EVALUATION OF THE KOBE PLOT AND STRATEGY MATRIX AND THEIR APPLICATION TO TUNA IN THE EPO

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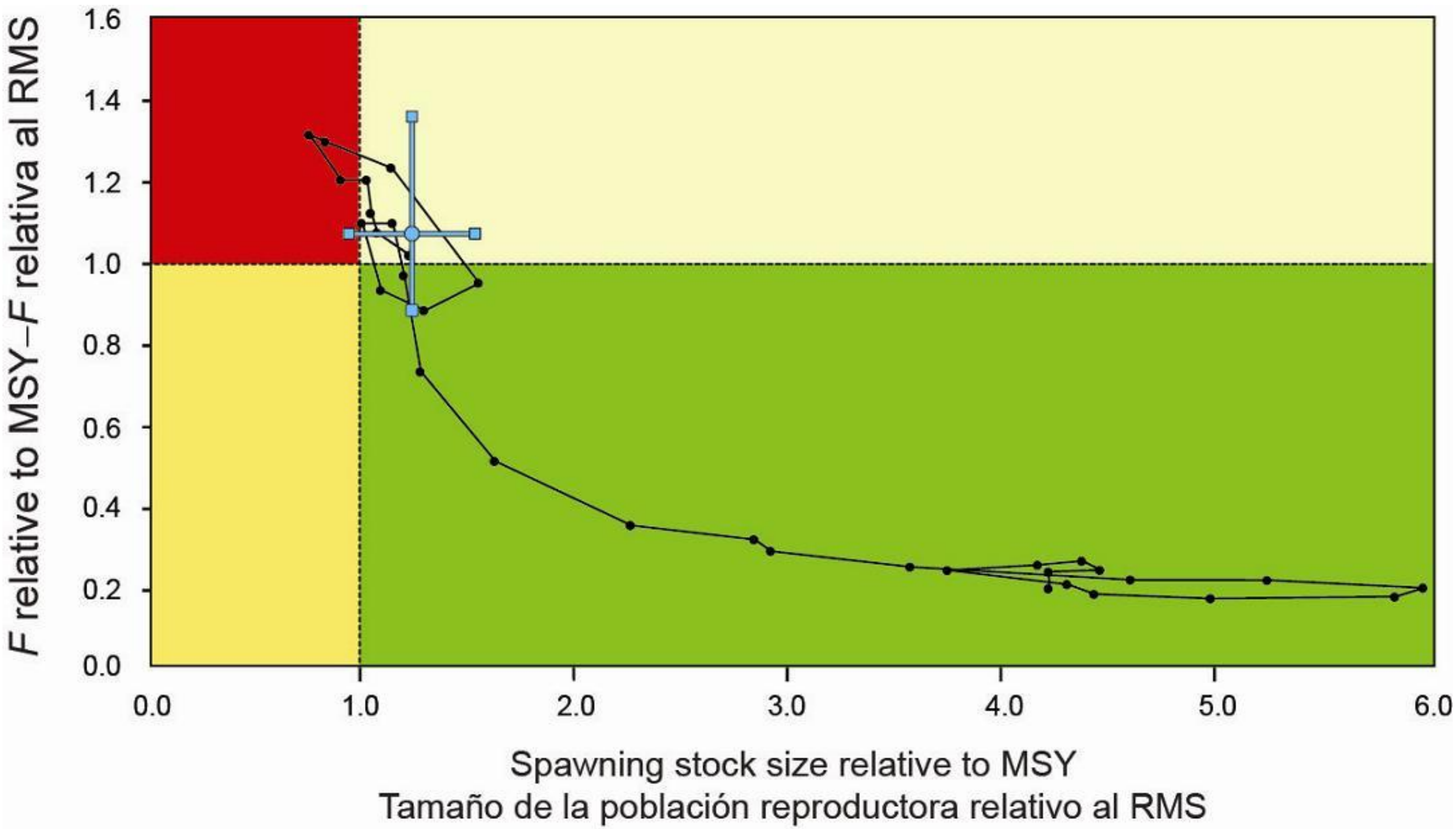
Introduction

