A SIMPLE BIOMASS-BASED MODEL FOR PROJECTIONS OF THE IMPACTS OF FURTHER WEST COAST SARDINE CATCHES ON BIOMASS WEST OF AGULHAS

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The following biomass-related information is available to inform on the impact of further west coast directed sardine catches (considered to be of 1+ fish) on the (essentially) 1+ abundance west of Agulhas which started the current "year":

1) *BI*: The November 2015 survey estimate: 131.5 thousand tons (CV = 0.31)
2) *BII*: The most recent two-stock assessment (FISHERIES/2016/AUG/SWG-PEL/22, which incorporates 1) above): 140.1 thousand tons
3) *BIII*: The June 2016 survey estimate: 147.8 thousand tons (CV = 0.52)

Note that 1) and 3) incorporate the acoustic survey bias estimate (i.e. original estimate has been divided by 0.749).

In addition the following west coast catches of (essentially) 1+ sardine had been made by the mid-point of the survey:

a) Directed sardine catch: 29.9 thousand tons
b) By-catch with redeye: 4.6 thousand tons

i.e. a total of 34.5 thousand tons.

The estimate in 3) also provides an estimate of the 1+ biomass in November 2015 if one can account for the catches removed subsequently, as well as for gains in weight through somatic growth and losses to natural mortality in the intervening period. This is readily achieved if the Shepherd production model assumption is made that that gains through somatic growth are near equal to losses to natural mortality, so that absent the contribution of incoming recruitment (not pertinent for the comparisons to follow), the simple dynamics model for biomass (here starting at age 1+) is:

$$B(t_2) = B(t_1) - C(\text{taken between } t_1 \text{ and } t_2) \qquad (1)$$

From this equation, the June 2016 estimate *BIII* above converts to an effective 1+ November 2015 biomass of:

$BIII^* = 147.8 + 4.6 = 182.3$ thousand tons

As a quick check on the Shepherd approximation, one can consider the relative weight gain from 1 to 2 years old multiplied by the loss to natural mortality. Taking mean lengths of 13.5 and 18 cm for ages 1 and 2 in November (from Fig. 12 of PEL/22), cubing and using $M = 1$

yr^{-1}, gives a multiplier of $(18/13.5)^3 * e^{-1} = 0.87$ (or 1.07 for $M = 0.8$). This multiplier would be lower for larger ages. Hence *BIII** would probably be negatively biased to some extent.

Both surveys can be taken into account by calculating an inverse variance weighted average of BI and BIII*. This results in a value:

BIV = 147.5 thousand tons

Here the survey estimate distributions were taken to be lognormal, so the averaging was carried out in log space. If normal distributions were to be assumed, the result would be 142.7 thousand tons.

The impact of possible future catches can be summarised in two ways given the model of equation (1):

i) Exploitation rate $ER = Catch/B(\text{Nov 2015})$
ii) Fishing mortality $F = -ln(1-ER)$ from $ER = 1 - e^{-F}$

Note that natural mortality *M* does not come into play here in the *ER vs F* relationship, given that it "cancels out" under the Shepherd assumption on which equation (1) is based.

Table 1: *ER* in relation to additional west coast catches and November 2015 biomass estimates

Estimate	Additional catch in tons			
	0	5000	10000	15000
BI – Nov survey (131.5)	0.26	0.30	0.34	0.38
BII- Assessment (140.1)	0.25	0.28	0.32	0.35
BIV – wt average *BI* and *BIII** (147.5)	0.23	0.27	0.30	0.34
*BIII** - June survey adjusted (182.3)	0.19	0.22	0.24	0.27

Table 2: *F* in relation to additional west coast catches and November 2015 biomass estimates

Estimate	Additional catch in tons			
	0	5000	10000	15000
BI – Nov survey (131.5)	0.30	0.36	0.41	0.47
BII- Assessment (140.1)	0.28	0.33	0.38	0.44
BIV – wt average *BI* and *BIII** (147.5)	0.27	0.31	0.36	0.41
*BIII** - June survey adjusted (182.3)	0.21	0.24	0.28	0.32