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TAC options given the revised stock assessment and maturity-at-length relationship

R. Hillary & J. Day

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Battery Point, Hobart 7000, Tasmania, Australia.

Contents

1 Background

This year is an assessment and TAC setting year for Macquarie Island toothfish. The current project was to explore a replacement for the current stock assessment [1], and this was presented at the previous SARAG in March [2]. Additionally, a proposed revision to the current maturity-at-length relationship for Macquarie Island toothfish has been submitted to the SARAG [3]. Although the original relationship was used for both the stock assessment models [1, 2], we include the implications for both current status and TAC recommendations given they clearly impact on both and a TAC decision is due this year.

To recap the high-level outcomes of the two stock assessment models from the March SARAG meeting:

- Both models used the same input data (catch biomass, length frequency, age-given-length frequency, tagging data) and the same key allometric relationships (weight and maturity-at-length)
- The main difference is in the use of the tagging data (in terms of the tagged fish model and likelihood)
- Both give very similar fits to the length frequency data and high-level fits to the tagging data (where comparable, given the model differences)
- Both estimated a current female SSB depletion of around 0.7
- The main population dynamic difference was in the estimates of recruitment: for the previous Stock Synthesis model a more smooth low-then-high-then-average trend; for the revised model a less auto-correlated series with more changable “low then high” dynamics

The proposed change in maturity is clearly substantial [3]: it moves the female length at 50% maturity from 139cm to 97cm but, more markedly, it moves the *age* at 50% maturity from around 30 years of age to 13–15. By effectively halving the age-at-maturity we can expect this will also have an impact on current status, when considered in conjunction with the differences in recruitment trend. In the previous models, given an effective age-at-maturity of around 30 years basically none of the estimated model recruitments would affect the female SSB until 2010 at the earliest and only significantly after 2015 (given when we begin estimating recruitment). This will not be the case when using the revised maturity curve.

2 Results

We do not go into statistical and graphical detail for brevity but the change in maturity basically changes **very little to nothing** in either the fits to the data or the estimates of recruitment trend, absolute abundance and fishing mortality. This should not really be a surprise though, given the only place this change has a quantitative role is in the reduction in mean recruitment given the female spawner biomass depletion level via the stock-recruit relationship. At the levels of SSB depletion and values of steepness we are working with this reduction is effectively zero so changes nothing basically. It also (again not surprisingly) tells us that nothing in the data we have can tell us if the revised maturity function is somehow “wrong” relative to the old one. Clearly, the current curve is not compatible with the actual maturity stage data and the revised one is [3], so we must rely on this data to inform our choice of relationship to use.

What it *does* change however, for the revised model, is current estimates of depletion: median of 0.85 (0.78–0.93 95% credible interval). As alluded to in the previous section, this is entirely due to how estimated recruitments play out in their effect on the spawning biomass. Previously they basically didn't historically and almost all their effect would have been in projections (or at most from 2010 onwards). Now, estimated recruitment trends "hit" the female spawner biomass around the mid-to-late 1990s which is when the highest historical catches were taken. Figure 2.1 shows the comparative SSB and recruitment estimates (both total and in terms of depletion) for the previous and revised maturity relationships. For the revised maturity curve the female SSB is over 3 times larger in absolute terms, as one might expect, but also far more influenced by recruitment in a relative sense - even thought the absolute recruitment values are basically almost identical for both cases.

In terms of spatial dynamics, Figure 2.2 shows the spatial breakdown of both absolute and relative female SSB for both maturity relationships. There are both relative and absolute differences between the two. In absolute terms, the relative difference between the Northern and Southern areas is much reduced. for the previous maturity relationship the Northern area was around 5–6 times larger than the South; for the new relationship that is substantially reduced to a factor of around 2. In relative terms the strong differential between the less depleted North and more depleted south (0.8 *vs.* 0.38) is also much reduced to 0.94 (North) and 0.67 (South) and neither region is estimated to be below 0.5 with any significant probability.

3 TAC options

From the outset, we are of the view that the current maturity curve is simply not compatible with the available maturity stage data and that the best *current* estimate we can provide is the one given in [3]. So we would recommend using the current maturity curve as the sole basis for setting the upcoming TAC, but we do include the associated TACs to emphasise how the change in maturity curve *in conjunction with the CCAMLR decision rule* affects the potential management advice. For all of the potential maturity scenarios and TACs **none** of the scenarios have the relative SSB going below 0.6 in the next 10 years.

