A method to recommend the final anchovy Total Allowable Catch for 2020 based on short-term projections of the anchovy resource

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The impact of alternative levels of anchovy catch on short- and medium-term projections of the anchovy resource are considered in the same manner as that followed by the Small Pelagic Scientific Working Group in March, now taking updated analyses and information from the recent recruitment survey into account.

In March 2020, the Small Pelagic Scientific Working Group (SWG-PEL) recommended an initial anchovy TAC after considering the different projected impacts on the anchovy resource of alternative constant catch levels under different future recruitment scenarios (de Moor 2020a, DFFE 2020). de Moor (2020b) has provided updated statistics on the projected impacts of alternative constant catch levels using a recently updated model of the anchovy resource (de Moor 2020c). This document attempts to re-apply the same method and reasoning used by some SWG-PEL members to recommend an initial anchovy TAC based on the results of de Moor (2020a) to now recommend a final anchovy TAC based on the results of de Moor (2020b).

Assumptions about future recruitment are of key importance in the short-term projections. As the anchovy fishery is largely a recruit fishery, and the size of the incoming recruitment was unknown in March, the initial TAC was recommend considering incoming recruitment to range between 20% and 100% of the historical average, with focus on the possibility of incoming recruitment being 50% or 75% of the historical average (Bergh 2020, Butterworth 2020, de Moor 2020e). A survey estimate of 2020 recruitment is now available (Coetzee *et al*. 2020), and can be used to update and potentially narrow the range of future recruitment levels to consider in recommending a final anchovy TAC.

The model predicted recruitment at the time of the survey, $N^A_{2020,r}$, can be back-projected to November as follows (de Moor 2020d):

$$N^A_{2019,0} = \left(\left(\left(N^A_{2020,r} e^{(0.5 t_{2020}/12)M^A_0} + C^A_{2020,0bs} \right) e^{(1/8 + 0.5 t_{2020}/12)M^A_0} + C^A_{2020,2,0} \right) e^{M^A_0/4} + C^A_{2020,1,0} \right) e^{M^A_0/8} \qquad (1)$$

where

$M^A_0 = 1.2$ year^{-1} denotes the rate of natural mortality of age 0 anchovy;

$t_{2020} = 1.57$ months denotes the time lapsed between 1 May and the start of the recruit survey on 17th June 2020;

$C^A_{2020,q,0}$ denotes the number of anchovy recruits caught during quarter q of 2020; and

$C^A_{2020,0bs}$ denotes the number of anchovy recruits caught between 1 May and the day before the start of the recruit survey in 2020.

The anchovy 0-year-old catch between 1 November 2019 and 16 June 2020 can be estimated using monthly cut-off lengths given in de Moor *et al*. (2012), with adjustment to the cut-off lengths in recent months based on the recruit survey cut-off

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length (de Moor 2018). Length frequency samples collected from commercial catches during the covid-19 lockdown period of late March to mid June 2020 have yet to be processed and captured. The commercial length frequency derived from samples available prior to the lockdown at the end of March is assumed to apply to all of March. Best approximation monthly length frequencies for April to June 2020 have been provided by van der Lingen (2020) based on the April to 16th June 2014 and 2015 commercial length frequencies. The April to 16th June spatial catch patterns in these two years correspond closely with that observed during 2020. To test the sensitivity of this assumption, April to 16th June 2018 commercial length frequencies were alternatively used, representing catch patterns which concentrated on areas where larger anchovy are typically caught. A further (perhaps more extreme) sensitivity assumed the June 2020 survey length frequency observed north of Cape Columbine to apply to the April to June 2020 catches (Coetzee *et al*. 2020). The recruit survey length frequency typically contains smaller fish than that observed in commercial catches (Coetzee pers comm). The alternative length frequencies are shown in Figure 1 and the resultant 0-year old catch prior to the 2020 survey in Table 1.

