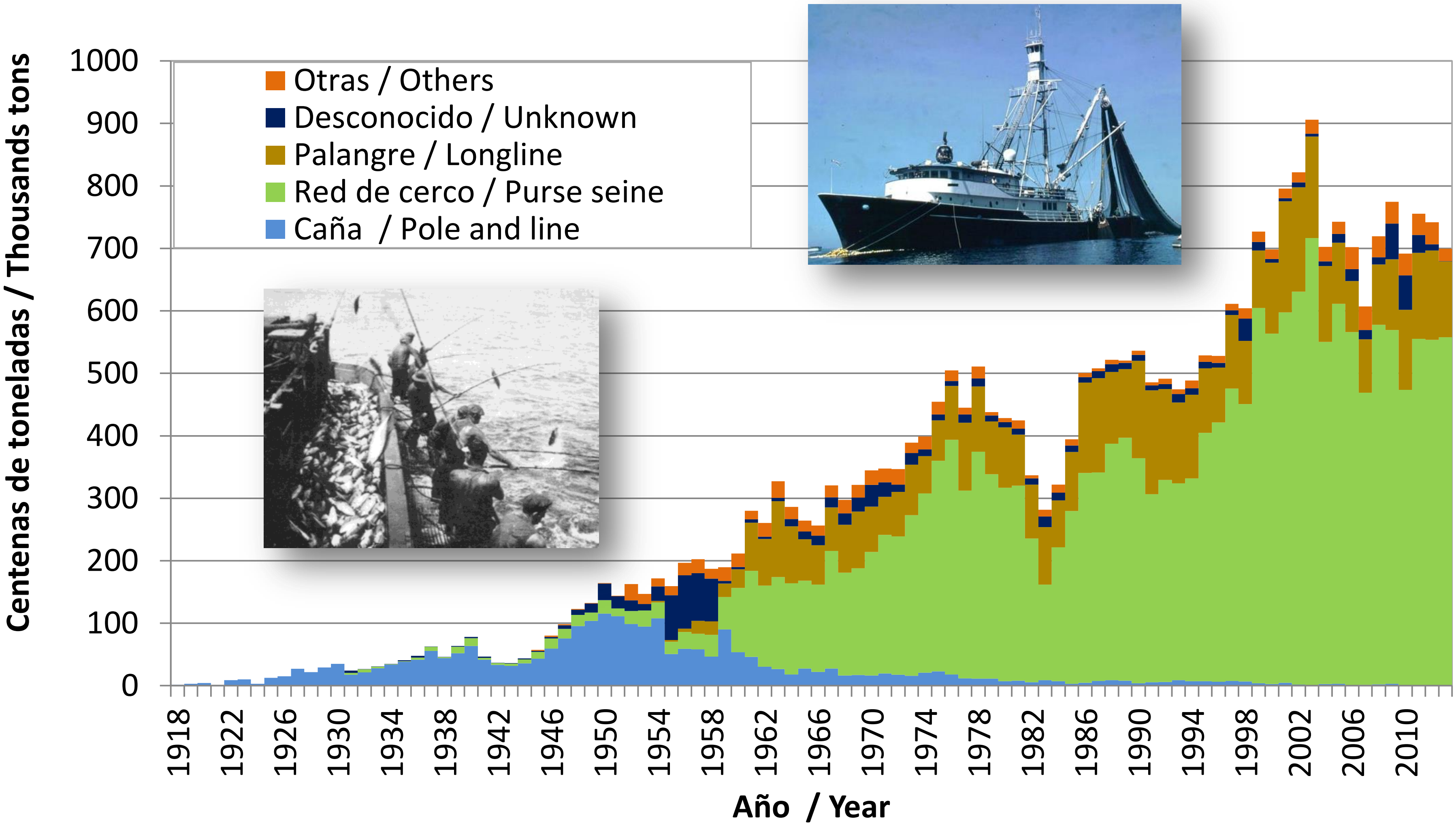
1. Eastern Pacific Ocean fisheries
2. Harvest strategies
3. Quantification of risk
4. Conclusions

1. Eastern Pacific Ocean (EPO) tuna fisheries

Catches in EPO by species



Catches in EPO by gear



2. Harvest strategies

- Antigua Convention
- Target reference points
- Limit reference points
- Harvest control rules
- MSE work

Antigua convention

ARTICLE II. OBJECTIVE

Objective: long-term conservation and sustainable use of the fish stocks

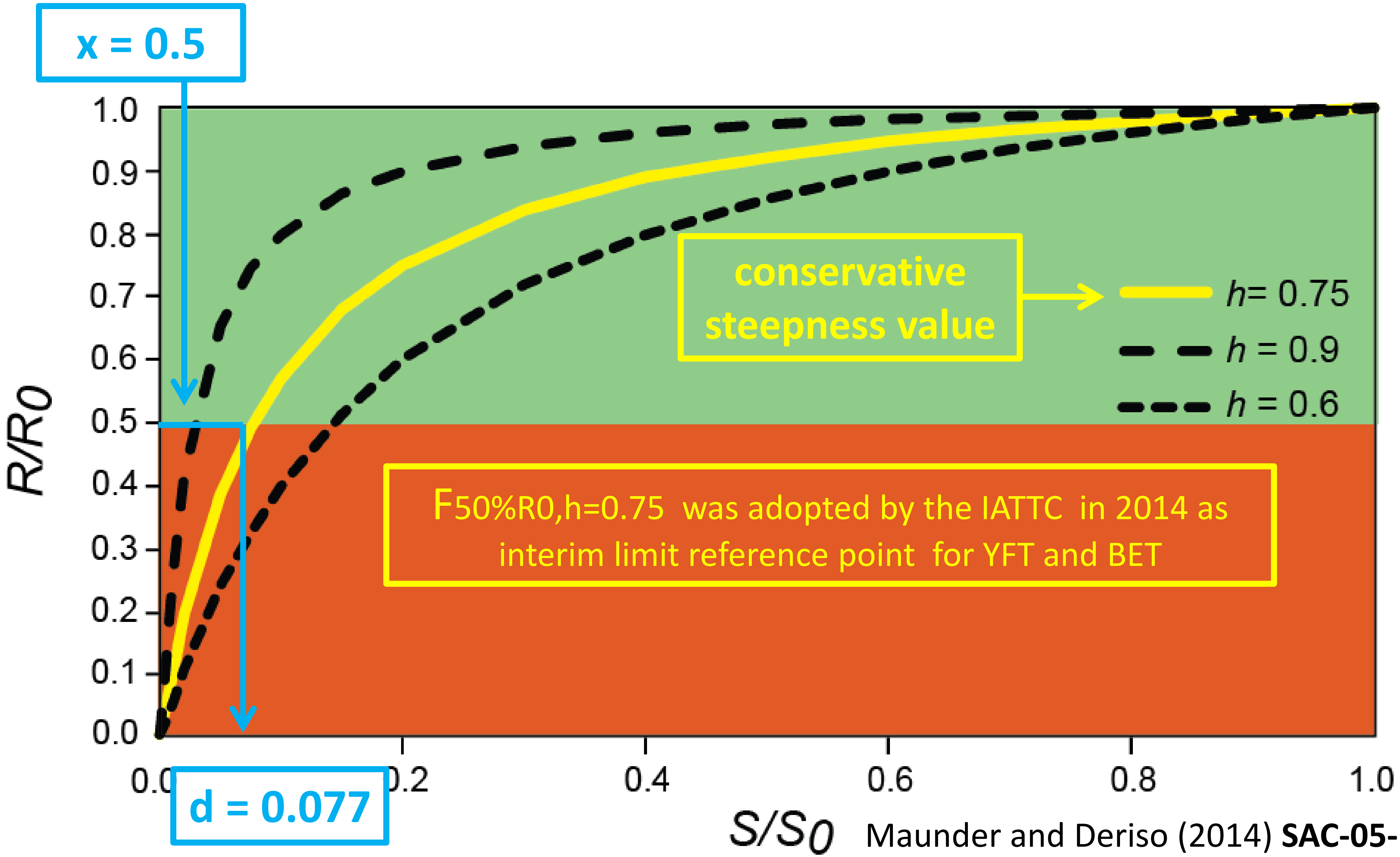
ARTICLE VII. FUNCTIONS OF THE COMMISSION

- "… adopt measures … to ensure the long-term conservation and sustainable use of the fish stocks … and to maintain or restore the populations of harvested species **at levels of abundance which can produce the maximum sustainable yield** …"
- "… adopt, as necessary, conservation and management measures and recommendations for species belonging to the same ecosystem … with a view to maintaining or restoring populations of such species **above levels at which their reproduction may become seriously threatened**;"
- "**apply the precautionary approach** … promote the application of any relevant provision of the Code of Conduct …"

Target reference point

- The IATTC staff has historically based its conservation recommendations on an **informal decision rule**.
- The **rule is based on checking** whether the **fishing mortality F_{cur}** is higher than that corresponding to the maximum sustainable yield (F_{MSY}).
- In the affirmative case, the effort is adjusted
- In the past ten years the adjustment has been done through **temporal closures** (limit on capacity and spatial closure exists)
- This implies that F_{MSY} is a **target reference point** (TRP).
- Adopted as an interim Target Reference Point