- The first joint meeting of the tuna RFMOs
  - standardize the presentation of stock assessment results and management advice.
  - Stock assessment results should be presented using the “four quadrant, red-yellow-green” Kobe plot.
- The second joint meeting of the tuna RFMOs
  - Recommended the Kobe strategy matrix
  - Provides alternative options for meeting management targets.
- The construction of the Kobe plot and Kobe strategy matrix are not straightforward
  - Critical evaluation
  - Application in the EPO

Kobe plot (EPO BET)



Kobe Strategy Matrix

- Presents management measures that would achieve the management target with a certain probability by a certain time.
- Management measures
  - Total Allowable Catch (TAC)
  - Fishing effort levels
  - Time/area closures
- It would also indicate uncertainty associated with data gaps.

Kobe Strategy Matrix

Management target	Time frame	Probability of meeting target			Data rich/Data poor
		A%	B%	*C*%	
Fishing mortality target	In x years				
	In x years				
	In x years				

Management target	Time frame	Probability of meeting target			Data rich/Data poor
		A%	B%	*C*%	
Biomass target	In x years				
	In x years				
	In x years				

Management target	Time frame	Probability of meeting target			Data rich/Data poor
		A%	B%	*C*%	
Status quo					

Kobe Strategy Matrix

Management target	Time frame	Probability of meeting target			Data rich/Data poor
		60,000 t	80,000 t	100,000 t	
S_{MSY}	In 5 years	70%	50%	5%	???
	In 10 years	90%	60%	20%	
	In 20 years	95%	75%	60%	

Kobe Strategy Matrix considerations (based on Adam Langley pers. com.)

- Selecting the appropriate models to undertake projections
- Sampling from the uncertainty envelope of accepted models
- Assumptions regarding future recruitments
- What level of catches or effort for the various fisheries
- Re-evaluation of the reference point definition with temporal changes in the *F*-at-age matrix

Focus of this presentation

- a) Temporal changes in the target reference points
- b) Calculation of uncertainty

Reference Points

- F_{MSY} and B_{MSY} are a function of both biological and fishery characteristics
- MSY quantities will differ depending on what type of gear is used or on the mix of effort among the gears
  - Calculate the cMSY_y quantities each year based on the effort mix (age-specific F) in that year or
  - Develop the MSY quantities based on a single selectivity that has some desirable characteristic.
    - Spawning Potential Ratio (SPR)
    - $C_{eq}/\mathrm{MSY}_{ref}$

Reference Points: EPO

- $F_y/F_{MSY\ y}$
- Recent *F* estimates are imprecise, so fishing mortality rate at age averaged over the most recent three years.

Reference Points: Stock-Recruitment relationship

- MSY quantities are dependent on the stock-recruitment relationship.
- The form and parameters of the stock-recruitment relationship are often highly uncertain
- Proxies often used
  - E.g. 35% or 40% of the unexploited biomass are often used for groundfish
- Alternatively, the stock-recruitment relationship could be fixed based on external information
- The steepness of the Beverton-Holt stock-recruitment relationship could be set at a conservative level (*e.g.* 0.75)
  - Small loss in yield when under-specifying steepness

Reference Point: variable recruitment

- Regime changes
- Take the recruitment variation into account when calculating B_{MSY}
  - Project the population over the historic period under F_{MSY} using the estimated annual recruitment deviates
  - Repeated for each year's age-specific F_{MSY} to create the Kobe plot taking into consideration both recruitment variability and changes in the allocation of effort among gears.
- To account for regime shifts, B_{MSY} could be based on average recruitment for the appropriate regime.

Reference Points: Calculating biomass

- There are several ways to calculate B_{MSY}.
  - Spawning biomass, because maintaining reproductive potential might be an important management goal.
  - Fish that are vulnerable to the fishery.
  - The biomass used to compare to B_{MSY} should be calculated using the same method.
- The management implications might differ depending on the method used to calculate the biomass.