Equation (1) uses the model predicted recruitment at the time of the survey. This differs from the survey observation due to (i) survey bias (k_r^A) and (ii) both survey and additional variance (Figure 2). Figure 3 shows the multiplicative difference between the survey observation and the bias corrected recruitment at the time of the survey, giving an indication of the uncertainty due to (ii). As a means to consider this uncertainty four alternative values for $k_r^A N_{2020,r}^A$ are considered in Table 1:

a) No uncertainty, $k_r^A N_{2020,r}^A = N_{2020,r}^{obs}$

b) One SE difference using the 2020 survey CV of 0.20: $k_r^A N_{2020,r}^A = (1 - 0.20)N_{2020,r}^{obs}$

c) Multiplicative differences between the survey observation and the bias corrected recruitment based on that estimated in recent years and close to 400 billion recruits (Figure 3): $k_r^A N_{2020,r}^A = 0.5 N_{2020,r}^{obs}$ and $k_r^A N_{2020,r}^A = 0.9 N_{2020,r}^{obs}$.

Using the 2020 recruit survey estimate of 377 billion fish (Coetzee *et al*. 2020), the recruitment in November 2019 likely ranged between 98% - 193% of historical recruitment (Table 1), with the sensitivities due to missing commercial length frequencies increasing this range to 96% - 198%.

A scientifically defensible final anchovy TAC can now be considered by narrowing down the range of recruitment scenarios considered by de Moor (2020b) to those including 90% and higher of historical recruitment, and then considering the impact of alternative levels of catch on the population along the same lines as recommended by de Moor (2020e). Tables referred to in the following bullet points are from de Moor (2020b).

- DFFE (2020) and Butterworth (2020) suggested the anchovy biomass in 2020 should ideally not decrease from that in 2019, or any decrease should be 'not too much'.

- The 1-year impact of catch on the population is to decrease the SSB from the 2019 level to a minimum of 60% (5%ile), 81% (20%ile) or increase by a minimum 120% (50%ile) under 300 000t (Tables 2a-c). The 1-year impact of catch on the population is to decrease the SSB from the 2019 level to a minimum of 57% (5%ile), 78% (20%ile) or increase by a minimum 117% (50%ile) under 350 000t (Tables 2a-c). When considering future recruitment scenarios from 110% and above, the 1-year impact of catch on the population is to decrease the SSB from the 2019 level to a minimum of 65% (5%ile), 91% (20%ile) or increase by a minimum 139% (50%ile) under 350 000t (Tables 2a-c).

- The 1-year impact of catch on the population is to decrease the SSB to a minimum of 75% (5%ile), 81% (20%ile) or 84% (50%ile) of that which could be expected were there no catch during 2020 (Tables 3a-c).

- Given the availability of the June 2020 recruit survey estimate, it is likely defensible to primarily consider the 20%ile results, rather than the precautionary approach of considering the 5%ile used by de Moor (2020e) in the absence of a 2020 survey estimate of recruitment. In the light of this, one could summarise the results of Tables 2 and 3 to suggest it is likely that some decrease in the SSB from the 2019 level will occur under 300 000t and 350 000t if incoming recruitment is 90 or 110% of the historical average. However, that decrease is less than 25% of what could be achieved under a no catch scenario which could be argued to be reasonable. If incoming recruitment is above 110% the SSB will likely increase between 2019 and 2020 even under a 350 000t catch scenario.

- The depletion of the resource at the end of 2020 is projected to reach a minimum of 62% (5%ile), 69% (20%ile) or 77% (50%ile) under 300 000t (Tables 5a-c). The depletion of the resource at the end of 2020 is projected to reach a minimum of 59% (5%ile), 66% (20%ile) or 75% (50%ile) under 350 000t (Tables 5a-c).

- After 10 years of constant catch under alternative recruitment levels, the resource is expected to equilibriate at a minimum depletion level of about 70% (5%ile), 79% (20%ile) or 85% (50%ile) under 300 000t (Tables 6a-c). The minimum equilibrium depletion level is predicted to be about 65% (5%ile), 75% (20%ile) or 82% (50%ile) under 350 000t (Tables 6a-c).

- If the 5%ile is again discounted in favour of the 20%ile, one could summarise the results of Tables 5 and 6 to argue that the depletion levels at 350 000t are projected to be reasonable, with the only depletion lower than 70% being if recruitment is 90% of the historical average (Table 1 suggests the likely range begins from somewhere between 90-110%).

