SSC risk table workshop: Frameworks for addressing scientific uncertainty, part 2

NOAA FISHERIES
Alaska Fisheries
Science Center

Grant Thompson

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Decision-theoretic approaches

Compare and contrast with P^* approach

- P^* approach
  - Set a value of P^* between 0 and 0.5
  - Compute the cumulative distribution function of the true-but-unknown value of the overfishing level, $CDF(truOFL)$
  - Set $ABC = CDF^{-1}(P^*)$
- Decision theory (DT) approach
  - Define a utility (loss) function specifying the desirability (undesirability) of each possible outcome (e.g., long-term yields)
  - Weight the utility (loss) of each relevant outcome by the probability of that outcome, then sum/integrate to get expected utility (loss)
  - Fish at the rate that maximizes (minimizes) expected utility (loss)

Advantages of the two approaches

- $P*$ approach
  - Sounds like hypothesis testing, so is natural choice for HT advocates
  - "Everybody's doing it"
    - Until the most recent revision of the NS1 guidelines, it was the only approach officially allowed
  - Computationally simpler than DT approach
    - Integrating a function versus maximizing the integral of a product
  - Resulting ABC is always less than OFL
- Decision theory approach
  - Rooted in Bayesian theory, so is natural choice for Bayes advocates
  - Considers all relevant outcomes
  - Provides an estimate of the optimal catch

Disadvantages of the two main approaches

- $P*$ approach
  - Considers only one possible outcome ($ABC > truOFL$), regardless of the amount of overestimating or underestimating
  - Does not provide an estimate of the optimal catch
  - As with α value in hypothesis testing, difficult to justify $P*$ value
  - Choice of model/data can have major impacts on form of CDF
- Decision theory approach
  - Computationally more complicated than $P*$ approach (see last slide)
  - Requires specifying a utility (loss) function
    - But can be estimated from experimental data
  - In some (rare?) situations, can result in ABC > OFL
  - Choice of model/data can have major impacts on form of PDF

Possible hybrid approaches

- Choose DT approach unless the resulting ABC exceeds OFL, in which case default to $P*$ approach
- Choose minimum of the ABCs resulting from the two approaches
- Use $P*$ approach for ABC, DT for a TAC option (if less than ABC)

Where did we leave this discussion?

- During development of Amendments 96/87 (implemented 11/10), it became apparent that some issues related to the treatment of ACLs in the NSGs were too complicated to address fully
  - Trailing amendments anticipated for some issues, such as the buffer between ABC and OFL
- Discussion paper developed in spring of 2011
  - Reviewed by SSC in 6/11
  - Reviewed by Joint Teams in 9/13
  - Follow-up comments by SSC in 10/13

Team and SSC recommendations (1 of 2)

- SSC recommendations (6/11)
  - "The SSC recommends a deliberative approach to improving the treatment of uncertainty in the groundfish FMPs and encourages the author and/or other analysts to further develop the document to:
    - "explore the advantages and disadvantages of the DT and $P*$ approaches using more realistic scenarios, and
    - "determine how the approaches would be applied across different tiers (Tier 1-4)"
  - "This will require continued research on developing appropriate models for understanding the interactions between fisheries in response to changes in harvest policy"

Team and SSC recommendations (2 of 2)

- Joint Team recommendations (9/13)
  - “The Teams did not recommend a preferred alternative for this issue, but did recommend that any future analysis of the DT approach [should] consider a variety of utility functions
  - “It was noted that AFSC economist Chang Sueng has done some work in this regard
  - “Furthermore, the Teams recommended that analysis of all options should evaluate risk for a range of years and species”
- SSC recommendations (10/13)
  - “In their September 2013 meeting, the Joint Plan Teams provided new advice..., which the SSC supports”
  - “The SSC encourages further development of these analyses over a reasonable time frame”

A probabilistic approach for linking the risk table to ABC reductions (including a comment on whether the highest level identified should be the only level that counts)

Goal: improve, not replace, use of the table

- An approach for implementing the risk table is described here, in which the current implementation is augmented in a way that ties the risk table directly to:
  1. the need for a reduction from $maxABC$, and
  2. the appropriate amount of reduction (if any)
- The approach is completely consistent with the current features of the risk table; for example:
  - $ncat=4$ “categories” (assess., pop. dy., env./eco. fishery perf.)
  - $nlev=4$ “levels” $(1, 2, 3, 4)$, with definitions as currently given
- However, the approach is completely flexible with respect to such things as the number and nature of the categories and the number and definitions of the levels, should any of those change in the future

