The assumptions associated with the indices of South African anchovy abundance provided by the Daily Egg Production Method

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Past publications on the development and application of the Daily Egg Production Method (DEPM) to estimate South African anchovy abundance are reviewed. These indicate that the current assumptions in the anchovy assessment model that the time series of DEPM indices can be assumed to provide an absolute index of anchovy spawner biomass remain intact, despite recent developments in estimating anchovy maturity and the bias associated with the hydro-acoustic survey.

Two time-series of abundance indices have standardly been used to assess the abundance of South African anchovy in November:

(i) the hydro-acoustic estimates of abundance (from 1984 to present), and

(ii) the Daily Egg Production Method (DEPM) estimates of abundance (from 1984 to 1993).

The former has been assumed to provide a relative, but fairly precise (lower CV) index of anchovy total biomass, and the latter, developed initially for northern anchovy off California (Parker 1980; Lasker 1985) has been assumed to provide an absolute, although fairly imprecise (higher CV) index of anchovy spawner biomass. DEPM-derived indices of anchovy spawner biomass were used to scale acoustic total biomass estimates during a period when the accuracy or applicability of the target-strength expression used in acoustic calculations was undetermined and before the development of target-strength expression for local anchovy stocks (Hampton 1996). The assumption that the DEPM indices are absolute estimates of spawner biomass have been key to scaling the anchovy abundance during past assessments of the resource (e.g. de Moor 2016, 2020a) as no information on the relative bias of the hydro-acoustic survey indices was used in those assessments.

There have been two recent developments with the anchovy assessment that have prompted reassessment of the assumptions made regarding the DEPM indices of abundance.

The first is that the assessment has been shown to be sensitive to alternative anchovy maturity ogives (de Moor 2020b, c), and annual maturity ogives are currently being estimated (Geja pers. comm.) to inform the ogives to be used in future assessments. Equation (1) of Armstrong *et al*. (1998) indicates that the DEPM estimates provide an index of mature/spawning biomass. There was therefore no underlying assumption of maturity by age/length during the estimation of the DEPM indices, and changes in such maturity ogives over time do therefore not require any re-estimation of the DEPM time-series. The assumption by the assessment model to fit model predicted spawning biomass (numbers x weight x maturity) to the DEPM indices therefore remains sound.

Secondly, de Moor *et al*. (2020) calculated a prior distribution for the bias of the hydro-acoustic survey estimates of abundance. Given this prior, the assessment now has sufficient information to (in some sense) update estimates of the bias in both the acoustic and DEPM estimates of abundance. The DEPM estimates of abundance were originally assumed to be

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absolute in order to scale the assessment in the absence of other information; now given the prior for the bias in the hydro-acoustic survey, it becomes possible to assume alternatively that the DEPM estimates provide a relative index of spawner biomass. Armstrong *et al*. (1988), Hampton *et al*. (1990), Shelton *et al*. (1993) and Hampton (1996) all assumed the DEPM estimates provided an absolute index of abundance. One author (DSB) recalls that at the time that the DEPM estimates were developed in the 1980s, the intent was to design the method to avoid any possible bias, duplicating the process used in California where the method had been developed shortly before that. The South African approach differed from that applied off California (and Peru) in that acoustically-estimated fish densities were incorporated as weighting factors for the spawning parameters (Armstrong *et al*. 1988). However, Armstrong et al. (1988) noted that it is possible that the DEPM indices underestimate abundance if the assumption of constant egg mortality rate between spawning and hatching is invalidated through, for example, cannibalism on dense aggregations of early-stage eggs. Density-dependent cannibalism has been reported for South African anchovy during pelagic surveys conducted in 1984 and 1985 (Valdes *et al*. 1987), but no further studies of this have since been conducted. The assumption by the assessment model to fit model predicted spawning biomass to the DEPM indices with a bias fixed equal to 1 is therefore the best that can be made at this time (in the absence of any further analysis that provides evidence of possible bias). The historical robustness tests to this assumption assuming a fixed bias of 0.75 or 1.25 will now be replaced with the assumption of DEPM being a relative index, with the DEPM bias indirectly informed from the prior for the hydro- acoustic survey bias.

Finally, it is noted that while the DEPM relates to female mass, fecundity and spawning fraction each evening, the resultant DEPM estimate is of total – not female only – spawning (i.e. mature male and female) biomass due to the inclusion of the estimated mean ratio of female to total spawning biomass ($\hat{\bar{R}}$ in equation (1) of Armstrong *et al*. 1988). The assumption by the assessment model to fit model predicted sex-aggregated spawning biomass to the DEPM indices is therefore sound.

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