	ATL	NMRL	SMRL	TAC
Old maturity	100	145	145	390
New maturity	100	250	250	600
Old maturity	150	75	175	400
New maturity	150	136	319	555
Old maturity	250	75	75	400
New maturity	250	155	155	560

Table 3.1: *TAC options for both the current and revised maturity-at-length curve and some representative Aurora trough fixed catch levels and North/South catch splits.*

In terms of TAC spatial splits, there are obviously a lot of options that could be explored. For representative purposes we explored three possible options:

1. 100t in the Aurora trough and a 50/50 split between the North and South
2. 150t in the Aurora trough and a 30/70 split between the North and South
3. 250t in the Aurora trough and a 50/50 split between the North and South

For the old maturity curve, basically the calculated TAC would be 400t and seems insensitive to the spatial split (see Table 3.1). For the revised maturity curve there is more variation in the TAC, it is clearly always higher for the revised maturity curve (as we would probably expect) and ranges between 555–600t. It seems that if more catch is taken from the Northern Area, then the TAC would likely be higher, given there is still more exploitable biomass estimated to be in the North than the South. In general, the estimated TAC is between 27–33% *higher* when using the revised maturity-at-length relationship.

4 Discussion

This paper outlines both the stock status implications and TAC calculations when comparing using the current maturity-at-length relationship with the revised maturity-at-length relationship detailed in [3]. Using the revised maturity relationship essentially changed nothing in terms of fits to the data, estimated data weighting parameters, recruitment (both absolute and relative) and overall numbers-at-age and harvest rates. In truth, we would not expect it to given that it only affects the mean recruitment level given female SSB and with depletion levels above 70% and a steepness of 0.75 there is little change in this even with such a significant shift in the maturity-at-age relationship.

What it *does* change however is both estimates of current status, and the TAC calculations using the CCAMLR rule. For the revised maturity curve the current estimates of stock status are 0.85 (0.78–0.93), as opposed to an estimate of 0.7 previously. It also drastically alters our perception of how much female reproductive biomass is in the Northern and Southern areas - the change reduced the North-South differential from around 5–6 times to around 2. Also, the disparate depletion levels between North and South are much reduced: from 0.8 to 0.38 before, to 0.94 and 0.67 now. In terms of TAC calculations, for the revised maturity curve the range (for the spatial options explored) was 555–600t, as opposed to 390–400t with the current maturity curve.

It is difficult to defend the current maturity relationship - with a 50% size-at-maturity of 1.4m - as it does not fit with the extensive maturity stage data we have [3] and the currently accepted method of determining spawning participation from maturity stage [4]. We are not in a position to truly state what is the “right” relationship - there is no histological data to try and clear up potential skip-spawning issues and, truly, without the close-kin data we are currently exploring for this fishery there is no way to know who is really producing the juveniles. That being said, we have a revised maturity relationship that fits the data given the definitions of maturity, makes far more sense relative to the other Patagonian toothfish species, and results in an expected maturity-at-age relationship that makes far more sense from a life-history reproductive strategy perspective than the current one.

