DRAFT DISCUSSION DOCUMENT

Addressing scientific uncertainty when making fishing level recommendations to avoid overfishing

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Disclaimer

This draft discussion document is being developed as a conceptual approach to incorporating scientific uncertainty in the required calculation of Acceptable Biological Catch. It was developed in an effort to consolidate ideas being discussed by a NMFS Working Group on ABC Control Rules and by each Scientific and Statistical Committee. At this time, the ideas presented here are those of the author and do not represent agency policy or technical guidance.

Introduction

The requirement is to set scientific recommendations regarding the level of catch that would obtain a large fraction of the maximum biological potential (MSY) while not overfishing the stock. This level of annual catch is termed Acceptable Biological Catch (ABC) and it must not exceed the level of catch identified as the overfishing level (OFL). The ABC is the upper limit for setting the Annual Catch Limit (ACL). Subsequent steps in the system take into account uncertainty in managing the fishery to achieve a specified level of catch, and take social, economic, and ecosystem factors into account to determine optimum yield (OY).

The calculated OFL represents the best scientific estimate of the true OFL. The true OFL can be estimated, but cannot be known exactly. If the ABC is set equal to the calculated OFL, then catching the ABC would result in a 50% chance of exceeding the true OFL. Depending on the level of uncertainty in the OFL calculation, there is a chance that catching the ABC exactly would result in greatly exceeding or undershooting the true OFL. The challenge is setting a buffer between the ABC and the calculated OFL so there is a known and acceptable level of risk of exceeding the true OFL. Ideally, the ABC calculation system would smoothly scale between a relatively large buffer when little is known about the effects of fishing on a stock, and a smaller buffer when we know more. The smallest buffer should result when we can include all major factors in the assessments, directly account for each factor's uncertainty, and have enough data to reduce this measure of uncertainty.

Uncertainty

What do we mean by uncertainty? The OFL and other results from stock assessments are calculated by applying models to data. The data are obtained by taking samples from the fishery and fish stock, so do not represent a census of the whole population and have some degree of sampling variability. The shape and width of the model's calculated probability distribution around the estimated OFL is mostly based on the degree of difference between the individual data points and the model's calculations. This is the statistical component of uncertainty. An additional component of uncertainty is due to the fact that models cannot include all the factors that operate in nature. Models attempt to recreate the major processes that affect the fish populations, but they cannot completely include all of the complex processes in nature itself. For example, specifying that natural mortality is equal to a constant, setting fishery catchability as a constant over time rather than allowing for drift, specifying full selectivity of old/large fish versus allowing for dome-shaped patterns, etc. are often considered to be necessary model simplifications because of incomplete information about a more flexible approach. But lacking data about the complexity of the natural system does not simply the natural system itself. Simpler model are stiffer than nature itself and model predictions will not exactly forecast all changes in fish stocks. A common symptom of this reality is retrospective patterns as a model is updated to include an additional year of data. In addition, different models or different configurations of a given model may fit the available data nearly equally well, but produce different estimates of important quantities like OFL. More complete evaluations of uncertainty include the uncertainty associated with various aspects of model structure and configuration. It is prohibitively difficult for each assessment and review panel to explore all possible assessment combinations in order to directly incorporate into the model the uncertainty associated with these configuration differences. Instead, a more qualitative framework is proposed here to consider the additional uncertainty associated with these unanalyzed factors.

Risk Aversion and Buffers

Uncertainty, risk aversion, and buffers are three linked factors. The degree of risk aversion means the degree to which the fishery policy seeks to avoid overfishing. This degree can be characterized as a probability level, P*, the acceptable probability that overfishing will occur. For example, a P* of 40% means that the ABC is being set at a level such that the probability of that level of catch exceeding the true OFL is no more than 40%. The probability itself is calculated from the degree of uncertainty in the assessment. The uncertainty works with the P* to create a buffer. For a specified P* level, assessments with high uncertainty will result in a larger buffer and assessments with low uncertainty will result in smaller buffers. Each has the same probability of exceeding the overfishing level, but in the low uncertainty case, any such overage is expected to be small because the overall uncertainty is small. Such an ABC system linking uncertainty, P* and buffers is described in Shertzer et al. Comparable approaches are used in rebuilding analyses where P_{Reb} is the probability of being rebuilt at some specified time in the future and uncertainty is taken into account when calculating the future fishing level (e.g. buffer between F_OFL and F_rebuild), that would achieve P_{Reb} of rebuilding.