Uncertainty

- Parameter uncertainty
- Model or structural uncertainty
- Statistical assumptions
- Process variation
- Implementation error (for management strategies).

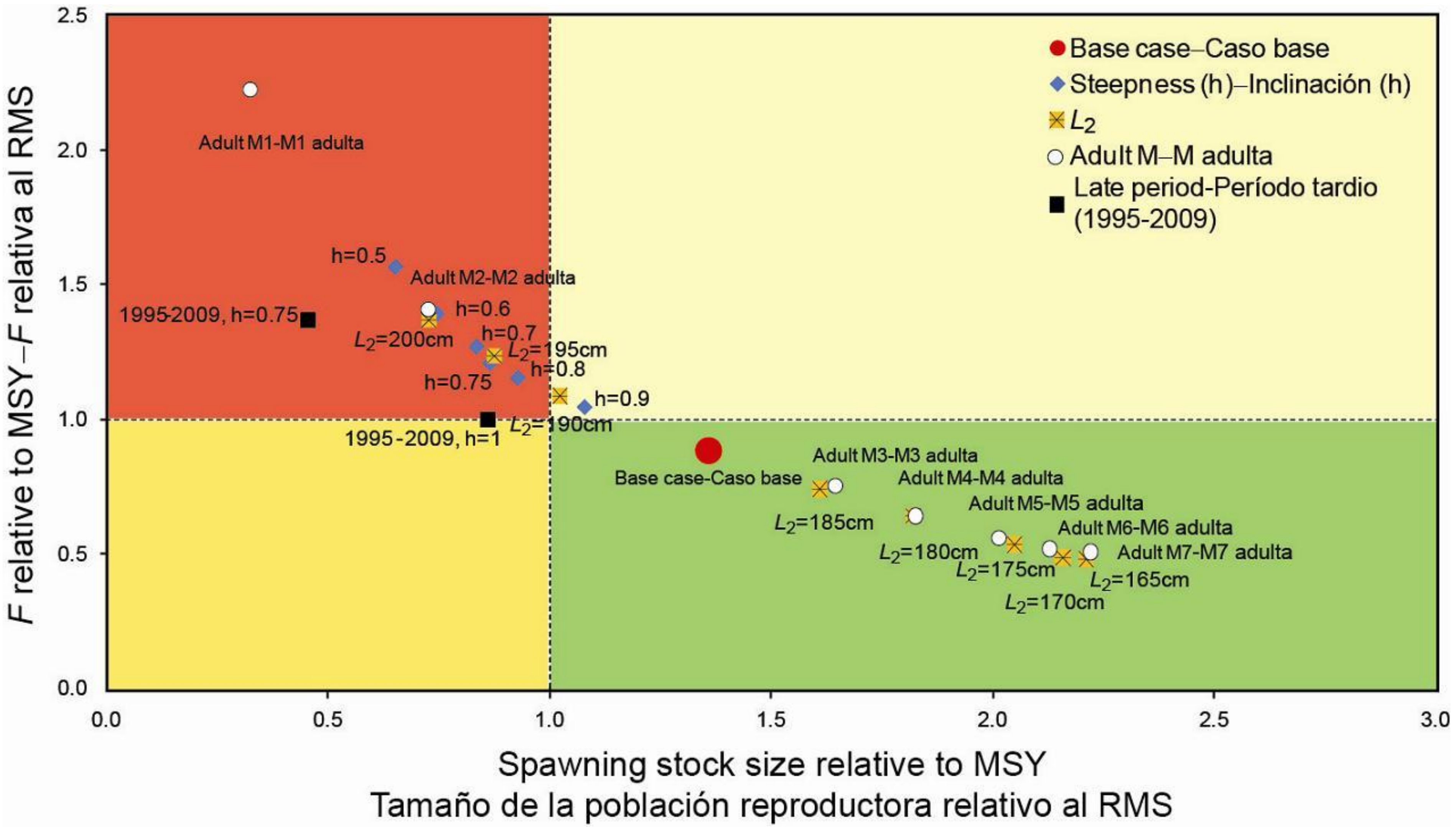
Calculating uncertainty

- Normal approximation
  - Least demanding
  - Symmetrical estimates of uncertainty
- Profile likelihood
  - Objective function optimized on the order of tens of times
  - Repeated for each quantity
- Bootstrap
  - Objective function optimized on the order of hundreds of times
  - Estimates the uncertainty for all quantities simultaneously.
- MCMC
  - Objective function calculated (not optimized) on the order of millions of times
  - Usually the most computationally demanding,
  - Estimates the uncertainty for all quantities simultaneously.
  - Provides true probability statements.
  - Require priors for all model parameters

Parameter Versus Model Uncertainty

- Assumes model is a reasonable representation of the population dynamics
- Parameter uncertainty is evaluated based on the precision of parameter estimates
- Model structure uncertainty is evaluated by running several models with different structural assumptions
- In some cases model structure uncertainty is defined as uncertainty due to assumptions about model parameters that are fixed in the model
- If model structures can be represented by different values of model parameters, then model structure uncertainty can be estimated as parameter uncertainty
- In general, model uncertainty is usually larger than parameter uncertainty.