Big picture: compare and contrast

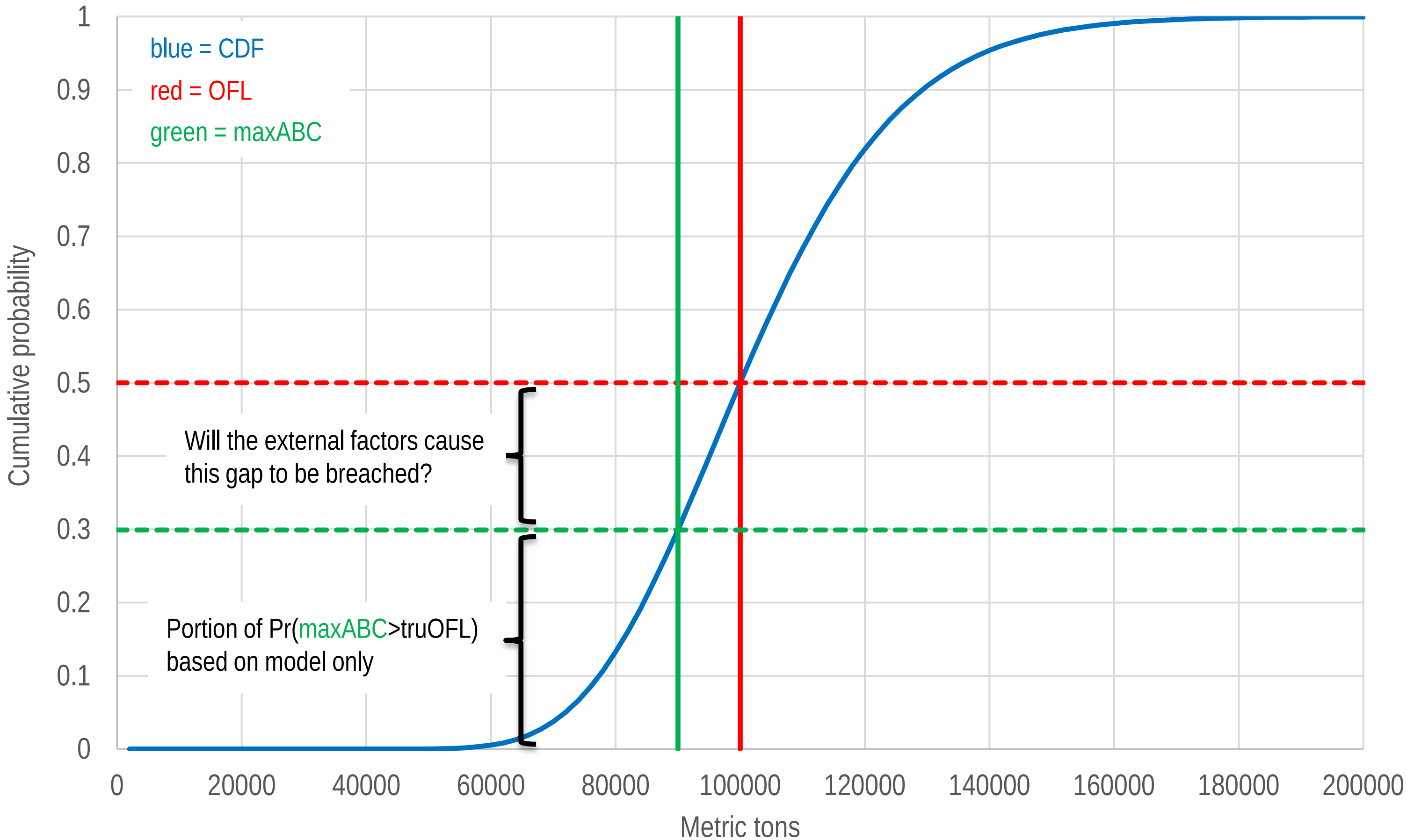
- Current approach:
  1. Author uses a set of subjective methods to arrive at scores for the categories in the risk table
  2. Author uses a *second* set of subjective methods to determine whether an ABC reduction is necessary
  3. If step 2 results in an affirmative determination, author uses a *third* set of subjective methods to determine the size of the reduction
- Proposed approach:
  1. Author uses a set of subjective methods to arrive at scores for the categories in the risk table
  2. The need for an ABC reduction is determined statistically
  3. If step 2 results in an affirmative determination, the size of the reduction is determined statistically