These systems are straightforward to implement when uncertainty can be fully described and P* can be assigned. The conceptual challenge is in dealing with situations where assessments cannot fully characterize the uncertainty in the calculation of OFL. The extreme case is where the only information about OFL is just the historical level of catch. Clearly such a situation has substantial uncertainty, but there is no direct basis for calculating this uncertainty. But underestimating the uncertainty will lead to an underestimate of the size of the buffer and result in a higher risk of overfishing. Perversely, as assessments improve and more fully characterize the uncertainty, the system would calculate a bigger buffer as this calculated uncertainty increased. A more comprehensive system will include accommodation for unmeasured uncertainty in addition to the uncertainty measured within the assessment.

Any one of the three factors: uncertainty, P*, and buffer could be adjusted to account for the unmeasured components of uncertainty:

- Adjust Uncertainty: The ABC system could add an adjustment to the measured uncertainty to account for the unmeasured components of uncertainty. These adjustments would basically be proxies for each major component of the total possible uncertainty.
- Adjust P*: The ABC system could use a smaller P* (lower risk of overfishing) when there are more unmeasured components of uncertainty.
- Adjust Buffer: The ABC system could have part of the total ABC buffer based on the quantitative link between uncertainty and P*, and part of the total buffer based on other factors not included in the uncertainty calculations.

Uncertainty Adjustment Approach

<add description here>

P Adjustment Approach*

<add description here>

Buffer Adjustment Approach

This approach includes one factor that represents the measure of uncertainty calculated within the assessment method, plus an additional set of factors that encompass other potential contributions to the overall uncertainty in the results of a stock assessment. The process incorporates a buffer contribution from the uncertainty calculated within an assessment and a buffer contribution from factors not directly analyzed in the assessment. When a factor gets fully analyzed, its contribution to the total OFL-ABC buffer is contained within the quantitatively calculated model uncertainty. When a factor is not considered or cannot be fully analyzed, it makes a contribution to the buffer in addition to the buffer contribution coming from the assessment model uncertainty.

1. A pragmatic first step is to set a level for the total buffer size associated with the worst case scenario. By starting with this step, all improvements in data collection and stock assessment methods can work to reduce the size of the buffer. Given the degree to which some assessment results are seen to bounce around from one update to the next or are shown to be sensitive to particular assessment configurations, it is plausible that this maximum buffer should be in the ballpark of 50% of the OFL.
2. The second step is to identify the set of uncertainty factors. A plausible, but not definitive, set is contained in the table on the next page. Alternatively, some regional situations may be too data limited to implement even this number of separate factors.
3. The third step would divide the total maximum buffer among the factors. Factors for which the assessment result is highly sensitive should have a higher proportion of the total maximum buffer.

Call these the factor weights (FW). For each factor, decide whether it has been sufficiently included in the assessment model to allow its uncertainty contribution to be contained within the uncertainty of the model results, or whether it needs a separate contribution to the uncertainty.

4. For each factor, its contribution to the total buffer would depend upon the factor weight and the score for that factor. For some factors, the score would be on a continuous scale from 0 to 1. For factors using the good/moderate/worst approach, a suitable numeric value between 0 and 1 would need to be assigned to each category.

Factor	**Factor Weight (FW)**	**Best**	**Moderate**	**Worst**
Model based uncertainty on OFL[1]		1. Use continuous scale rather that best/moderate/high 2. Calculate uncertainty (CV) of forecast OFL Compare this CV to a worst case CV 3. If CV < worst CV, then buffer = (calc CV)/(worst CV)*FW.		
A) Major process factors (natural mortality, growth, spawner-recruitment, selectivity, etc.)		Estimation of major factors is within the assessment model	At least one is poorly estimated and its prior is not precise	Held constant at assumed value, or subsumed within a simpler model
B) Alternative models and/or model scenarios (e.g. explicit model error)		Results integrate (model average) over a large range of plausible models.	Alternatives considered, but results based on one "best case"	Alternatives not considered
C) Status Determination Criteria		Directly calculated from estimated Fmsy and Bmsy	Uses proxies based on stock's reproductive potential	Uses simpler proxies (e.g. M)
D) Retrospective pattern (e.g. hidden model error)		No retrospective pattern	Some pattern, and adjustment factor included in OFL	Strong pattern and not adjusted
E) Vulnerability score from Productivity/Susceptibility analysis		Most PSA components quantified in model	Some PSA components in model	Nil PSA components in model
F) Long-term ecosystem effects on stock's productivity		M, spawner-recruitment, growth, and fecundity trends account for ecosystem changes	Parameter that is most sensitive to ecosystem changes is quantified	Ecosystem effects on stock productivity not considered
G) Years since last assessment		Calculate buffer contribution from number of years, generation time, recruitment variability, natural mortality		

