A POSSIBLE STRAIGHTFORWARD APPROACH TO TAC UPDATE GIVEN A SURVEY ESTIMATE OF RECRUITMENT

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Abstract

A simple Bayesian-like approach is suggested as a basis for updating the initial anchovy TAC for 2020, given the further information provided by the abundance estimate from the mid-year recruitment survey, in an objective “comparable-risk” manner.

Background

Essentially what was available from previous analyses at the time in February that the 200kt directed anchovy fishery TAC was recommended, was the following:

1) A set of assumptions for incoming recruitment: {*R(i)*}.
2) A set of alternative TAC options: {*T(j)*}.
3) Calculations for a number of “consequences” for the full cross of *R(i)* and *T(j)* values, e.g. one such “consequence” was the 20% percentile of the ratio of abundance at the end of this year compared to that in the absence of any anchovy catch. For the moment consider a single such consequence (which can be decided in due course), with then a set of values {*C(i,j)*}.

Eventually, one such *T* value was recommended: *T(j#)* = 200kt, with still a range of consequences: {*C(i,j#)* for each *i*}.

Implicitly it seems that what the PWG was doing was establishing a prior probability distribution for the *R(i)*’s, *P(R,i)*, where in this (here discrete) representation: Sum over *i* [*P(R,i)*] = 1.

In this sense then, the threshold/criterion value used to determine the TAC recommendation was:

Ccrit = Sum over *i* [*P(R,i)* * *C(i,j#)*] (1)

Given the recruitment survey result, *P(R,i)* becomes updated to *Pup(R,i)*. The revised “comparable-risk” TAC recommendation is then determined as follows:

Find the value of *j* = j& such that: Sum over *i* [*Pup(R,i)* * *C(i,j&)*] = *Ccrit* (2)

Updating *P(R,i)* given the recruit survey result

Assume for the moment that there is an agreed prior probability vector {*P(R,i)*} (see also subsequent discussion).

Following a Bayesian approach:

Pup(R,i) = *P(R,i)* * *L(i|surv)* / Sum over *i* [*P(R,i)* * *L(i|surv)*] (3)

where *L(i|surv)* is the likelihood that the actual recruitment is *R(i)* given the result from the survey.

Now *L(i|surv)* could be obtained from the assessment and projection used in February to obtain the results leading to the *C(i,j)* matrix, but that vector (over *i*) could be messy to compute, and preferably awaits the survey results themselves before computation; that in turn would make prior sensitivity testing ((whose desirability is explained below) problematic. Hence a simpler approach is suggested below to get an approximation to *L(i,surv)*.

What is needed is the distribution *P(surv,i)* for the recruit survey estimate that is predicted if the true recruitment was *R(i)*. Simply (see some qualifications/caveats later below), regress historical recruit survey results against the corresponding estimates from the assessment:

$$\ln surv(y) = \ln R(y) + \ln k + eps(y) \qquad eps(y) \sim N(0, sig^2) \qquad (4)$$

where *R(y)* is the assessment estimate of recruitment and *surv(y)* is the recruitment survey result for historical year *y*.

This equation (4) regression yields estimates for *k* and *sig*. From these for the current year, for each postulated *R(i)* value, a normal distribution for *ln surv(i)* follows. Given eventually the point estimate for survey result, *surv(obs)*, one takes the approximate value of *L(i|surv)* to be the value of that normal distribution curve value calculated at *ln surv(obs)*.

A simple example

This example is intended ONLY to illustrate the method. Although the values of *R(i)* and *T(j)* bear some resemblance to the actual situation (the former are shown relative to the historical average, and the latter in kt), the *C(i,j)* values are totally invented, being no more than convenient round numbers which trend in appropriate directions with *R(i)* and *T(j)*. Similarly, the likelihood values following a survey, *L(i|surv)*, are similarly invented.

R(i)	***T(1) = 150***	***T(2)=200***	***T(3)= 250***	***P(R,i)***	***L(i|surv)***	***Pup(R,i)***
0.75	0.9	0.8	0.7	0.4	0.9	0.36/0/70=0.51
0.50	0.8	0.7	0.6	0.4	0.7	0.28/0.70=0.40
0.25	0.7	0.6	0.5	0.2	0.3	0.06/0.70=0.09
Ccrit(j)	0.82	0.72	0.62			
Ccrit(j) update	0.842	0.742	0.642			

Note that as the previous decision (for anchovy) was for *T(2)* = 200 kt, the threshold value on which to determine the revised TAC recommendation is *Ccrit* = 0.72.

Following the survey, a TAC value needs to be selected for which *Ccrit(j) update* would be 0.72. From the table above, that value lies between 200 and 250 kt, and linear interpolation gives a revised TAC recommendation of 211 kt.

As perhaps might be needed, the calculation could be made more exact by including more values for *T(j)* (and possibly also *R(i)*).