- Kobe plot and Kobe strategy matrix should include results from different model structure assumptions.

EPO BET Kobe plot with sensitivities



Statistical assumptions

- Sampling distribution assumptions
- Data weighting

Process variation

- Most processes assumed invariant over time.
- Exception is recruitment
- Unmodeled process variation can lead to bias or underestimation of uncertainty
- Statistically rigorous approaches are available to model process variation, but they are computationally intensive
- Approximations are available

Process variation: projections

- Include process variability
- Recruitment is often highly variable and can comprise a substantial portion of the biomass
  - Sampled from a parametric distribution based on assumptions or the historic data
  - Sampled from the historic data directly
    - Recruitments sampled
    - Deviates around the stock-recruitment relationship sampled and applied to that relationship.
- Regime shifts
  - What regime will persist in the future
  - Should each regime be sampled with a given probability
- Short-term projections
  - May have information on recruitment from pre-recruit surveys or relationships with an environmental index.
- Long-term projection
  - Do not have information and rely on the stock-recruitment relationship and recruitment variability

Implementation error

- Changes in catchability
  - Targeting
  - Environment
- Different gears catch different sized fish
  - Gear mix can change
  - Influences impact on stock
  - Influences references points
- Could apply management strategy evaluation instead of Kobe strategy matrix