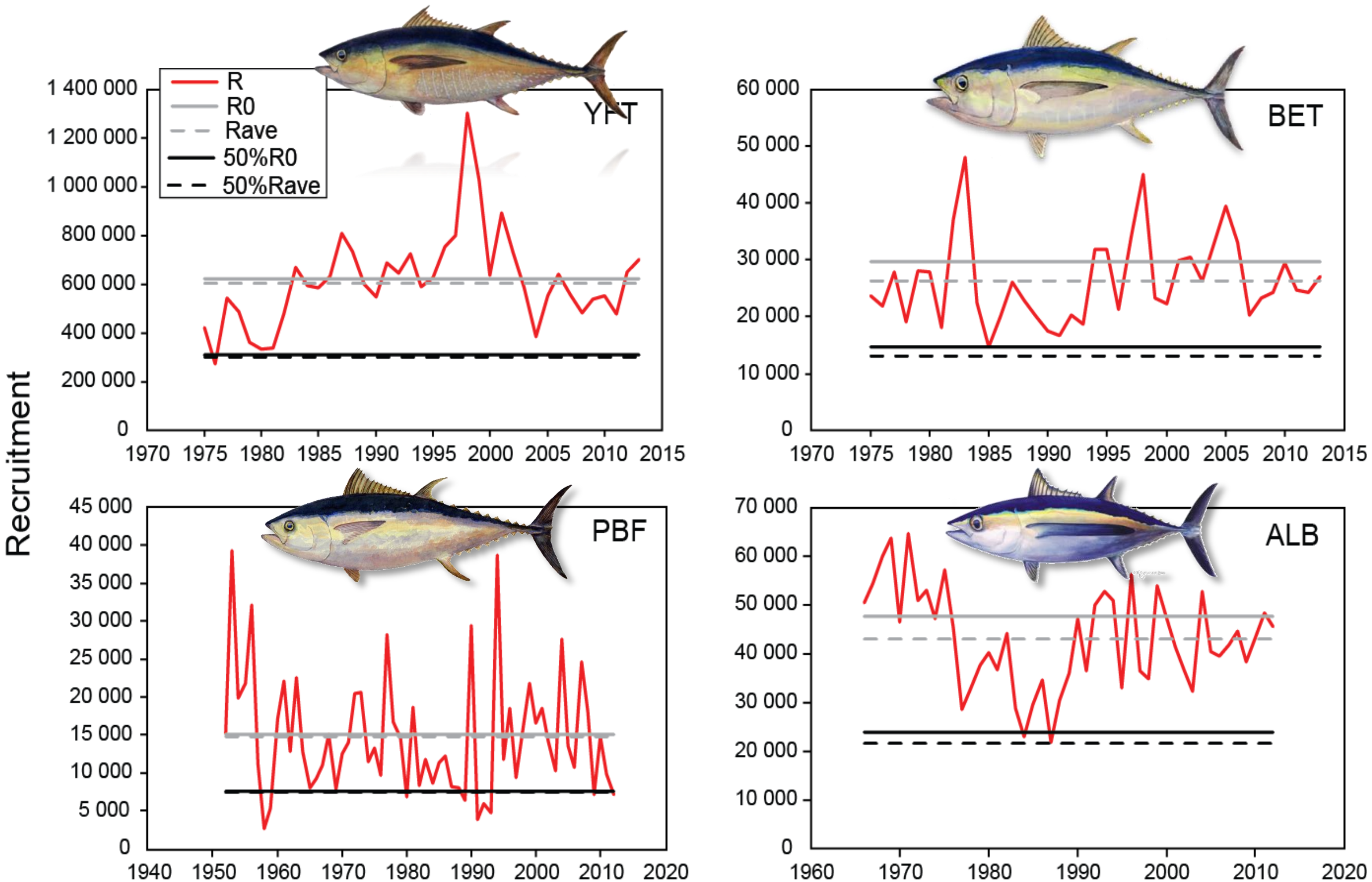
Limit reference point: IATTC



Maunder and Deriso (2014) **SAC-05-14**

Limit reference point

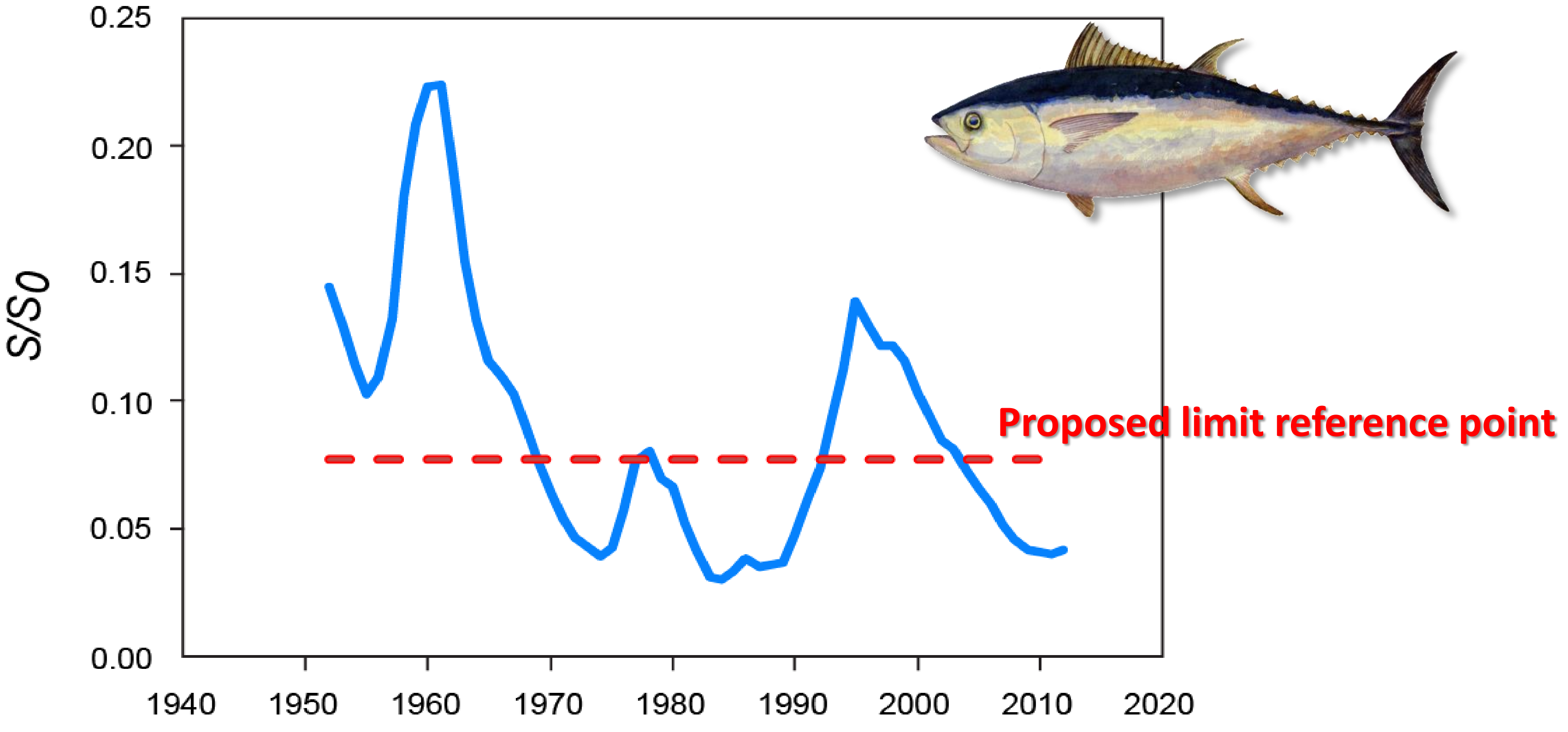
How often the recruitment has been below 50%R0?



Maunder and Deriso (2014) **SAC-05-14 presentation**

Limit reference point

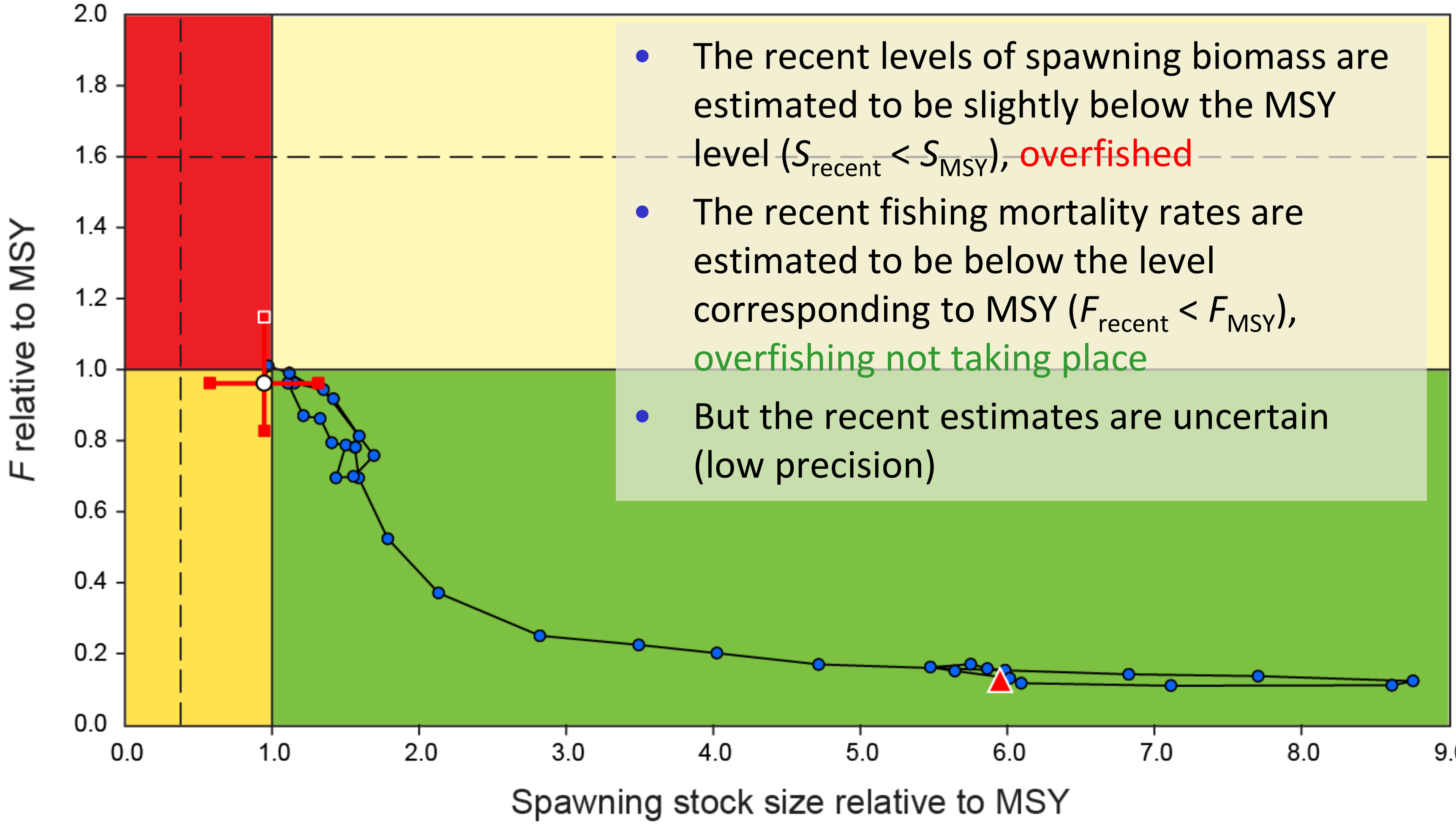
North Pacific bluefin tuna



Maunder and Deriso (2014) **SAC-05-14**

Kobe plots – BET example

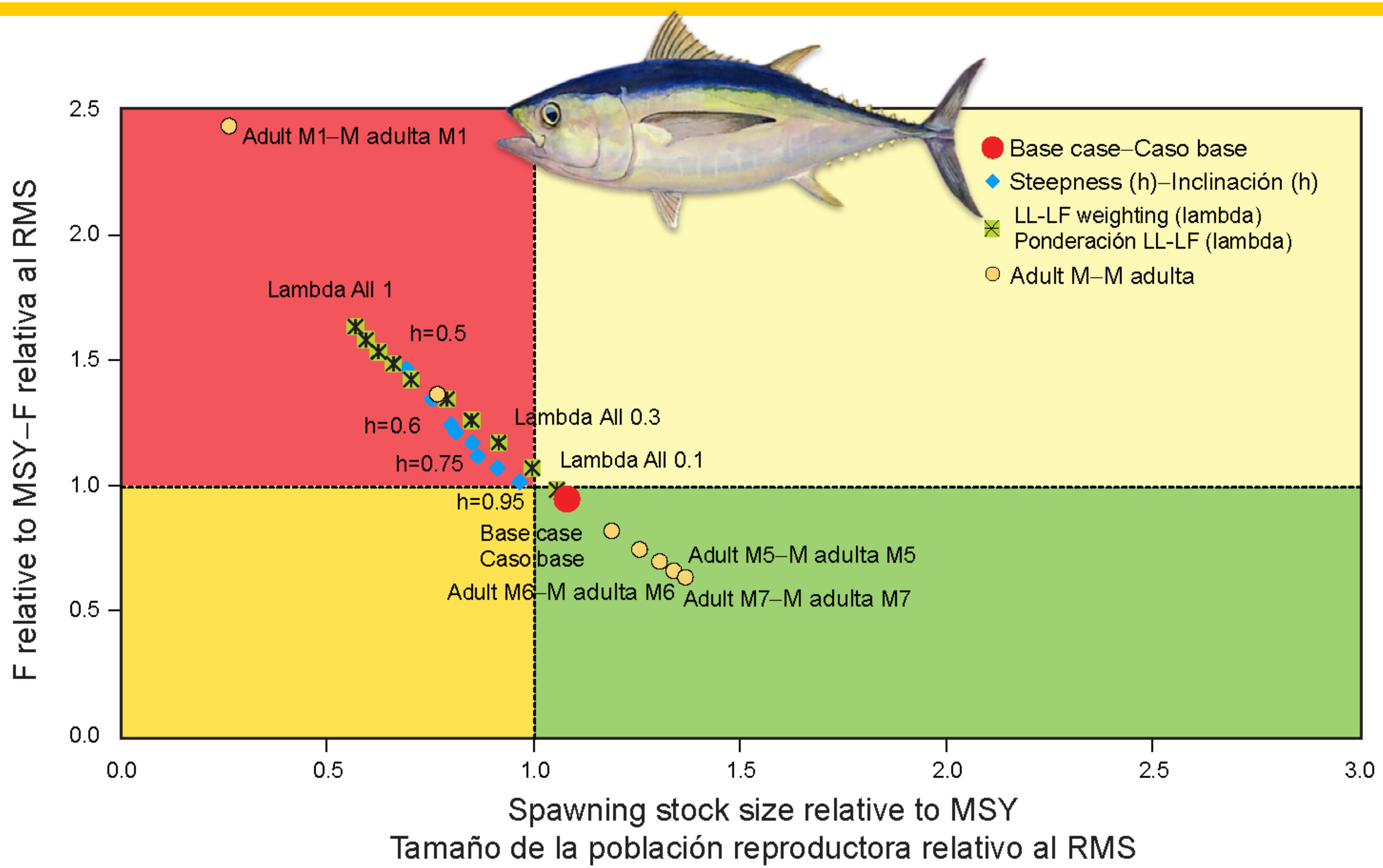
Limit reference points of 0.38 S_{MSY} and 1.6 F_{MSY} have not been exceeded



- The recent levels of spawning biomass are estimated to be slightly below the MSY level ($S_{recent} < S_{MSY}$), overfished
- The recent fishing mortality rates are estimated to be below the level corresponding to MSY ($F_{recent} < F_{MSY}$), overfishing not taking place
- But the recent estimates are uncertain (low precision)

