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

Mark N. Maunder and Alexandre Aires-da-Silva
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

<table>
<thead>
<tr>
<th>Management target</th>
<th>Time frame</th>
<th>Probability of meeting target</th>
<th>Data rich/Data poor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A%</td>
<td>B%</td>
</tr>
<tr>
<td>Fishing mortality target</td>
<td>In x years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biomass target</td>
<td>In x years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Status quo</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Kobe Strategy Matrix

<table>
<thead>
<tr>
<th>Management target</th>
<th>Time frame</th>
<th>Probability of meeting target</th>
<th>Data rich/Data poor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>60,000 t</td>
<td>80,000 t</td>
</tr>
<tr>
<td><strong>S&lt;sub&gt;MSY&lt;/sub&gt;</strong></td>
<td>In 5 years</td>
<td>70%</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>In 10 years</td>
<td>90%</td>
<td>60%</td>
</tr>
<tr>
<td></td>
<td>In 20 years</td>
<td>95%</td>
<td>75%</td>
</tr>
</tbody>
</table>
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)
    • $C_{eq}/MSY_{ref}$
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 $B_{\text{MSY}}$
  – Project the population over the historic period under $F_{\text{MSY}}$ using the estimated annual recruitment deviates
  – Repeated for each year’s age-specific $F_{\text{MSY}}$ 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, $B_{\text{MSY}}$ 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