A quantifiable interpretation of “concern”

- The currency of the risk table is “concern,” which is left undefined
- In the proposed approach, “concern” is interpreted in terms of the probability that $maxABC$ exceeds the true-but-unknown overfishing level ($truOFL$, as distinguished from the overfishing level specified on the basis of the assessment model point estimate, OFL)
- In the proposed approach, an ABC reduction is necessary if the probability of $maxABC$ being greater than $truOFL$ exceeds 50%
- Two types of probability need to be considered:
  - Probabilities of overfishing that are internal to the model
    - These are routinely quantified
  - Probabilities of overfishing that are external to the model
    - These are associated with the factors identified under the categories in the risk table, and are *not* routinely quantified

An example

- μ = ln(100k), σ = 0.2, $maxABC$ = 90k



Thinking in terms of joint probabilities

- The joint probability of overfishing, $Pjnt$, can be written in terms of the internal probability of overfishing, $Pint$, and the external probability of overfishing, $Pext$, as follows:
  - $Pjnt = 1 - (1 - Pint)(1 - Pext)$
- Because there are $ncat$ categories in the risk table, $Pext$ itself is a joint probability, and depends on the probabilities associated with the $ncat$ individual categories as follows:
  - $Pext = 1 - \prod_{j=1}^{ncat}(1 - Pext.ind_j)$
- From this perspective, the past practice of ignoring all categories other than the one with the highest level appears to make little sense, as it in effect sets all other $Pext.ind_j = 0$
- Note that the above equations assume that the events are independent
  - This may not be accurate, but it is a reasonable starting point

From discrete *level* to continuous *score*

- What is needed is a way to move from the information already contained in the risk table categories to a set of probabilities
- Both the current and proposed approaches begin by requiring authors to specify a value of $level$ for each category
- The proposed approach expands on this by allowing authors to specify an (optional) $intralevel$ value for each category, with a range of 0 to 1
- A continuous $score$ is then defined for each category j as:
  - $score_j = \left(level_j - 1 + intralevel_j\right)/nlev$,

    with a range of 0 to 1
- If an author prefers not to specify an $intralevel$ value for each category, a default value (e.g., 0.5) could be assumed instead