In summary, attempting to re-apply the same method and reasoning as used by some SWG-PEL members in March to recommend an initial anchovy TAC for 2020, suggests a final anchovy TAC for 2020 of 300 000t is scientifically justified, and a TAC of up to 350 000t could also be reasonable justified.

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Table 1. The November 2019 back-projected recruitment based on alternative levels of recruit catch and recruitment at the time of the June 2020 survey.

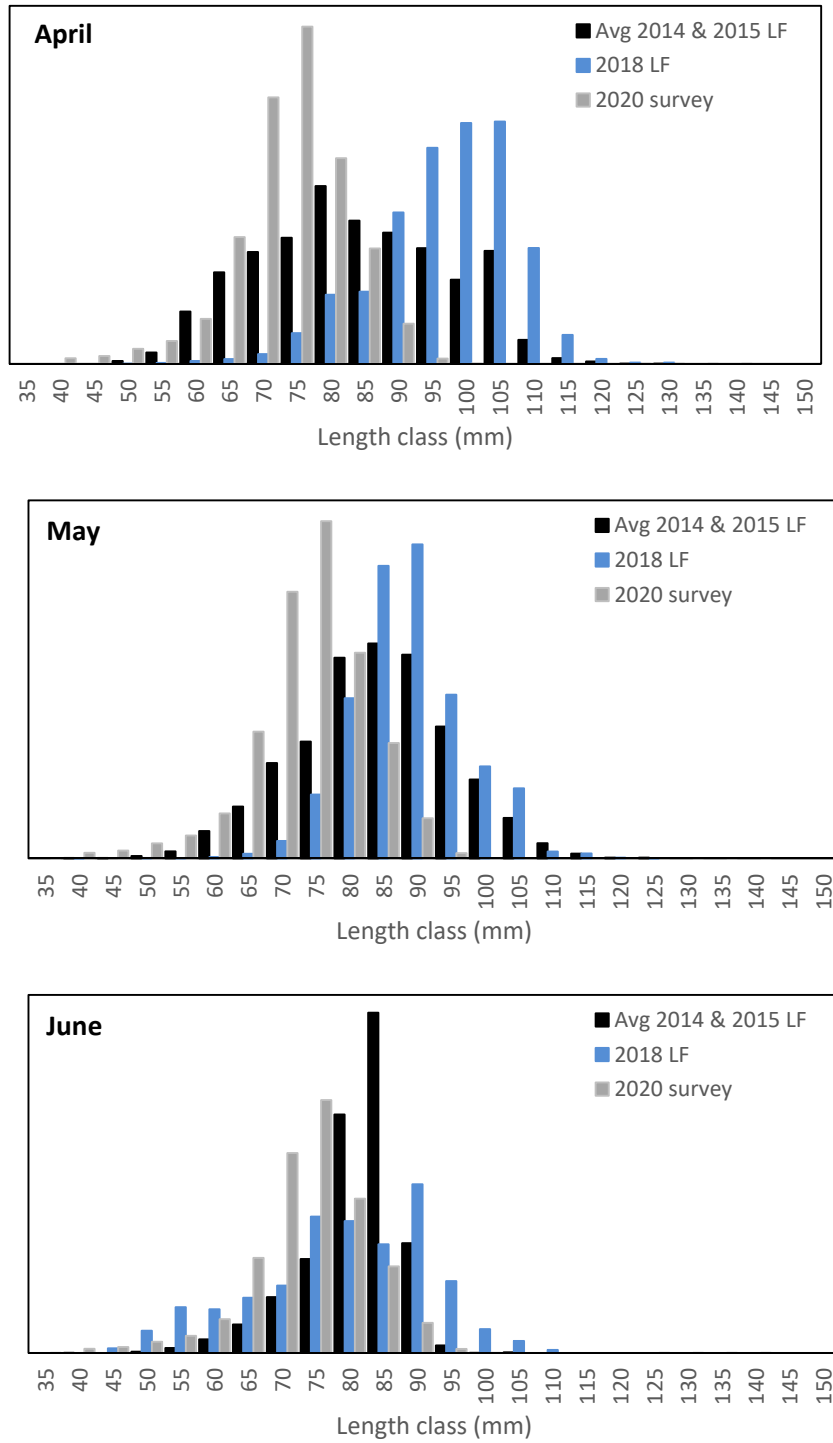|		April – June Length frequency		
		Best approximation	2018 Commercial LF	2020 Survey LF
$k_r^A N_{2020,r}^A$	$C_{2020,1,0}^A$	0.003	0.003	0.003
	$C_{2020,2,0}^A$	4.09	1.17	11.16
	$C_{2020,0bs}^A$	2.65	1.43	11.09
	$N_{2020,r}^{obs}$	1095	1088	1122
	$(1-0.20)N_{2020,r}^{obs}$	878	871	906
	$0.5 N_{2020,r}^{obs}$	553	546	581
	$0.9 N_{2020,r}^{obs}$	986	979	1014