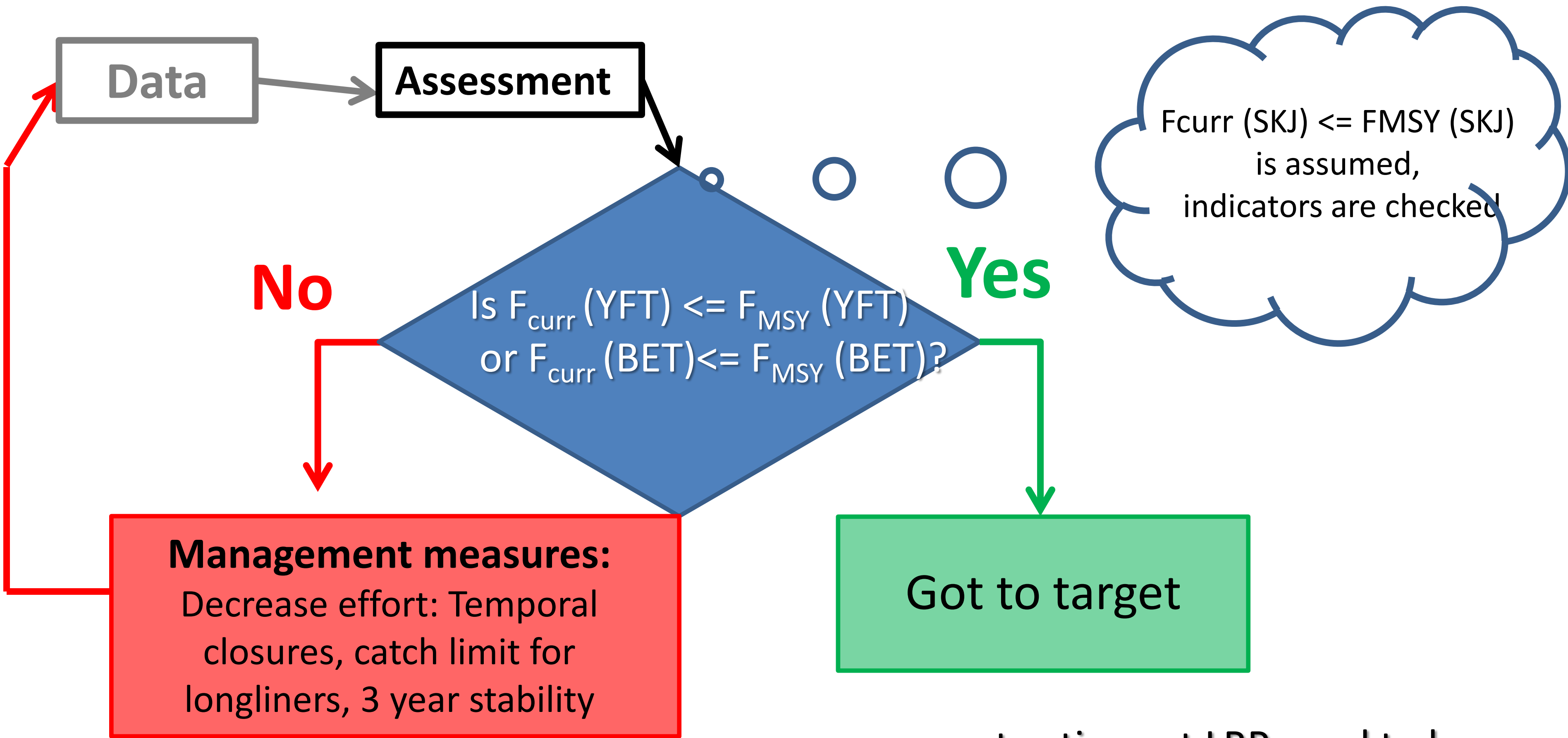
Modified from Aires-da-Silva et al 2014 **SAC-05-08a**

Structural uncertainty: full assessment BET example



Aires-da-Silva et al (2013) SAC-04-05a

Multispecies harvest control rule



Other measures: capacity limit, spatial closure (corralito), full retention

management actions at LRP need to be addressed…

MSE work

Concluded or in progress

- MSE for PBT (Maunder, 2014)
- MSY-seeking harvest control rules (Maunder et al in prep)
- Testing of LRP
- MSE for dorado (mahi mahi)

Planned

- MSE for ALB and PBF (in collaboration with ISC)
- MSE for tropical tunas

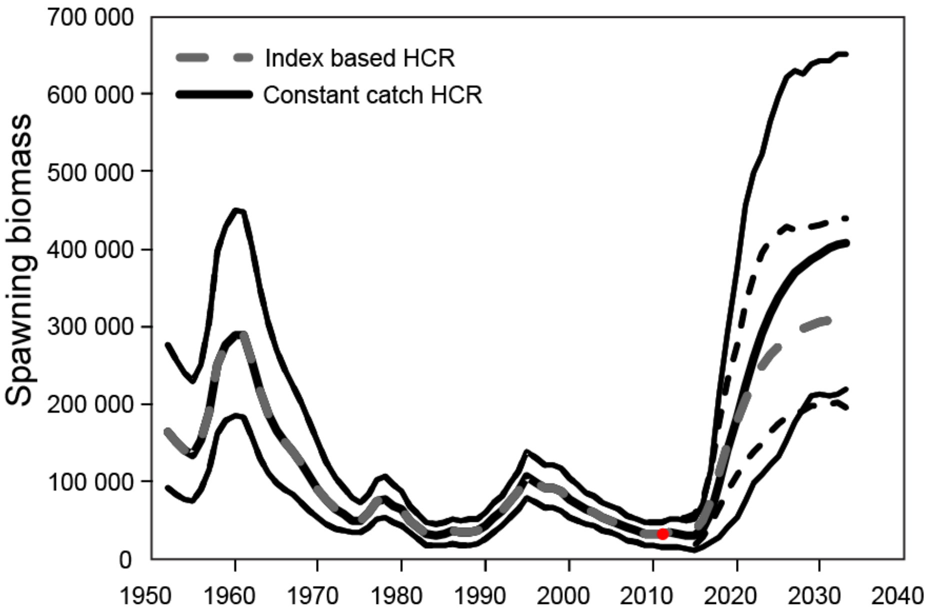
MSE for PBF in SS3

- SS3 stock assessment model (SAM) from ISC used as an operating model (OM)
- Bayesian MCMC to develop states of nature: directly estimates probability, allows the inclusion of priors, and estimates uncertainty for all parameters and their correlation simultaneously
- Two Harvest Control Rules compared
- *Main advantage*: operational model is available (SS)
- *Main disadvantage:* It doesn't include all main sources of uncertainty (e.g. steepness, natural mortality, growth)

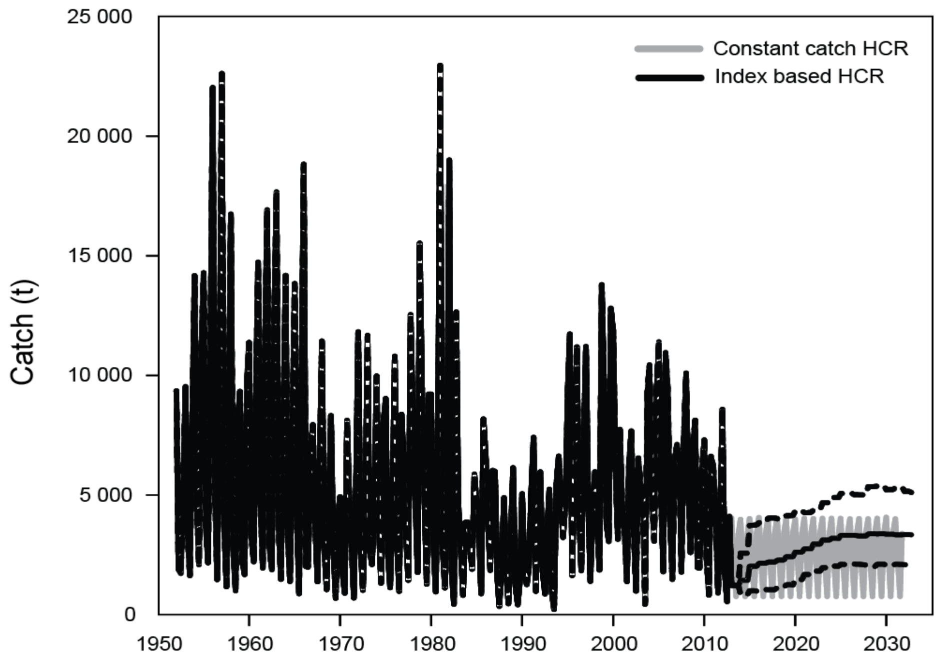
Maunder (2014) **SAC-05-10b**

Pacific bluefin tuna application

Spawning biomass



Catches



Control rule 1: Constant catch HCR

Higher initial catches, stabilized the population at a larger size, smaller long-term catches

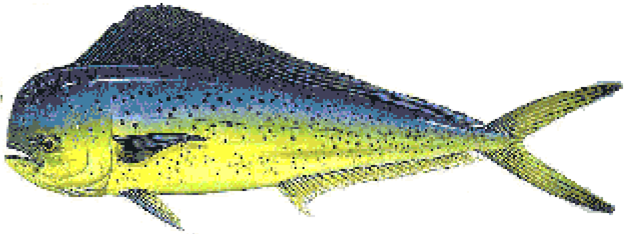
Control rule 2: index-based HCR (based on CPUE)

Lower initial catches, stabilized the population at a smaller size, larger long-term catches

Maunder (2014) **SAC-05-10b**

MSE for tropical tunas

- Reference points
  - Target: F_{MSY} and B_{MSY}
  - Limit: $F_{0.5R0}$ and $B_{0.5R0}$
- HCR
  - F <= FMSY for both species
  - What action when $B<B_{50\%R0}$
- Other management objectives
- Other management options
- Operating models
  - Use assessment models
  - What additional uncertainty
- What performance measures
  - Probability that $B<B_{50\%R0}$ leading to drastic management measures



MSE for dorado

- Collaborative process led by IATTC
  - No assessment, a preliminary SS3 OM model available
- Defining the objectives
- MSY unknown, indicators can be used (e.g., mean size, CPUE)

Conclusions

- Target and interim limit reference points already in place
- Need to determine action if limit reference point exceeded
- Interim HCR used
- HCR needs to be simulation tested (MSE)
- Progress has been made on MSE and there are plans for the near future

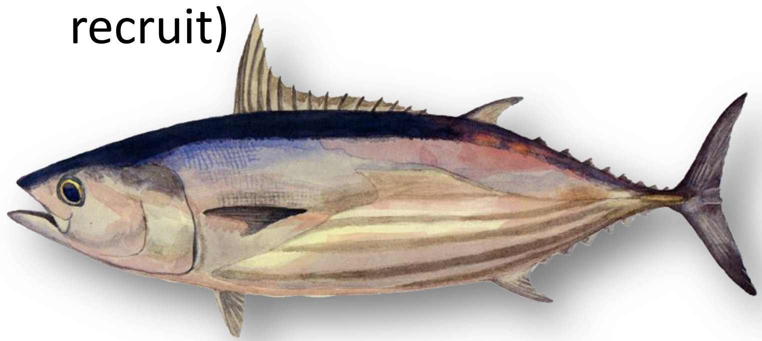

Questions?

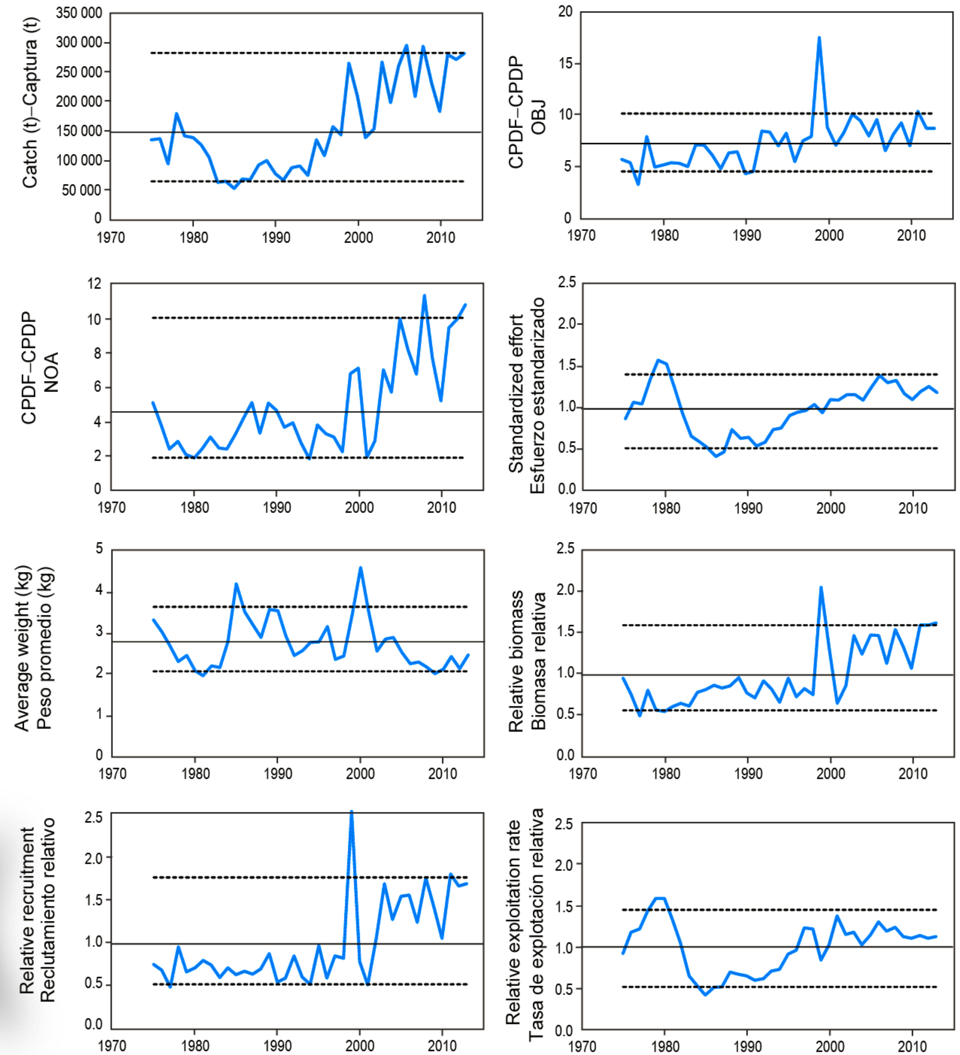
3. Addressing uncertainty

Indicators

SKJ

- Assessments are hard to do: very variable productivity, rapid growth, environmental effects
- Maunder and Deriso (2007) proposed indicators
- Other analyses support the good condition of the stock (PSA, SEPODYM, Yield per recruit)