From *score* to individual external probability

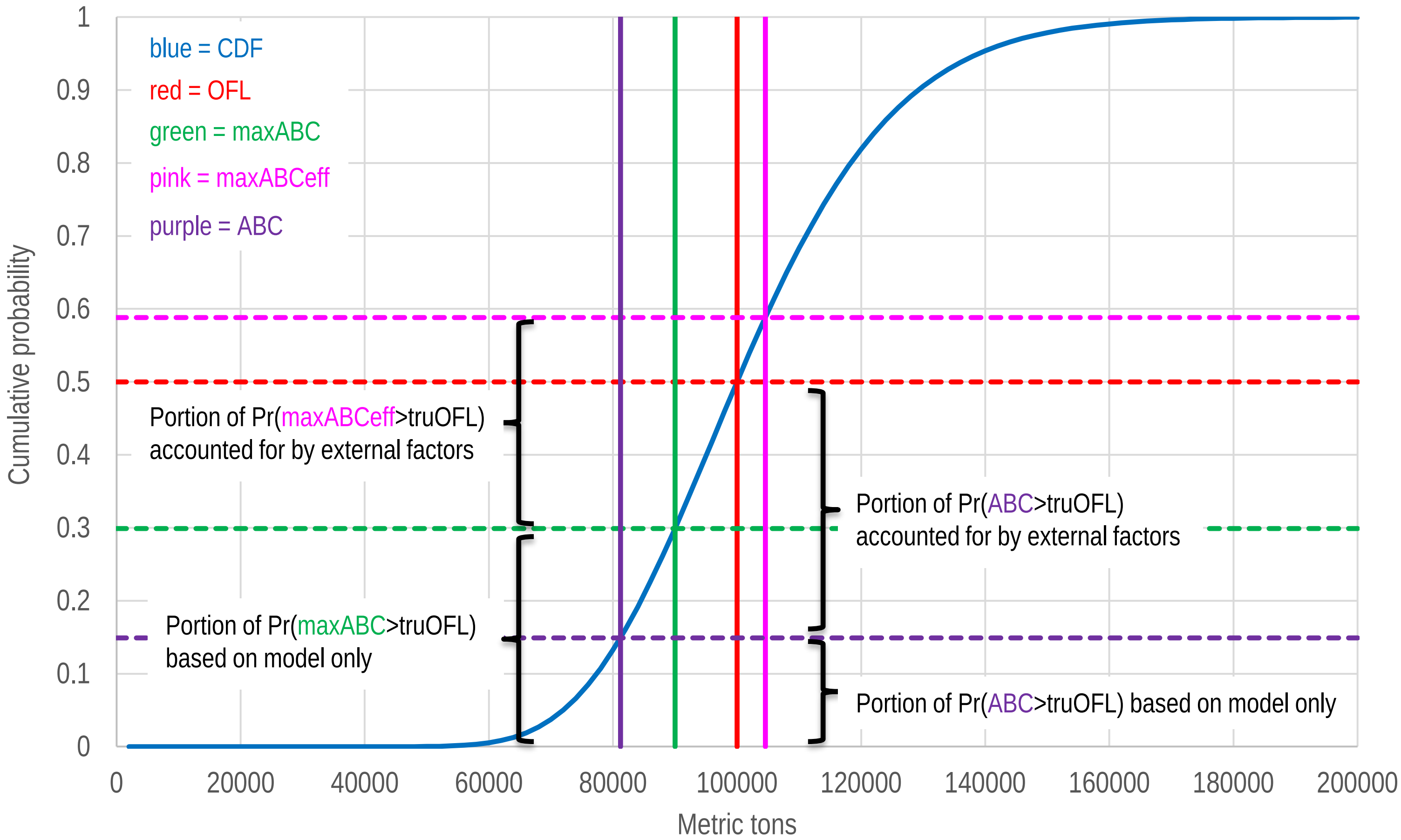
- The next step is to convert each $score$ into a probability as
  - $Pext.ind_j = Pmax \cdot score_j{}^{\alpha}$, where
    - $Pmax = 1 - 2^{-1/ncat}$ and
    - α is a parameter (choosing a value for α will be addressed later)
  - The coefficient $Pmax$ is needed in order to:
    - Keep the external probability of overfishing from expanding in the event that more categories are added in the future, and
    - Keep the ABC associated with $Pjnt = 0.5$ positive
- Putting it all together: $Pjnt = 1 - (1 - Pint)(1 - Pext)$, where
  - $Pext = 1 - \prod_{j=1}^{ncat}\left(1 - Pext.ind_j\right)$, where
  - $Pext.ind_j = Pmax \cdot score_j{}^{\alpha}$, where
  - $score_j = \left(level_j - 1 + intralevel_j\right)/nlev$

Final steps

- The next step is to solve for $Pabc$, which is the value of $Pint$ that sets $Pjnt = 0.5$, viz.:
  - $Pabc = (1 - 2Pext)/\big(2(1 - Pext)\big)$
- Finally, ABC is set as follows:
  - If $Pabc \geq Pint$, then set $ABC = maxABC$
  - If $Pabc < Pint$, then set $ABC = CDF^{-1}(Pabc)$

Finishing the example

- $\mu = \ln(100\text{k})$, $\sigma = 0.2$, $maxABC = 90\text{k}$, $\alpha = 0.25$, $score_j = 0.375$ for all j



Looking at the example "by the numbers"

- Given by the model: $Pint = 0.299$
- Set by the author:
  - $level_j = 2$ for all j
  - $intralevel_j = 0.5$ for all j
- Set by the SSC(?): $\alpha = 0.25$
- Everything else is a simple calculation:
  - $score_j = (2 + 0.5 - 1)/nlev = 0.375$ for all j
  - $Pext.ind_j = \left(1 - 2^{-1/ncat}\right)0.375^{0.25} = 0.125$ for all j
  - $Pext = 1 - \prod_{j=1}^{ncat}(1 - 0.125) = 0.412$
  - $Pjnt = 1 - (1 - 0.299)(1 - 0.412) = 0.588 > 0.5$
  - $Pabc = (1 - 2 \cdot 0.412)/\left(2(1 - 0.412)\right) = 0.149$
  - $ABC = CDF^{-1}(0.149) = 81205$ (a 9.8% reduction)

Choosing a value of α

- Consider values of $Pabc$ conditional on $score_j$ being constant across j
  - Recall that an ABC reduction is necessary only if $Pint > Pabc$