Figure 1. The length frequencies used to calculate the commercial catch of 0-year-old anchovy in April to June 2020.
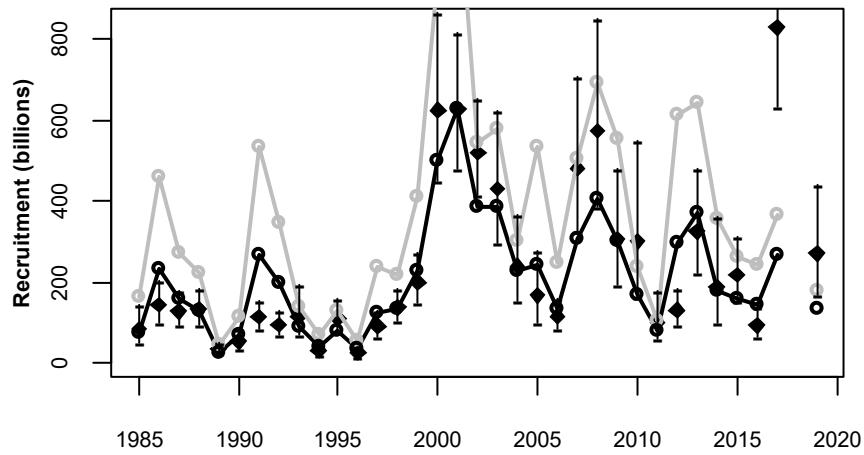
Figure 2. The model predicted recruitment at the time of the survey (grey), the bias corrected model recruitment at the time of the survey (black line and open circles) and the survey estimates of May/June recruitment (diamonds). The survey indices are shown with 95% confidence intervals reflecting survey inter-transect variance.
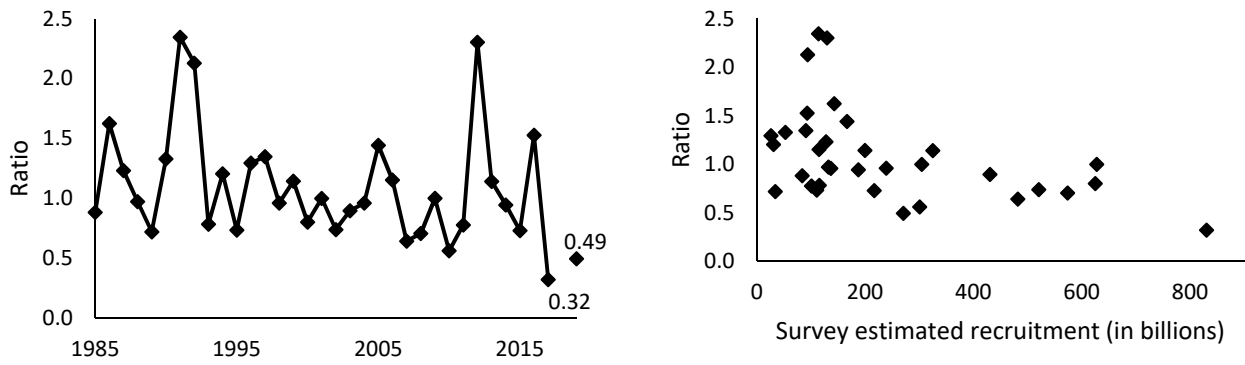

Figure 3. The ratio of the bias corrected model predicted recruitment at the time of the survey to the survey estimate of recruitment plotted (i) against year (left) and (ii) against the survey estimate of recruitment.