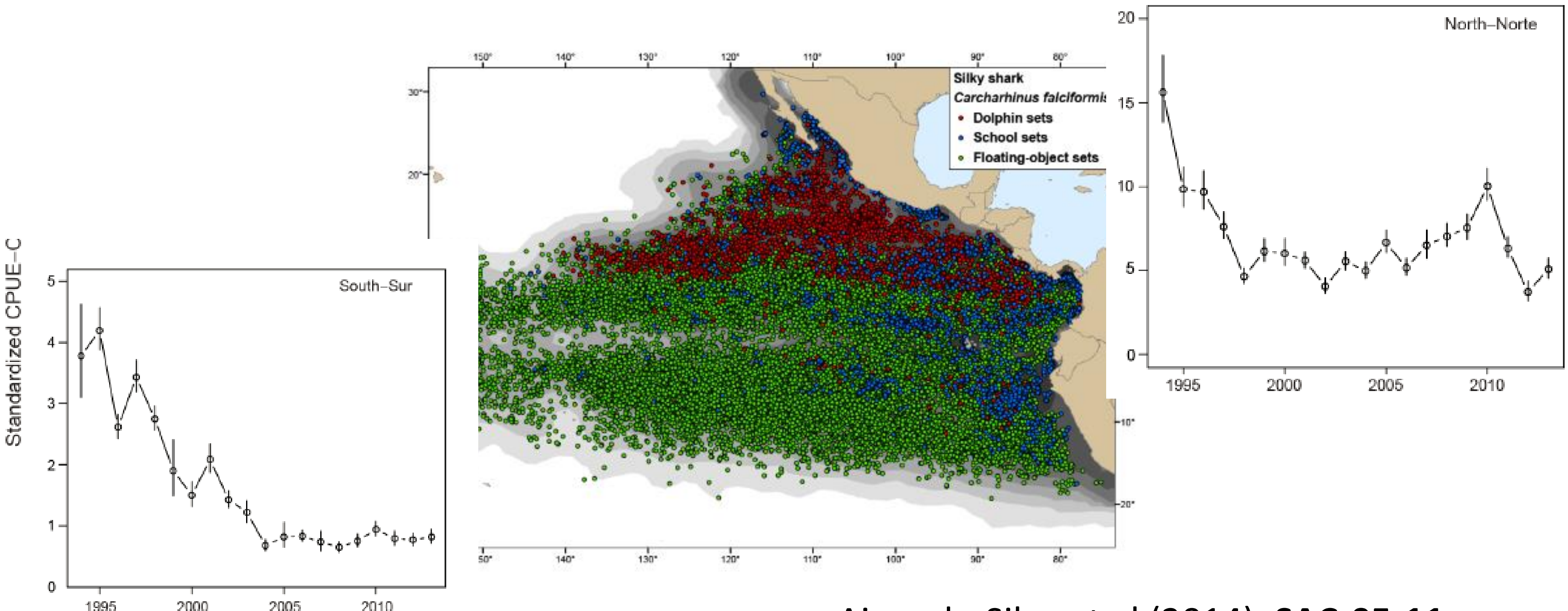


Maunder (2014) **SAC – 05 -09 a**

Indicators

Silky shark, other bycatch species

- New requirements that result from the Antigua convention
- Silky shark assessment attempted, not enough information of total catches, indicator based on PS-OBJ cpue developed



Aires-da-Silva et al (2014) **SAC-05-11a**

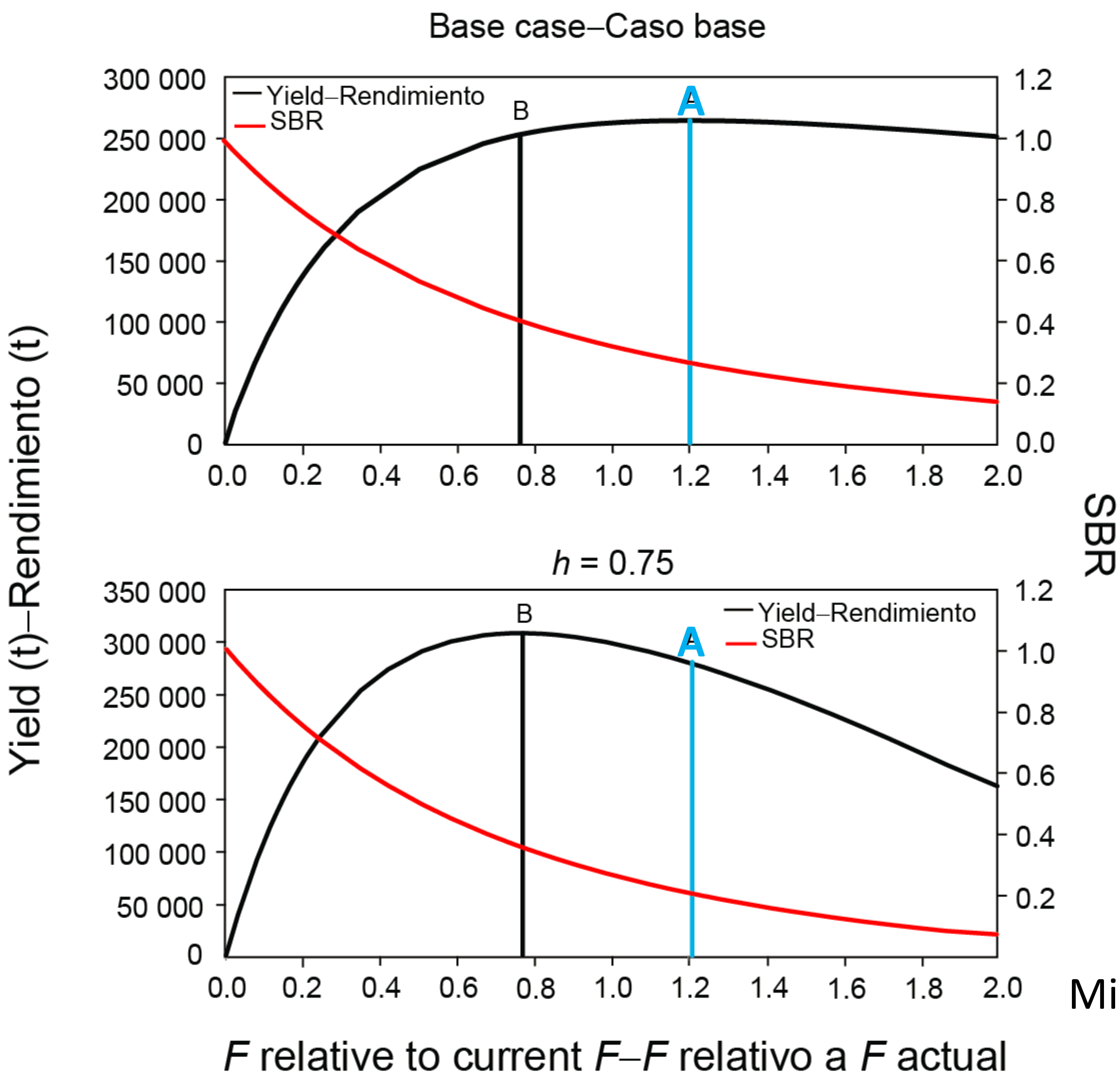
How uncertainty is estimated is the stock assessments

- Asymptotic confidence intervals (normal approximations)
- Data weighting:
  - Variability of LL fishery cpue is fixed, others estimated (NOA, DEL)
  - Length frequency sample size fixed to the number of wells

How structural uncertainty is treated

- Annual assessment cycle: update assessments
  - Base-case with steepness value h=1
  - Sensitivity case with steepness value h=0.75
  - Base-case used to provide advice
  - Recruitment variation taking into consideration through the use dynamic reference points
- Every 2 or 3 years: full assessments
  - Main uncertainties explored :
    - Steepness of the stock-recruitment relationship
    - Natural mortality
    - Mean size of old individuals
    - The assumption of proportionality between index of abundance and stock size
    - Variation in selectivity*
  - Base-case selected

Structural uncertainty: update assessments YFT example



A – fish according to base-case (h=1) advice

B – fish according to sensitivity-case (h=0.75) advice

Yield – long-term equilibrium yield

SBR – long-term equilibrium spawning-biomass per recruit

Minte-Vera et al (2014) SAC-05-07

Plans to treat structural uncertainty

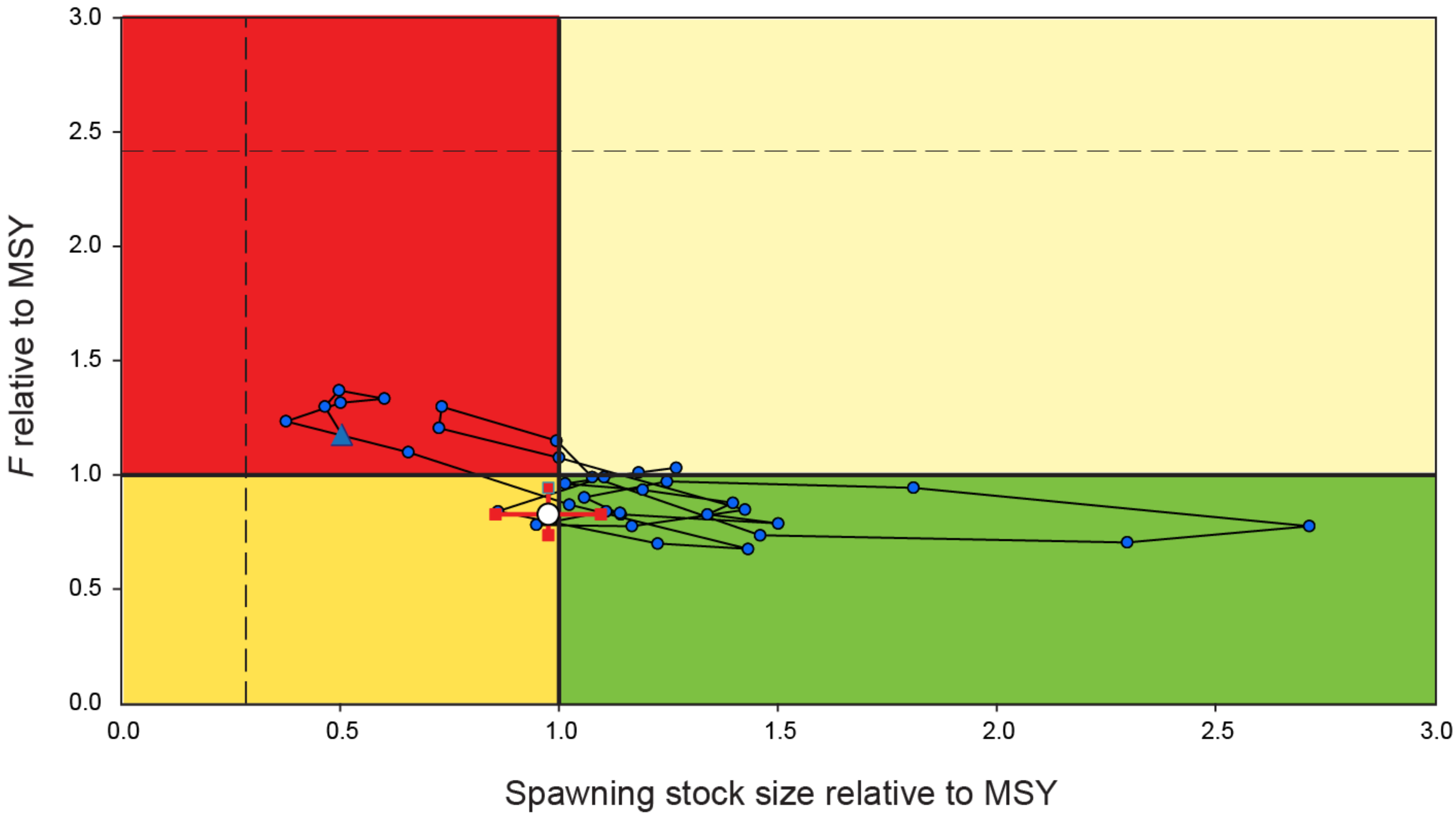
- Observation error on length frequency: to be estimated using bootstrap (Francis-Pennington method) (Lennert-Cody et al in prep)

- Process error to be estimated using time-varying selectivity (Aires-da-Silva et al in prep)

- This procedure may add more uncertainty to the analysis

Kobe plots – YFT example

Limit reference points of $0.28S_{MSY}$ and $2.42\ F_{MSY}$ have not been exceeded