[1] Alternatively, a buffer contribution based on model uncertainty and a specified P* could be used here.

Example:

Step 1: An FMP amendment is developed which establishes that assessed stocks will have an ABC buffer that is 60% unless reduced by including more factors in the assessment and by reducing the uncertainty in the assessment through including more information.

Step 2: The factors to be included are quantitative model uncertainty plus factors A-G in the table above.

Step 3: The total maximum buffer of 60% is divided into:
20% directly associated with assessment uncertainty; and the following maximum possible contributions for other factors:
(A) 7.5%; (B) 10%; (C) 5%; (D) 5%; (E) 5%; (F) 5%; (G) 2.5%.

Steps 2 and 3 could be developed jointly by the SSC and Science Center for each FMP and established in the terms of reference for all assessments within a FMP.

Step 4:
To be undertaken by the SSC upon receiving results from the peer review of the assessment.

Assessment: The CV on the assessment result for OFL is 10%. This is 1/5 of a worst case CV of 50%, so the buffer contribution for assessment uncertainty is 1/5 * 20% = 4%.
Factor A: Score = 0.5; Buffer = 0.5*7.5% = 3.75%. Because the data are not sufficient to directly estimate natural mortality or steepness
Factor B: Score = 0.1; Buffer = 0.1*10% = 1%. Because the assessment has been able to consider 12 scenarios and integrate results over these scenarios
Factor C: Score = 0.5; Buffer = 2.5%. MSY and Fmsy not directly estimable
Factor D: Score = 0.1; Buffer = 0.5%. No retrospective pattern noted
Factor E: Score = 0.5; Buffer = 2.5%. < protocol for calculating this score needs development>
Factor F: Score = 0.9; Buffer = 4.5%. Biological factors in model are held constant over time and possibility of link to ecosystem changes has not been investigated.
Factor G: Score = 0.5; Buffer = 1.25%. Assessment interval is 4 years
Total Buffer = 20%.

Catch Data Only

Some data-poor situations have little other that a history of catch to consider as data. In this case, application of a quantitatively calculated buffer between OFL and ABC may be infeasible. The following table is offered as a structured approach to considering historical catch and possible management actions. In some cases, the expert judgment could be guided by using the Depletion Corrected Average Catch model and the Vulnerability Evaluation (Productivity-Susceptibility Analysis) process.

Total Catch Level[2]	Expert Judgment	Possible Action
Very small or none	Inconceivable that catch could be affecting stock; F <<<Fmsy	Ecosystem Component Do not include in the fishery
Small	Catch <<MSY and abundance >>Bmsy Catch is enough to warrant including stock in the fishery and tracking	Include in Fishery and allow growth Set ABC and ACL above historical catch; set ACT at historical catch level. Allow increase in ACT if accompanied by cooperative research and close monitoring.
Moderate	catch < MSY and abundance > Bmsy. Possible that any increase in catch could move into overfishing.	Cap Current Fishery Set ABC on basis of historical catch and stock's vulnerability. Set OFL to unknown. Don't allow catch to increase until assessment can be done.
Moderately high	catch >= MSY or abundance <= Bmsy	Reduce Fishery Set OFL on basis of historical catch and stock's vulnerability. Set ABC below OFL to increase stock abundance. Perhaps progressive periodic reduction in ABC until assessment can be done. Consider the PSA score to guide ABC reduction.
Small to high	Quantitative assessment can be conducted	Set OFL based on assessment result and use the framework described below to set ABC.

[2] Total catch includes all observed and estimated catch, bycatch and discards. The interpretation of total catch is relative to the perceived abundance of the stock.