Some refinements

Basically, the regression of equation (4) is replicating what is done within the MPLE anchovy assessment, but in a simpler way. Certainly, some refinements could be added to bring it closer to the assessment approach, but there needs to be consideration of which are desirably included given their likely effect, i.e. the trade-off between the extra time needed for analysis *vs* meaningful impact on the final recommendation. Possibilities for consideration are as follows.

1) In the assessment, account is taken of losses to natural mortality and to the fishery before the (annually variable) time at which the survey commences, essentially adjusting the $R(y)$ term on the right-hand side of equation (4). That then also needs to be taken into account when using that equation for providing the likelihood for a recruitment survey result this year.

2) The approach of equation (4) assumes that the total variance sig^2 is independent of year. In reality, and as assumed in the assessment, this may vary with year because the survey sampling error variance contribution changes from survey to survey, even if the variance of other factors contributing to the additional variance (e.g. acoustic calibration error) do not. However, the survey sampling variance does not dominate the total variance, and in any case is not very precisely estimated, so assuming it to be constant might be a simpler and more robust approach as long as the survey effort does not change greatly from survey to survey. This approach would, however, need further adjustment if a coming survey fails to cover the full area that is customary for the provision of recruitment estimates, which would require modifications to the estimates of both k and sig when developing $L(i|surv)$.

3) Retrospective bias impacting distributions for the expected survey results could occur, here through the estimate of the value of k in equation (4); checks should be made for any indication that estimates for this value have trended over time.

Prior testing

The approach requires the specification of a prior probability distribution for the recruitments $R(i)$'s, $P(R,i)$.

While that might not be straightforward, the real key question is whether or not the ultimate TAC recommendation arising from the application of such an approach is particularly sensitive to the specification of this prior.

For the example above, changing that prior to be uniform (non-informative) would change the TAC recommendation from 211 to 216 kt. This is perhaps not a trivial difference, but it needs to be seen in the context that a change such as that made here to the prior is really rather extreme.

It is suggested that it would not to too difficult to come up with a "reasonable" suggestion for such a prior. An opening suggestion would be for a trapezium over the range 0.25 to 1.00 (in terms of multiples of the historical average), with values of 0.3 at each end and 1.0 at the intermediate values of 0.50 and 0.75.

What is first needed though, and which should be relatively straightforward to investigate, is a check of how sensitive actual TAC recommendation outputs would be to reasonable variations in such a prior.

Subsequent discussion

In discussions of this suggested approach in the PWG TG, reservations were raised about the realism of achieving agreement on a prior for different recruitments which reflected the overall PWG view at the time when the February TAC decision was made.

This led to the realisation that a simpler form of the approach could also be defended, which had the additional advantage of removing any need to test prior sensitivity. This was to consider those prior views about recruitment to be subsumed in the TAC decision finally reached. The requisite prior $P(R,i)$ then becomes uninformative, so that the first part of the exercise becomes no more than the standard approach of updating such a prior given the survey result in the absence of any other data or preconceptions, so as to provide a posterior distribution for recruitment based on the survey result only. That posterior could then be used, in identical manner to that described above, to update the original TAC decision in the light of the further information provided by the survey result (alone).

Postscript

Comments have been offered about the reliability of this method for practical use for the anchovy TAC revision related to the following.

1) *In practice, suggested revised TAC results have proved more sensitive than hoped to the specification of the P(R,i) prior.*
   Indeed this is the case, but this simply confirms earlier concerns implicit in the reservations expressed about this in the *Subsequent discussion* section immediately above. It was for that reason that the alternative simpler (and perfectly defensible) approach of using a uniform prior was substituted, based on the reasons given there. Hence this comment does not negate use of the method.

2) *A uniform prior is inappropriate because some lower values of recruitment lead to situations where some of the TACs cannot be taken, so that these lower values need to be excluded.*
   This reflects a misunderstanding. As common in OMP evaluations, in certain circumstances a specified TAC cannot be taken, often because that would require exceeding a plausible upper limit on fishing mortality that has been imposed in the Operating Model dynamics. The outcome, that the achieved catch is less than set/intended (and consequently any associated risk to the resource comparatively less than would otherwise would have been the case), is the appropriate one given its greater realism, and is a feature of standard OMP testing outcomes and their evaluation. Hence, it does not provide any basis to modify an uninformative prior, as is appropriate given ONLY the further information provided by the recruitment survey result. Updating for the situation under consideration here can be only on the basis of **new** "data" (e.g., in addition to the survey result, that a certain catch has already actually been taken since the earlier February initial TAC decision, which informs a lower bound on recruitment).

Hence consideration of results from this approach for anchovy needs (only) to be for a full matrix of TAC and recruitment options, and under the assumption of a uniform prior for recruitment. Clearly though, revised TAC results will depend on the consequence measure being considered and the associated consequence percentile suggested, so that (as for the February decision) some approach to "integrating" over these would still need to be considered.

Note also that these comments do not apply to the similar analyses conducted for the sardine recruitment survey result. There a prior for *R(i)* was implicitly specified when making the original TAC/TAB decision. Furthermore, inferences about the resultant posterior for *R* do not depend on the approach suggested for revising the TAB.