Modified from Minte-Vera et al (2014) SAC-05-07

Recruitment variation taken into consideration: computation of dynamic reference points

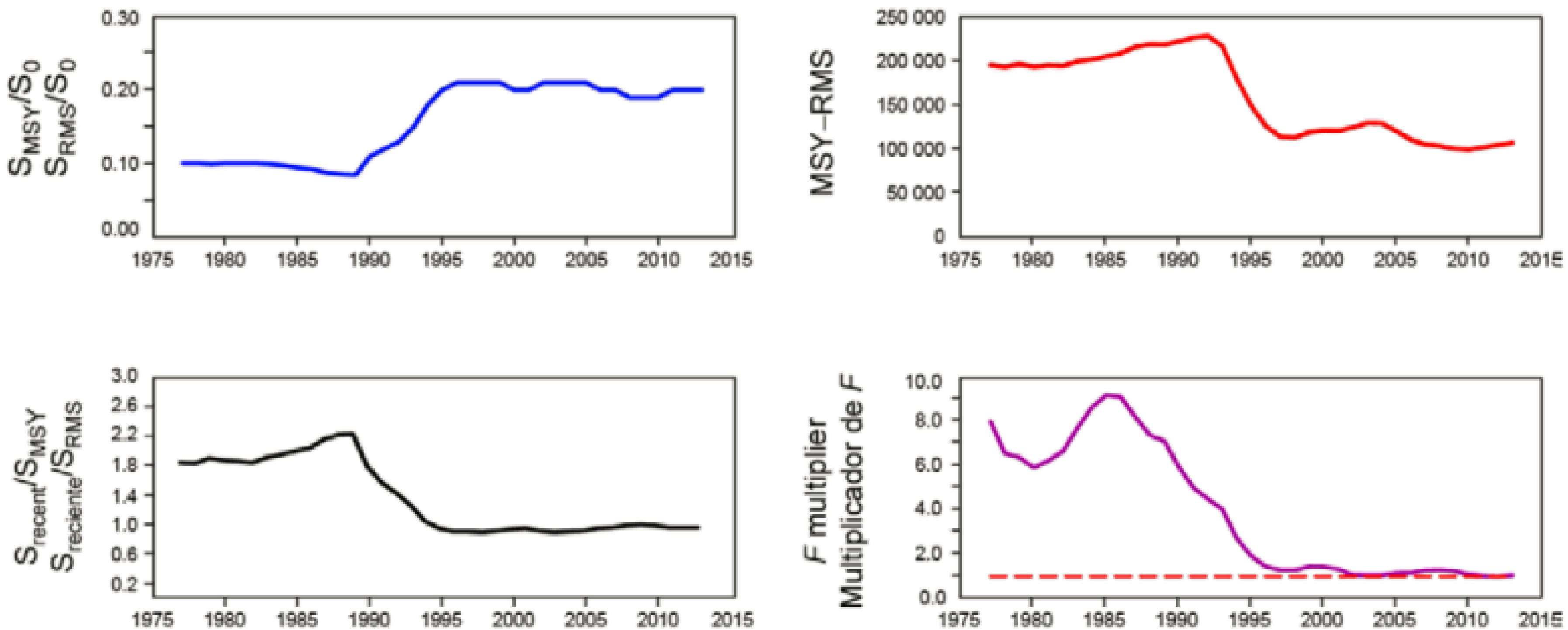


FIGURE 6. Estimates of MSY-related quantities calculated using the average age-specific fishing mortality for each year. (S_{recent} is the spawning biomass at the beginning of 2014.)

Aires-da-Silva et al 2014 SAC-05-08a

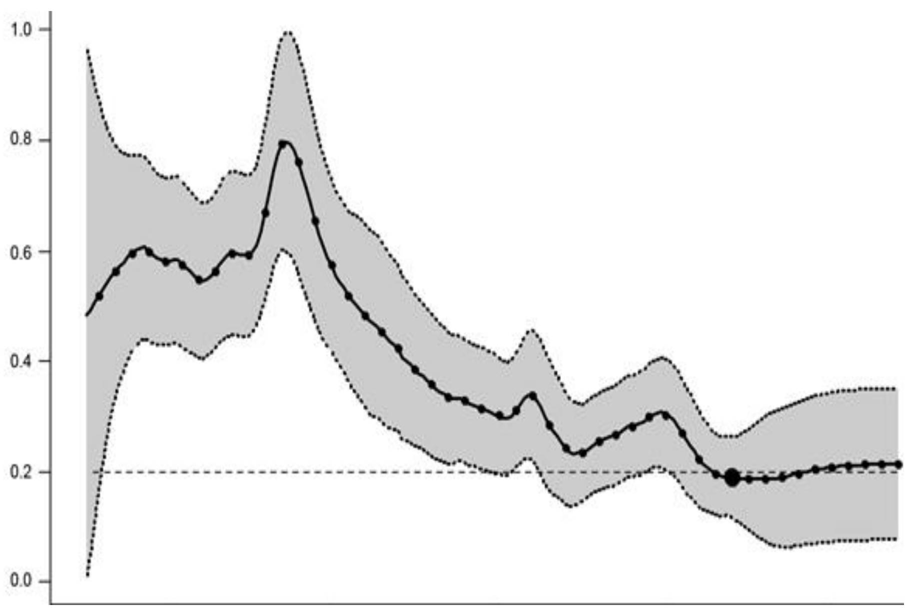
Uncertainty in projections: estimation error and two scenarios of productivity

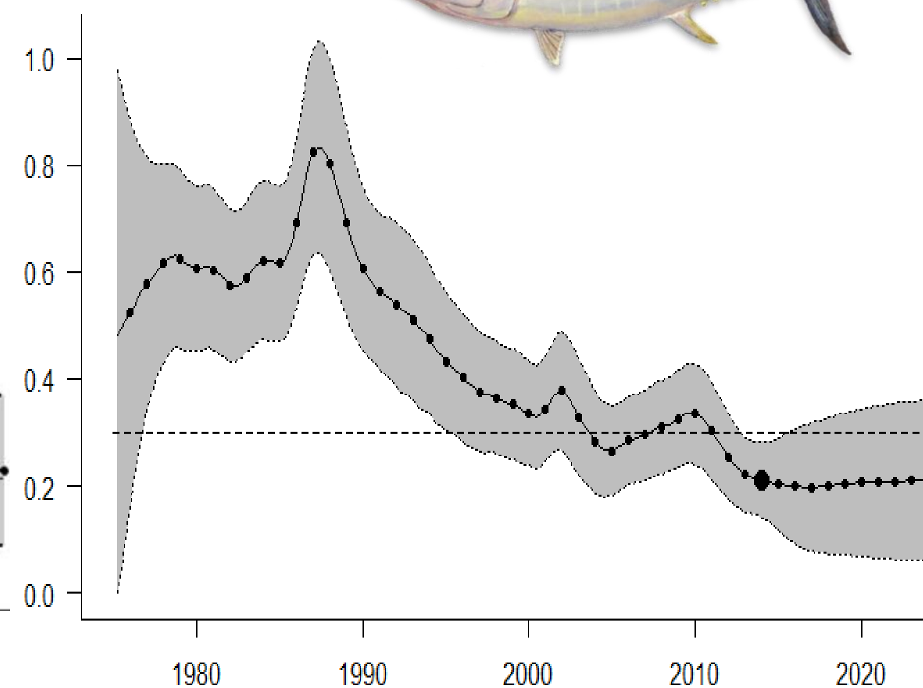
BET

Base-case (h=1)

Sensitivity case (h=0.75)

Spawning Biomass Ratio (SBR)





Year

Aires-da-Silva et al 2014 SAC-05-08a

Uncertainty: Kobe matrix - BET example

- Computed using fishing mortality
- Normal approximation for computing the probabilities
- Only use the base case model

Proposed reference point	State of nature steepness	Fraction of the current (2010-2012) fishing mortality required to ensure the following probability of being below the target or limit			
		95%	**90%**	**80%**	**50%**
Target $F = F_{MSY}$	Base case	0.899	0.933	0.974	1.053
	h = 0.75	0.713	0.738	0.767	0.825
Limit $F = 1.3\ F_{MSY}$	Base case	1.168	1.213	1.266	1.369
	h = 0.75	0.927	0.959	0.998	1.072

Minte-Vera et al 2013 - SAC-04-09a

Uncertainty: Kobe matrix - BET example 2

- Integrated over model structure uncertainty:
  - **M** natural mortality, **h** steepness, **Linf** size of the largest animal
  - With *a priori* and equal weights

TABLE 3. Kobe strategy matrix for bigeye tuna, using the base case assessment and integrating over model structure uncertainty, including values of natural mortality, average length of the oldest bigeye tuna, and steepness of the Beverton-Holt stock-recruitment relationship. The contents of the table are the fraction of the current fishing mortality that is required to ensure the given probability that the fishing mortality is below the fishing mortality corresponding to MSY.

Management target	Weights	Probability of meeting target		
		95%	90%	80%
$F > F_{MSY}$	Base case	0.83	0.86	0.90
	A priori	0.54	0.60	0.67
	Equal	0.43	0.49	0.59

Maunder et al 2012 SAC-03-06c

Decision table for bigeye in the EPO in 2012

Biomass reference points

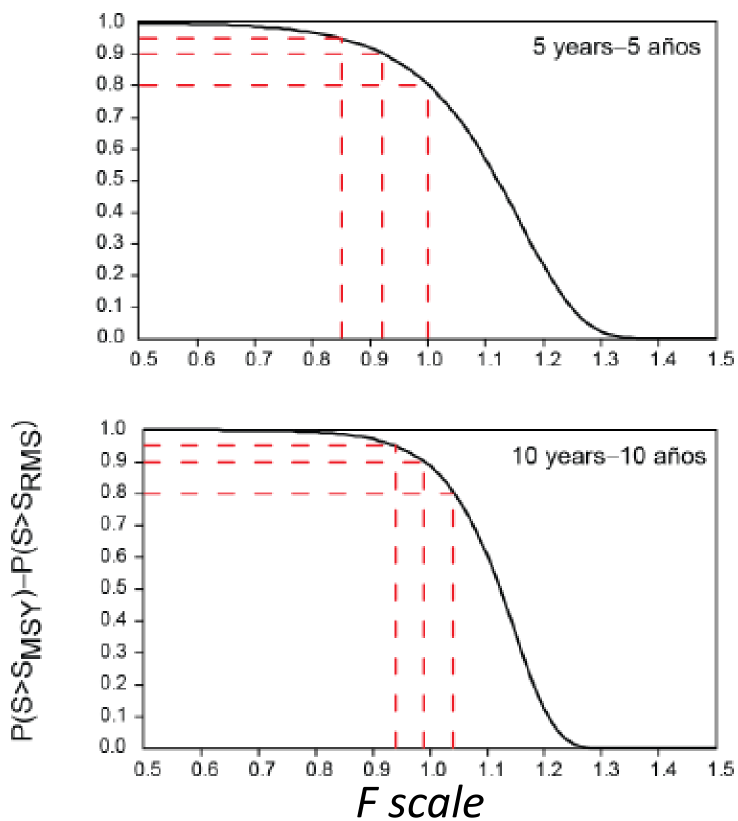
Proposed reference point	State of nature steepness	Time frame (years)	Probability of being above the target or limit by fishing at	
			F_{cur}	F_{MSY}
target $S = S_{MSY}$	Base case	0	0.794	0.794
		5	0.485	0.349
		10	0.579	0.488
	h = 0.75	0	0.259	0.259
		5	0.125	0.124
		10	0.179	0.333
limit $S = 0.5\ S_{MSY}$	Base case	0	0.998	0.998
		5	0.904	0.995
		10	0.931	1
	h = 0.75	0	0.997	0.997
		5	0.808	0.981
		10	0.796	1

F_{cur} is the average fishing mortality for the last three years in the current assessment (2010-2012)

Minte-Vera et al 2013 - SAC-04-09a

Risk curves: BET example

FIGURE 1. Probability that the spawning biomass (*S*) after a given numbers of years is above the spawning biomass corresponding to MSY (S_{MSY}) for different fractions of the current (2009-2011) fishing mortality rate. The dashed lines represent 80%, 90%, and 95% probabilities.



Maunder et al 2012 **SAC-03-06c**

"Mini" MSE for BET

HCR 1: apply the h=1 advice	Performance indicators			
Structural Uncertainty	P(S> SMSY)		P(S> 50% SMSY)	
time frame	in 5 years	in 10 years	in 5 years	in 10 years
Steepness h=0.75	0.012	0.004	0.912	0.94
Stock muy productivo	0.349	0.488	0.995	1
HCR 2: apply the h=0.75 advice				
Structural Uncertainty	P(S> SMSY)		P(S> 50% SMSY)	
time frame	in 5 years	in 10 years	in 5 years	in 10 years
Steepness h=0.75	0.124	0.333	0.981	1
Stock muy productivo Steepness h=1	0.799	0.971	0.999	1

Minte-Vera et al 2013 - SAC-04-09a

Conclusions

- Target and interim limit reference points already in place
- Need to determine action if limit reference point exceeded
- Unofficial HCR used
- HCR needs to be simulation tested (MSE)
- Uncertainty presented, but not fully integrated into management
- Progress is being made and we have plans for the near future

Thank you!