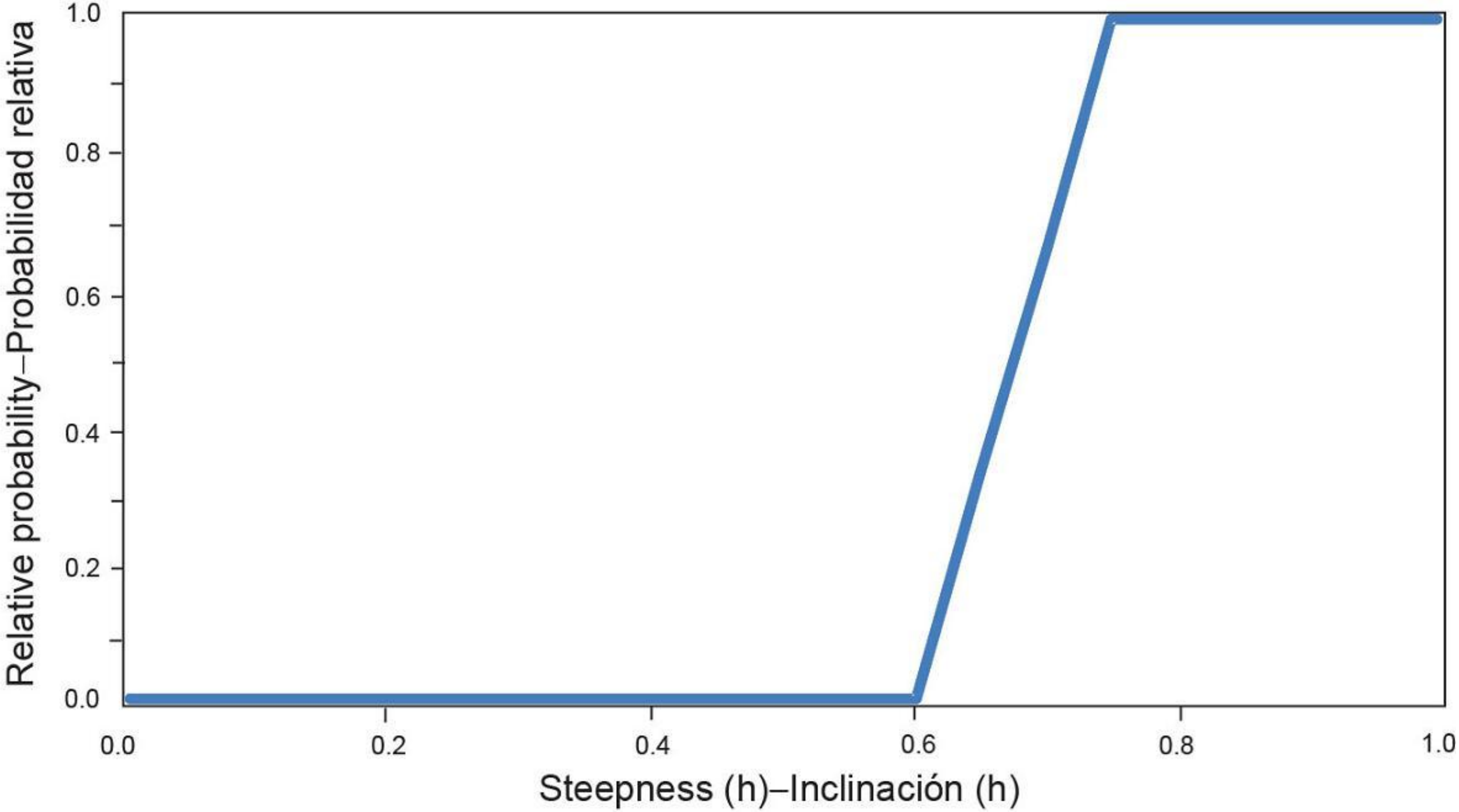
EPO Fisheries

- Main uncertainties
  - 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*

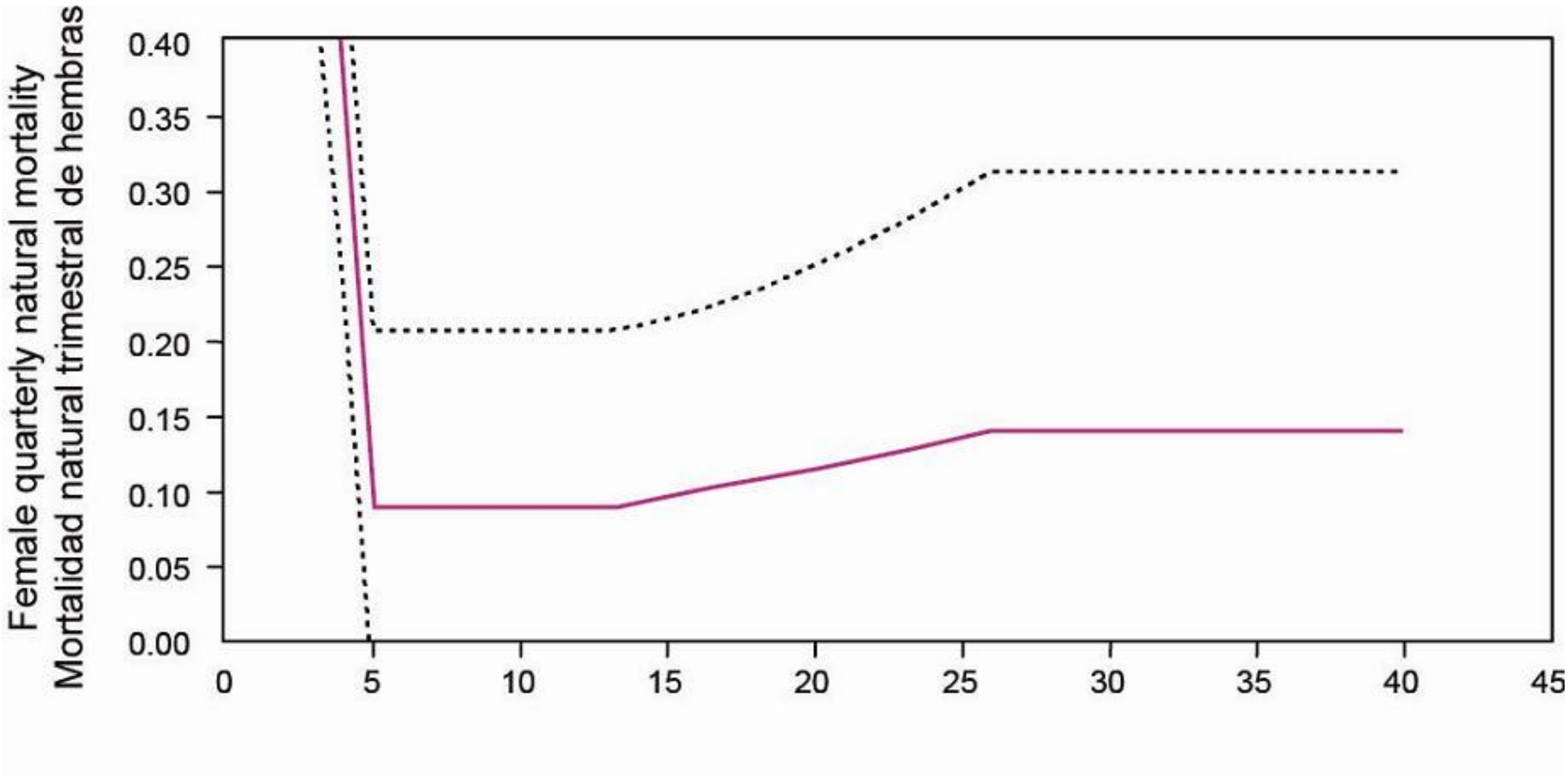
Steepness of the stock-recruitment relationship

- Estimation
  - Imprecise
  - Biased towards one (no relationship)
  - Influenced by quirks in data
  - Regime shifts and autocorrelation
- Prior
  - Meta analysis from ISSF workshop
  - Bluefin = 0.6
  - Tropical tuna > 0.75

Steepness prior for tropical tuna



BET natural mortality



Average length of old fish

- Aged with otolith up to age 4
- Mean length at age also from tagging growth increment
- Statistical rigorous approach available to integrate both otolith and tagging
- Few large individuals tagged
- Growth curves not flexible enough

EPO Fisheries: MCMC for BET

- Takes several days
- Appears to converge (without previous mentioned modifications)
- Not possible to quickly get results for multiple scenarios
- May be possible to get estimates of key components of Kobe plot and Kobe strategy matrix
- Need to deal with inherent bias in steepness

EPO Fisheries: future directions

- Interim methods
  - Sensitivity analyses to model assumptions
  - Provide probabilities for each sensitivity
- Stock Synthesis modifications
  - Growth
    - More flexible curves
    - Appropriate priors or integrate growth increment data
  - Natural mortality
    - Age-specific structure that is amenable to assumptions and priors
- Future analyses
  - Use MCMC on model with the above improvements
  - Include priors and/or integrated data
  - Run separate models for different steepness values and integrate results
  - Add variation in selectivity for some fisheries