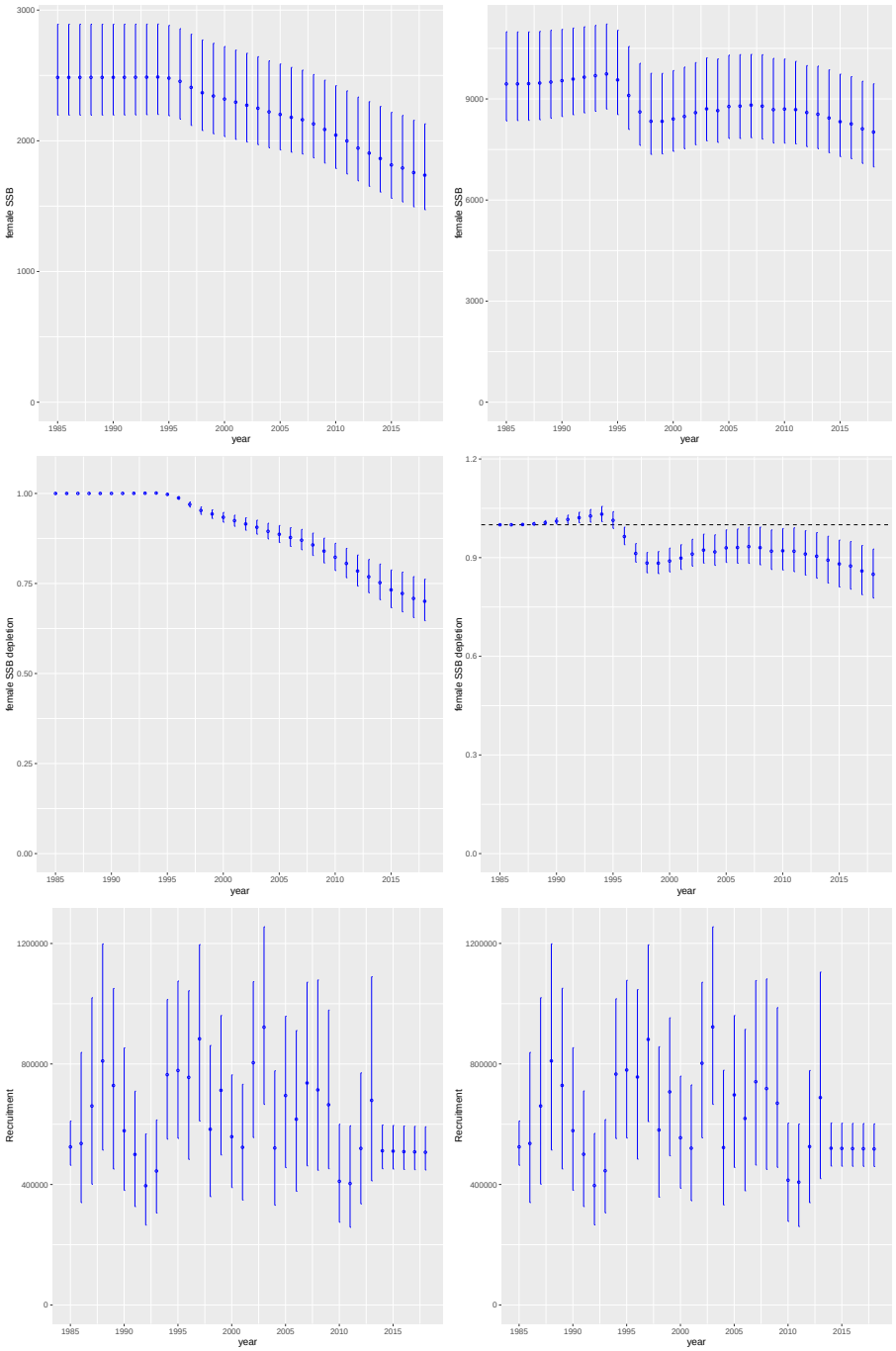

Figure 2.1: *Absolute (top) and relative depltion (middle) summaries for female SSB and total recruitment (bottom) for the previous (left) and revised (right) maturity relationships.*

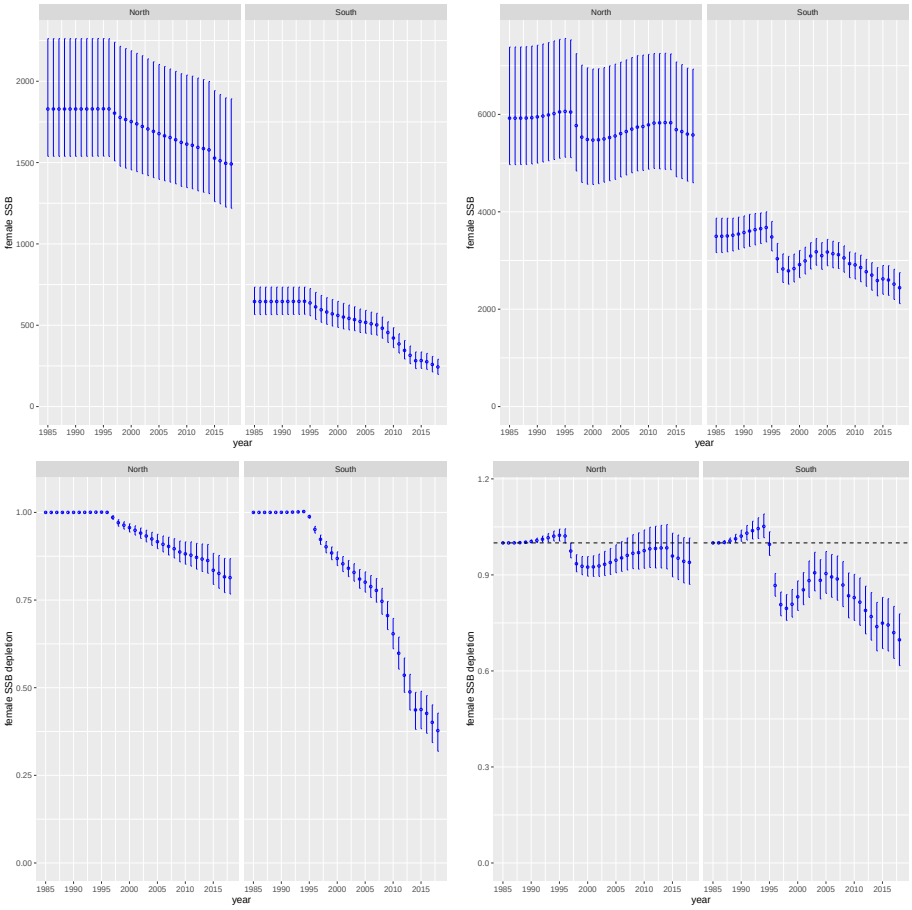

Figure 2.2: *Absolute (top) and relative depltion (bottom) summaries for female spatial SSB for the previous (left) and revised (right) maturity relationships.*

References

[1] Day, J. and Hillary, R. M. (2019) Stock Assessment of the Macquarie Island fishery for Patagonian toothfish (*Dissostichus eleginoides*) using data up to and including August 2018. *SARAG 59*.

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[4] Kock K.-H. and A. Kellermann (1991) Review: Reproduction in Antarctic notothenioid fish. *Antarctic Science*, **3**:125–150

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CONTACT US

t 1300 363 400
+61 3 9545 2176
e csiroenquiries@csiro.au
w www.csiro.au

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