EXTRAS

Main assessment models used

- **Stock synthesis 3**: an age-structured integrated model
- Fit to length-frequency data, CPUEs and conditioned on catches
- Model starts at an exploited state in 1975
- Areas as fleets approach
- Main uncertainties:
  - Natural mortality
  - Steepness of the stock-recruitment relationship
  - Length of oldest individuals

YFT

- 16 fisheries defined by gear (set type) and area of operation
- Data weighting: the CV of the southern LL fishery was fixed, purse-seine estimated

BET

- 23 fisheries defined by gear (set type), area of operation and time
- Size composition down-weighted
- Fit to Central and Southern LL CPUE only

Limit reference point

- The limit reference point (LRP) development took into account that it should be **based on biological grounds** to protect a stock from serious, slowly reversible or irreversible fishing impacts
- Its is based on the **predicted reduction in recruitment** compared to virgin recruitment

- Reduction in Recruitment Based LRP

$$P(BH(\mathbf{d},\mathbf{h}) < x\%R_0) > \pi$$

uncertainty

For BET, YFT: an approximation using x=50%R0 and h=-0.75 and F
F is obtained by finding the equilibrium fishing mortality corresponding to *d* (F50%R0,h=0.75)

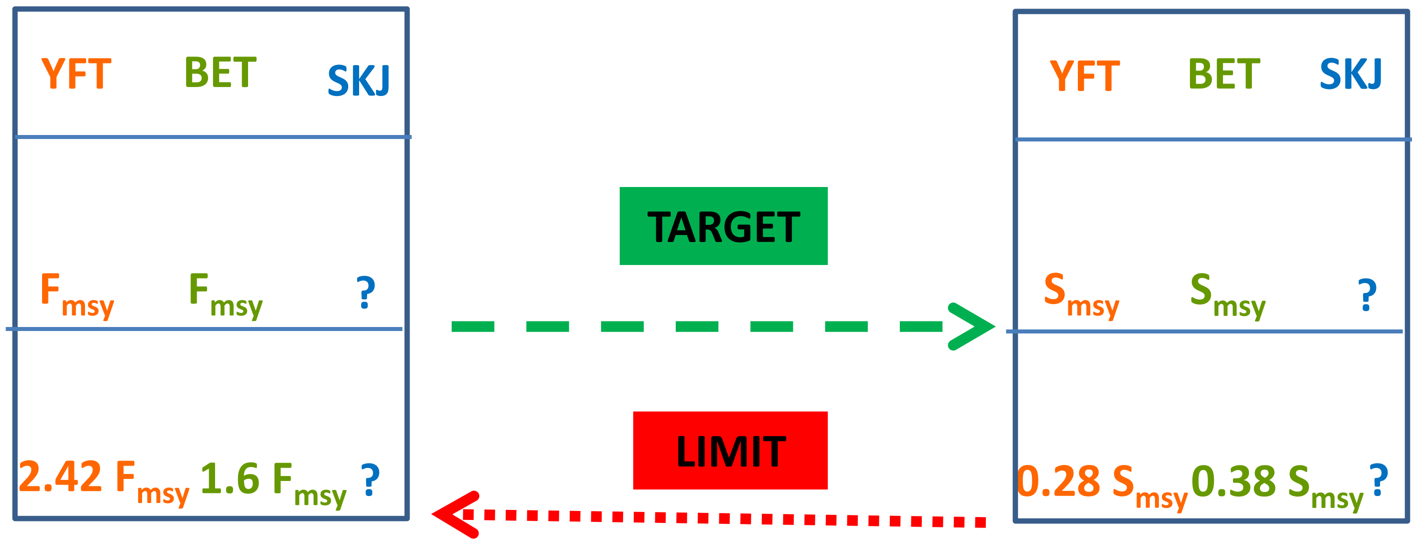
Maunder and Deriso (2014) **SAC-05-14**

Symbol	Description
P	Probability
π	The critical value for the probability that recruitment will fall below x%R_0
x%R_0	fraction of the recruitment expected in unexploited conditions
BH()	Beverton-Holt stock-recruitment relationship
$d = S/S_0$	depletion level
h	Steepness

Current values for reference points

FISHING MORTALITY (F)

SPAWNING BIOMASS (S)



The corresponding limit fishing mortality reference point ($F_{50\%R0,h=0.75}$) is obtained by finding the equilibrium fishing mortality corresponding to the depletion level ***d=0.077***

Determine states of nature: Run the SS stock assessment in MCMC mode to generate the states of nature

Mark's "recipe":

- **Extend the modelling time frame** to include the period over which the MSE will be conducted in .dat file and .ctl files.
- **Add zero catches** for all fisheries for the period of N years over which MSE will be conducted. Add N years of CPUE data to survey.
- **Turn the forecast off** and set forecast years to zero
- **Modify control file** so that recruitment bias correction is 1 for all years. Five lines: endNoBias,startFullBias,endFullBias,startNoBias,maxBiasAdj
- **Make catchabilities parameters** so that MCMC samples from them
- Make **recruitment deviates not dev_var_vector** (not sum to zero)
- **Run the model using the MCMC mcsave** option. e.g. SS –mcmc 1000000 –mcsave 1000 (you can also use the –noest option if the model has already been run with the hessian estimated).
- **Run the model using the MCMC mceval** option. e.g. SS -mceval
- The draws from the posterior of the estimated parameters will be in the file posteriors.sso

Maunder (2014) **SAC-05-10b**

Evaluate the harvest control rules
under different states of nature

Mark's "recipe" cont…

For each HCR:

a. **Take a sample of the parameters from the posterior** and insert them in the par file. This will require matching up the parameters in each file since the posteriors.sso only has the estimated parameters and the par file has all the parameters
b. **Change starter file** to initiate the model parameters from the par file and do not estimate parameters
    a. 1 # 0=use init values in control file; 1=use ss3.par
    b. 0 # Turn off estimation for parameters entering after this phase
c. **Put in data** where you would like the model to simulate data including the years, sample size/sd, and types.
d. **Add one data bootstrap** in the starter file
    a. 3 # Number of datafiles to produce: 1st is input, 2nd is estimates, 3rd and higher are bootstrap
e. **Run the model using the –nohess** command line option
f. Take the **simulated data and apply the harvest control rule** and calculate the quota.
g. **Put the quota in the data file as the catch** for the appropriate year.
h. **Repeat** e-g for each **year** of the MSE
i. **Store** the appropriate information from the SS output files (e.g. ending biomass, average catch)
j. **Repeat** a-i for each sample from the **posterior**

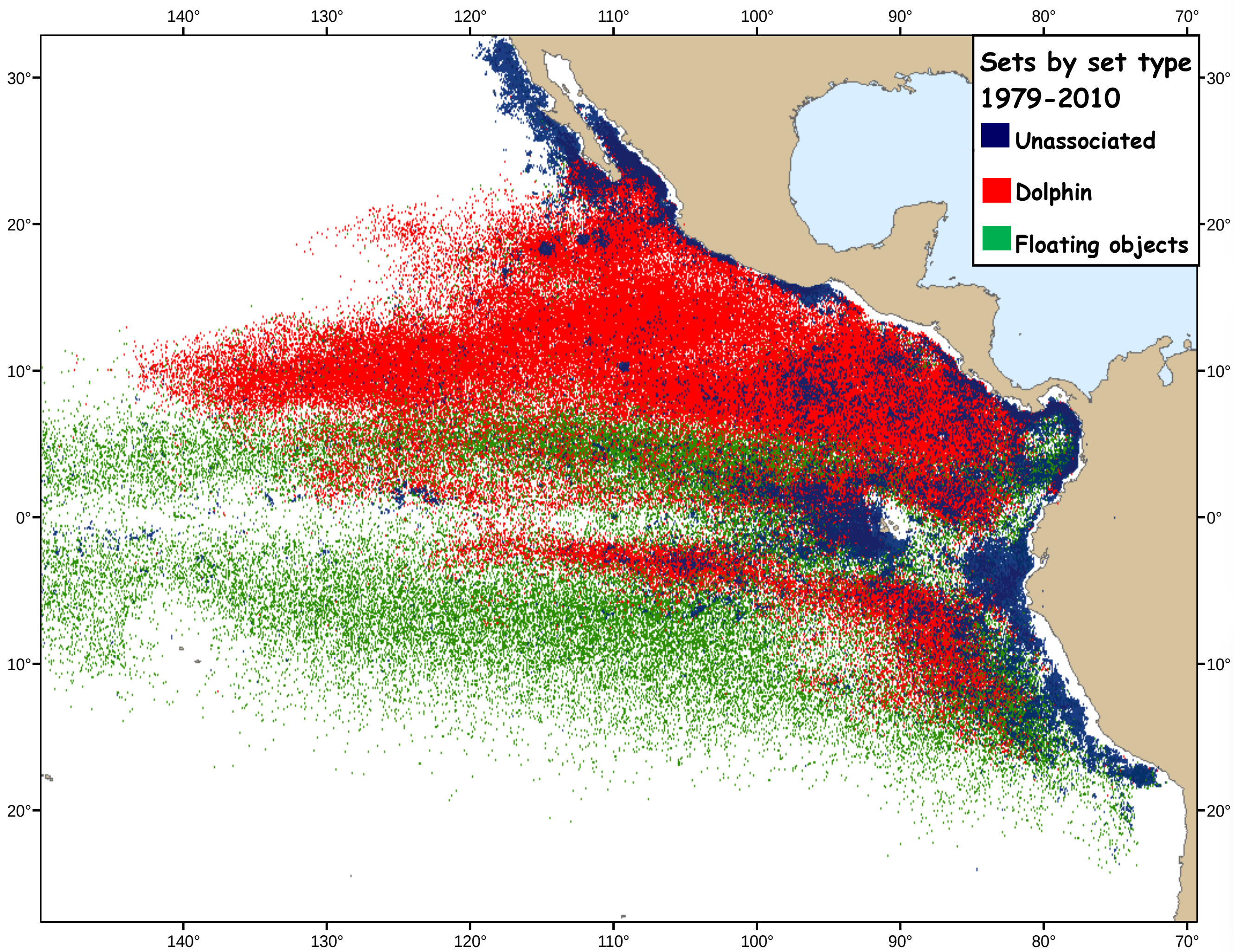
Maunder (2014) **SAC-05-10b**

In development…

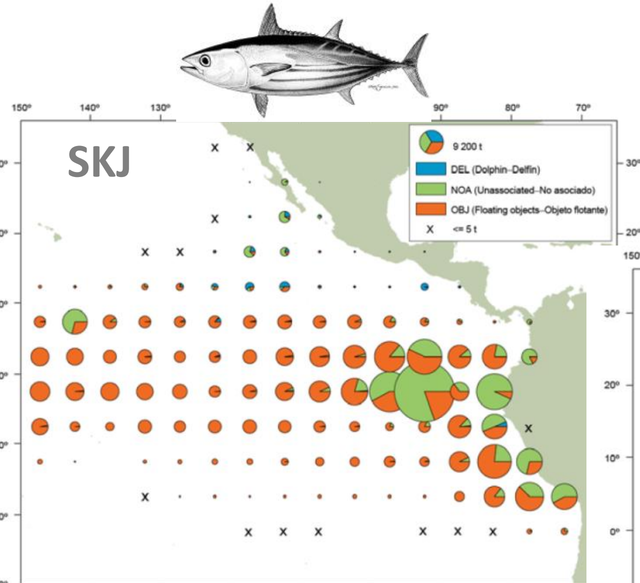
MSY-seeking decision rules (Maunder et al, in prep):

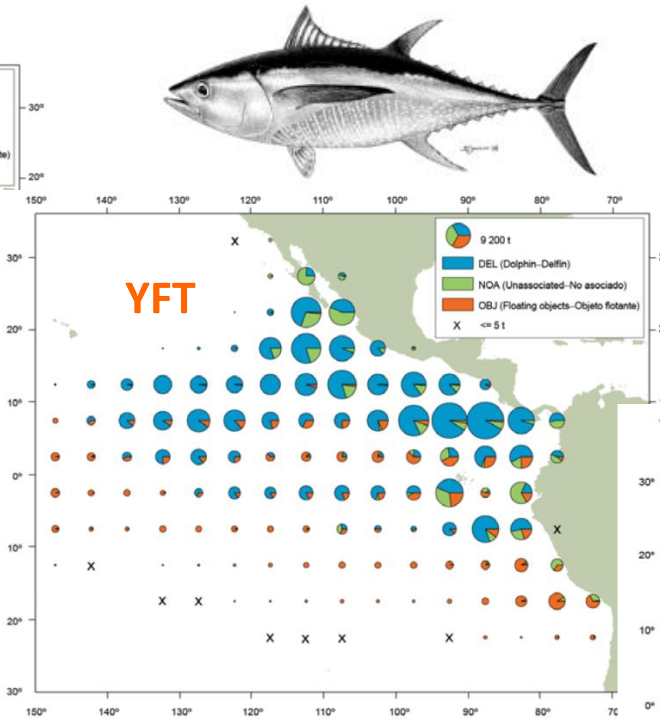
- Most HCR attempt to maintain stability, avoid adverse effects, or rebuild to pre-defined targets
- But, the objective of tuna management in the EPO (Antigua convention) is to maximize yield
- This prompt for the **development of MSY-seeking decision rules**…**coming soon!**

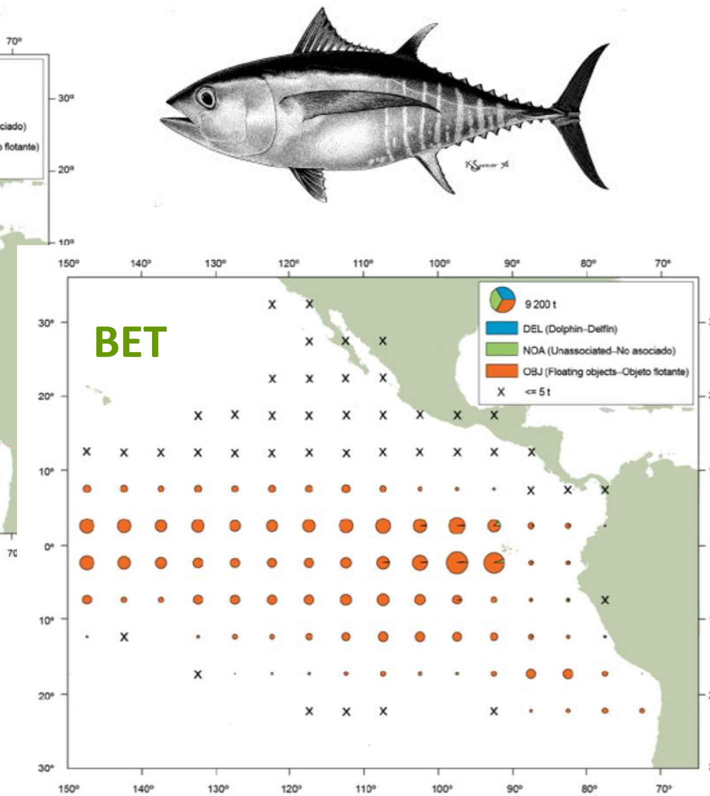
Purse seine sets the EPO



Purse seine catches in the EPO



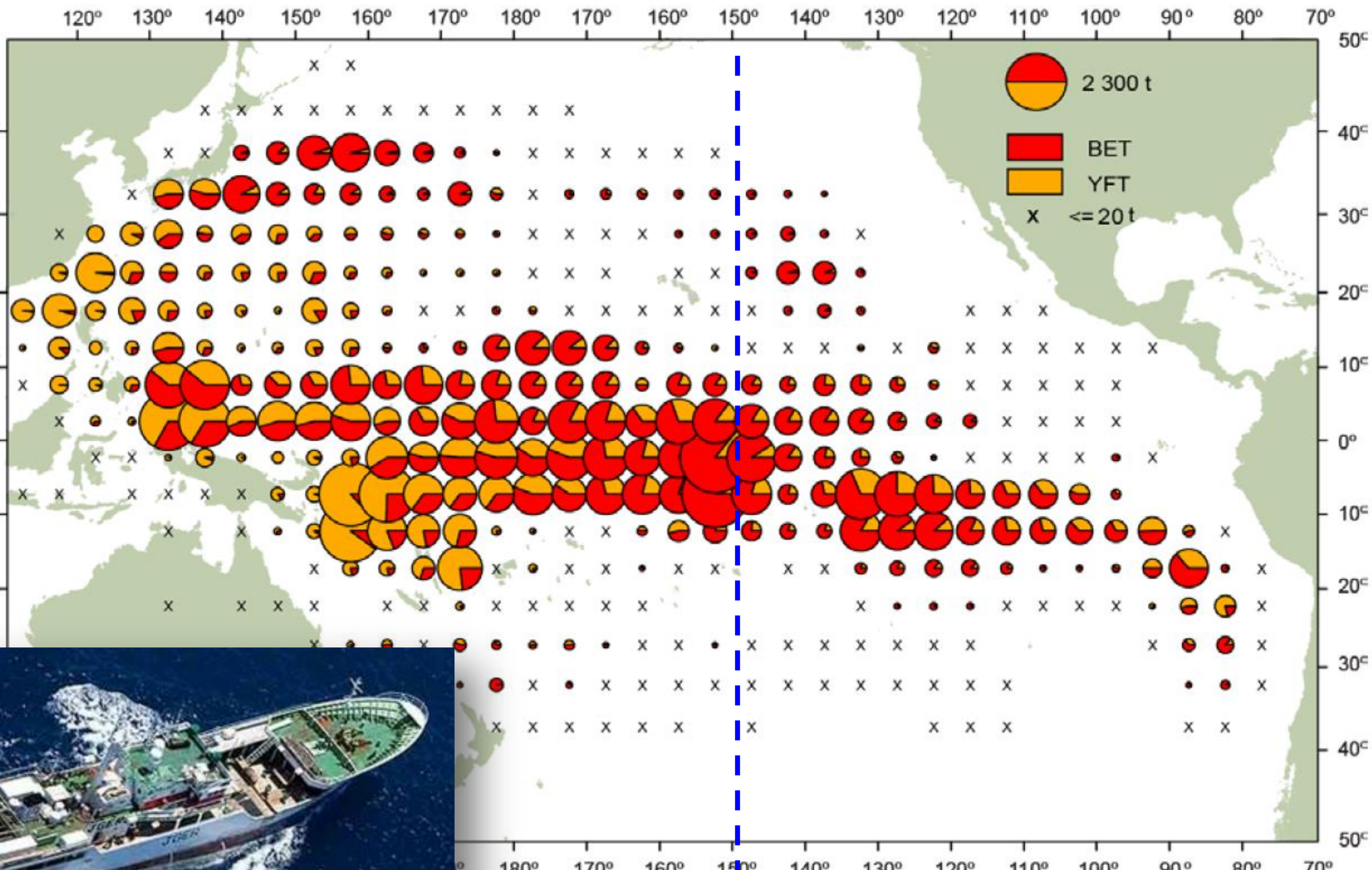




- **OBJ –** Floating objects sets
- **NOA –** Unassociated (school sets)
- **DEL –** Dolphin sets

Averages annual catches for 2008-2012

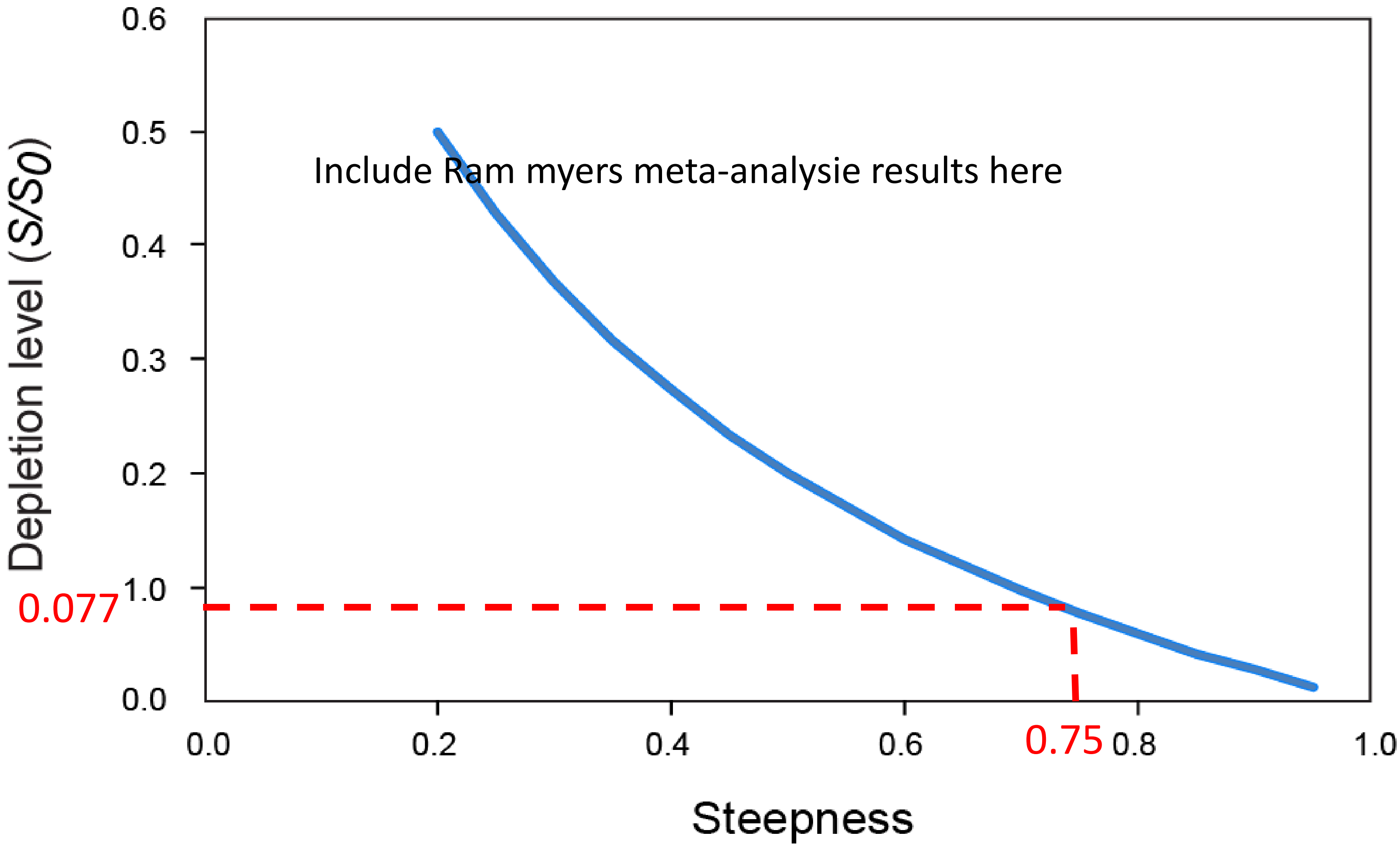
Longline tuna fishery in the EPO



Longline average annual catches

2008-2012

Biomass LRP for 50%R0



Pacific bluefin tuna application

Rule 1: Constant catch HCR

- All fisheries that catch juvenile bluefin have their catch set at 50% of the average catch from 2002-2004, by quarter.
- Other fisheries have their catch set at the average catch from 2010-2012.

Control rule 2: index-based HCR

- Based on two CPUE-based indices of abundance: an index of spawning biomass based on Japanese longline CPUE, and an index of recruitment (one-year-olds) based on Japanese troll CPUE.
- The catch for each fishery is a harvest rate times the current index of abundance averaged and lagged appropriately.
- The index used differs by fishery, and is related to the ages selected by the fishery.
- An average of the index over one or more years is used to correspond to the ages caught by the fishery.
- The harvest rate is calculated as the average catch in the past three years (2010-2012) divided by the average index in the past three years, averaged and lagged appropriately.
- This “current” harvest rate is then multiplied by 0.5 to approximate the first harvest control rule and allow for rebuilding.

Apply the harvest control rule

Mark's "recipe" cont…

- Take the historical observed data (or the simulated data for this period) and add the simulated data for the future years if appropriate (from data.ss_new) and conduct the assessment and apply the control rule to determine the quota.
- Only take the newly created data point each year because all data points, including the ones that have already been used in the decision rule for previous years, are randomly generated.
- Make sure you take the value for the third data set, which is the one that is randomly generated.
- If you are using the catch in the decision rule (e.g. if the assessment model for your decision rule is based on a surplus production model) make sure you take the catch from SS and not from the previous assigned quota because if the quota is too high the setting for maximum F in SS may cause the catch used in SS to be lower than the quota.

MSE with stock assessment model as operating model for PBT

Advantages

- You do **not need to know the production function** (i.e. you do not need to know natural mortality or the stock-recruitment relationship, which are both typically highly uncertain)
- Basing the reduction (when the index decreases) on the catch rather than the productivity reduces the risk of stock collapse if catchability is misspecified.

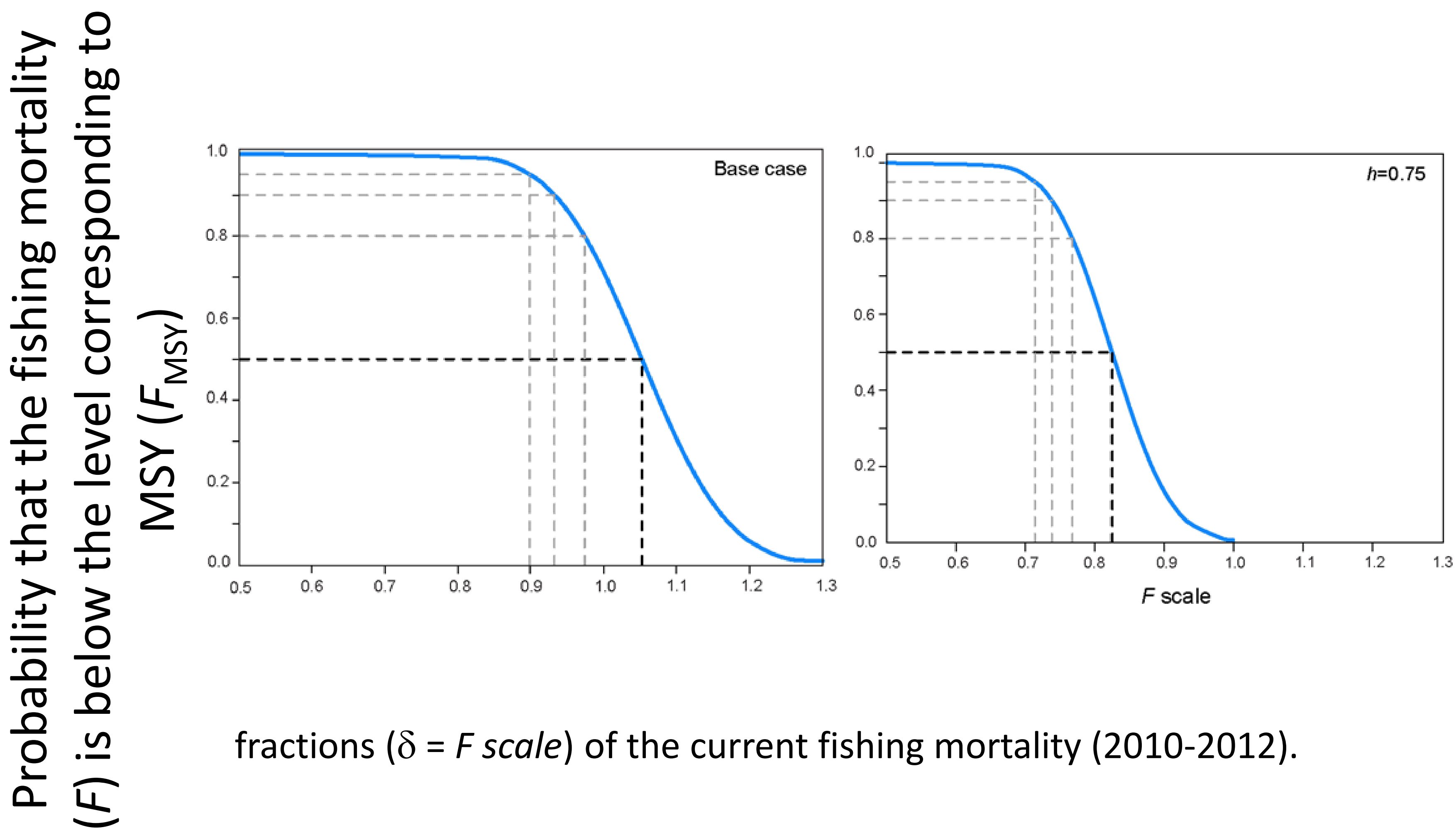
Issues

- A non-linear relationship between the index and abundance
- High variability in the index due to observation or process error
- Uncertainty in the estimate of catchability
- Application of the harvest control rule **might be complicated when there are multiple fisheries with different age-structured selectivities** that differ from those of the index of abundance and/or the measure of surplus production.
- **Not clear if it finds MSY if biomass is above B_{MSY}**

SKJ status

- Productivity Susceptibility Analysis (PSA)
  - SKJ susceptibility to floating object fishery is about the same than for juvenile BET (so fishing mortality about the same)
  - SKJ productivity higher than BET so F_{MSY} higher
  - Therefore, if BET fishing mortality at or below FMSY, so is SKJ
- Fishing mortality rates estimated by SEPODYM and tagging data appear to be low
- Size that maximizes yield per recruit smaller than size of fish caught

Risk curves for bigeye



fractions (δ = *F scale*) of the current fishing mortality (2010-2012).

Fishery impact plot – BET example

what if a certain fishery was not present" (Maunder et al…) (project the population from the estimated recruitments without the catch for that fishery)

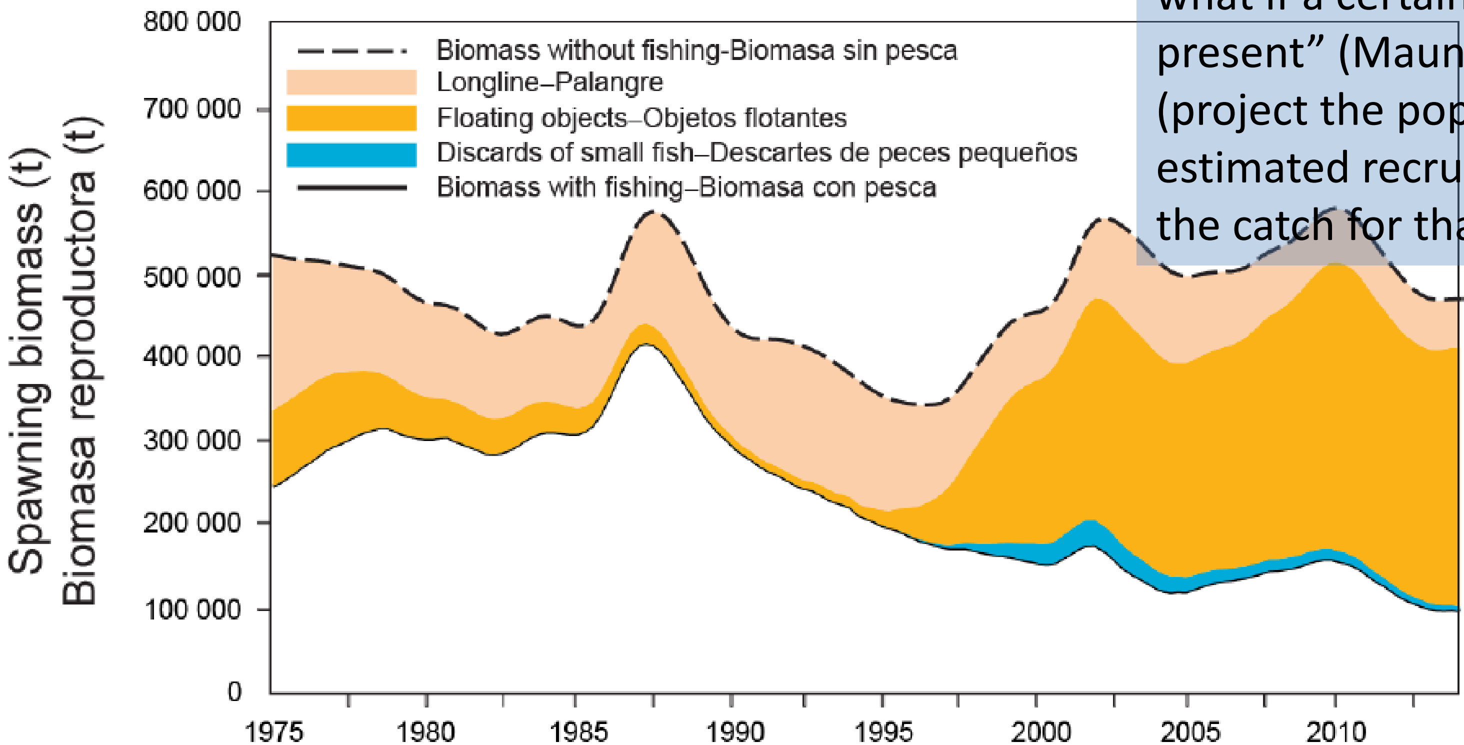


FIGURE 3. Trajectory of the spawning biomass of a simulated population of bigeye tuna that was not exploited (top line) and that predicted by the stock assessment model (bottom line). The shaded areas between the two lines show the portions of the impact attributed to each fishing method. t = metric tons.
FIGURA 3. Trayectoria de la biomasa reproductora de una población simulada de atún patudo no explotada (línea superior) y la que predice el modelo de evaluación (línea inferior). Las áreas sombreadas entre las dos líneas señalan la porción del efecto atribuida a cada método de pesca. t = toneladas métricas.

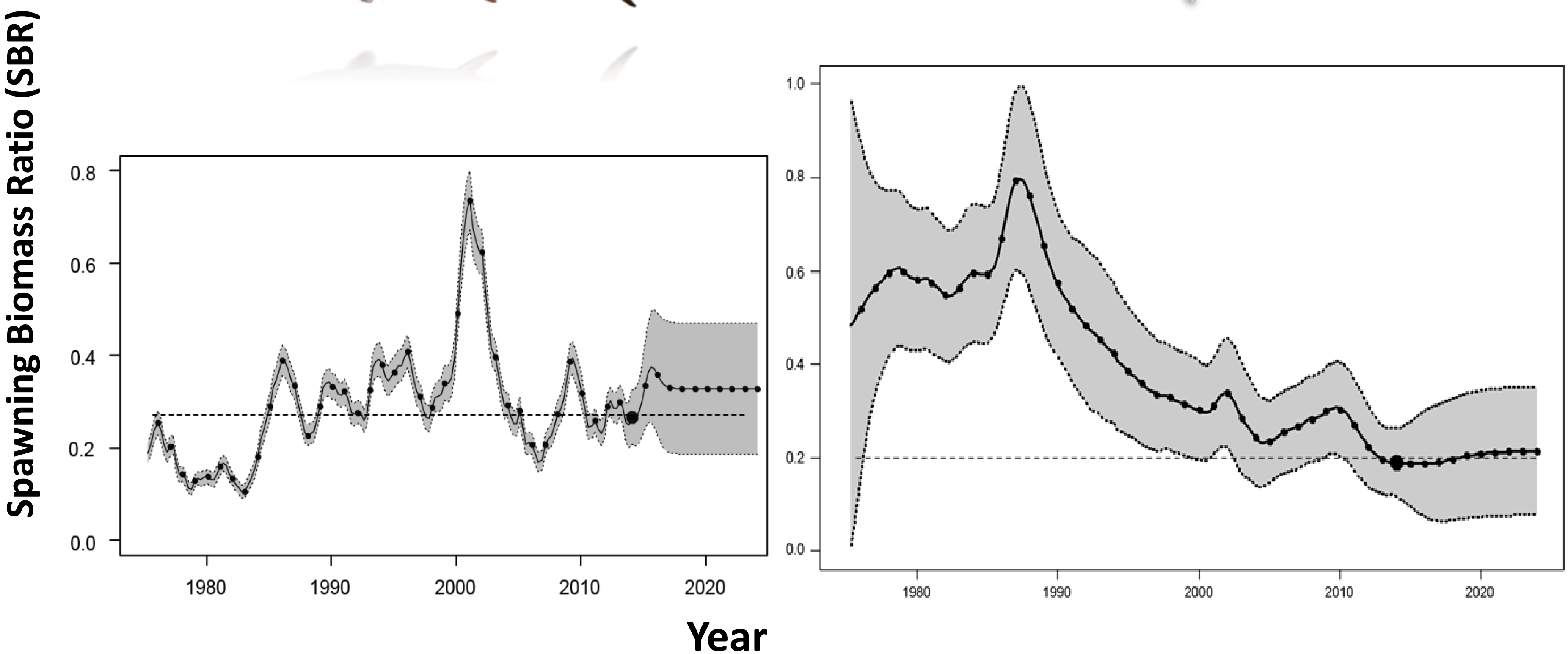
Aires-da-Silva et al (2013)

Uncertainty in projections: estimation error and two scenarios of productivity

Base-case (h=1)

YFT

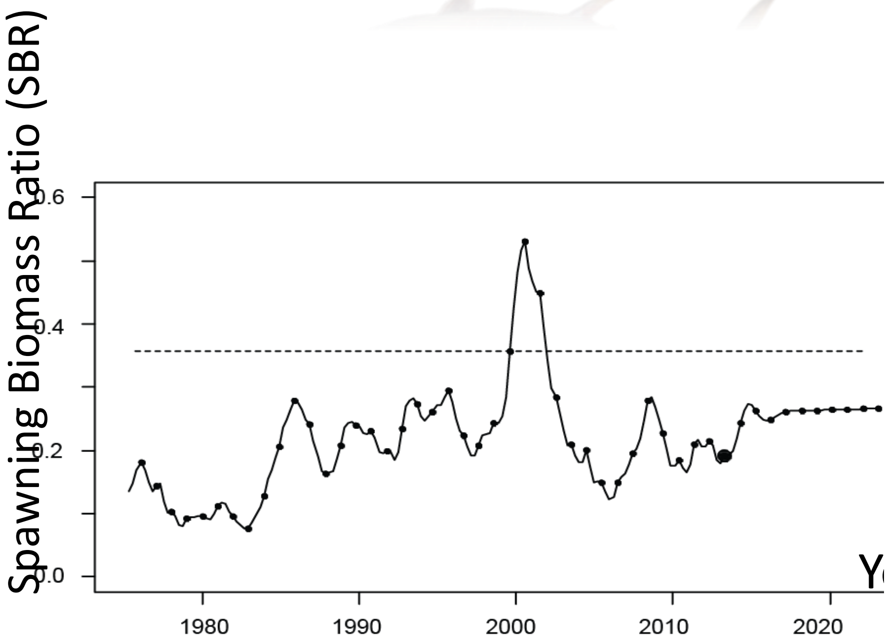
BET



Projections

Sensitivity-case (h=0.75)

YFT



BET