Incorporating seasonality in sardine spawning into estimations of the transport success of eggs spawned on the South Coast to the West Coast nursery area

CD van der Lingen[1,2] and A McGrath[2]

[1] Offshore Resources Research, DAFF; [2]Marine Research Institute and Department of Biological Sciences, UCT

Introduction

Estimating the proportion of sardine eggs spawned off the South Coast that are transported to the West Coast and recruit into the western sardine sub-stock (*p*) is important for assessment model development (Butterworth *et al.* 2016). Progressive steps in estimating *p* to date are as follows:

1. The coupled 3D hydrodynamic – individual based model of Miller *et al.* (2006) suggested that a low proportion of sardine eggs spawned on the South Coast (to the east of Cape Agulhas) would be successfully transported to the West Coast. Transport success was estimated from four South Coast spawning areas: CAB_{In}, CAB_{Off}, EAB_{In} and EAB_{Off}, with overall *p* values of 0.145, 0.151, 0.027 and 0.027, respectively.
2. Fixed values of transport success (*p*) from the entire CAB (0.148) and entire EAB (0.027) to the west coast nursery grounds are the average of the inshore and offshore values for these regions from Miller *et al.* (2006); these have been calculated so as to match pelagic biomass survey strata.
3. To account for differing distributions of sardine off the South Coast, these fixed values were weighted by the relative contribution to the sardine biomass off the South Coast of fish on the CAB and EAB in each year (1984-2015) and then summed to give an annually-varying estimate of *p* ranging from 0.029 to 0.148 and with a mean value of 0.083 (Coetzee 2016).
4. The values of *p* provided in Miller *et al.* (2006) were the average from a large number of simulations (864) in which spawning area (9), month (12), depth of egg release (3), year (8) and trial (3) were varied between simulations. Frequency distributions of *p* values (irrespective of *Year*, *Month*, *Trial* and *Depth*) arising from these simulations have been derived separately for the $CAB_{Combined}$ and $EAB_{Combined}$ (see Fig. 4 of van der Lingen *et al.* 2016).

Dunn *et al.* (2016) highlighted the importance of repeating the simulations using a higher-resolution and spatially more extensive 3D hydrodynamic model and adding more biological realism to the coupled 3D hydrodynamic – individual based model. This could be addressed by including releasing particles during peak spawning periods and adding larval behaviour such as diel vertical migration. As a short-term approach to weighting estimates of *p* by the relative amount of spawning, Dunn *et al.* (2016) suggested that monthly outputs of *p* should be weighted by monthly gonado-somatic index (GSI) values of sardine off the south coast. This has been done and this document describes the results of that analysis.

Data and analysis

GSI data

Monthly mean GSI (= gonad mass/wet body mass) values (both sexes combined) were calculated separately for sardine from commercial catches taken off the West (32 837 fish) and South (13 370 fish) coast (divided at Cape Agulhas) over the period 1995 to 2015.

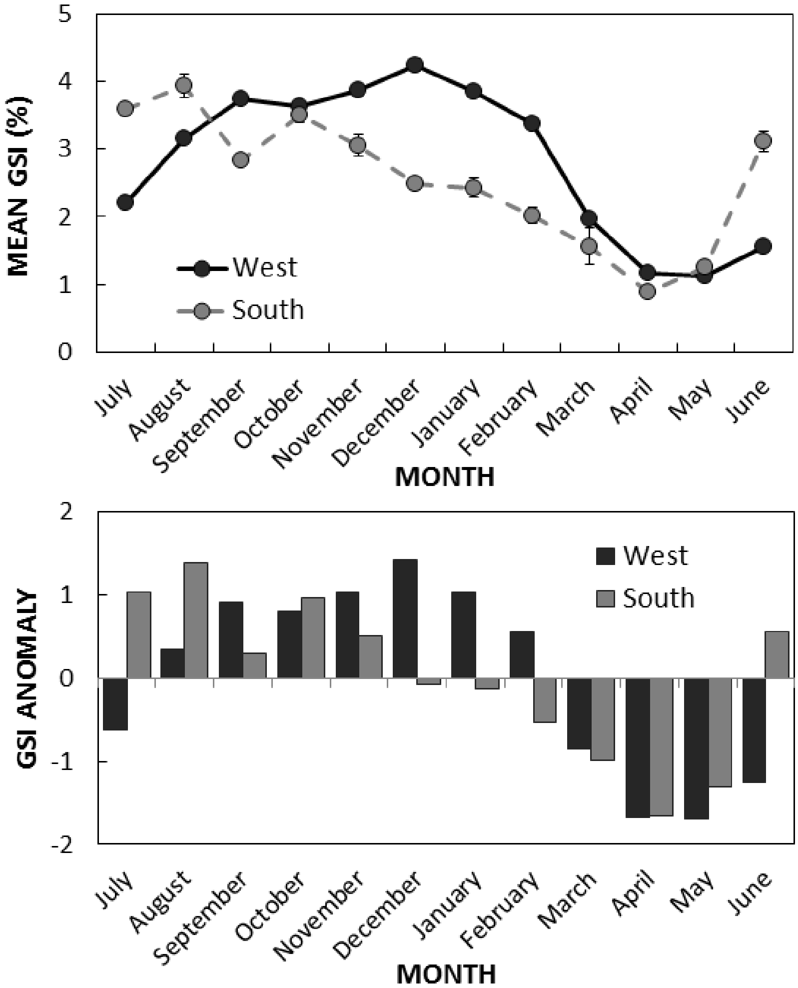

Figure 1: Mean (± standard error) monthly GSI (upper plot) and GSI anomaly (= mean monthly GSI – overall average GSI) for sardine caught off the West (dark circles/histograms and solid line) and South (light circles/histograms and dashed line) coast over the period 1995-2015.

Sardine off both the West and South coast show clear seasonal cycles in GSI (Fig. 1). However, where the periods of lowest mean monthly GSI coincide and are only separated by one month (March-June in sardine off the West Coast and February-May for fish off the South Coast), periods of highest mean monthly GSI are separated by 3-4 months (Fig. 1). Sardine off the West Coast show elevated GSI values from August to February (spring to summer) with a peak in December, whereas those off the South coast have higher GSI values from June to November (winter to spring) with a peak in August – a four month difference. The spawning seasonality of sardine off the West Coast reported here is consistent with previous studies of sardine spawning seasonality off the West Coast that used ichthyoplankton data and which indicated spawning throughout the year with a peak from August to March (van der Lingen and Huggett, 2003).

Weighting the coupled 3D – IBM data

Frequency distributions of modelled transport success to the West Coast nursery area from the $CAB_{Combined}$ and $EAB_{Combined}$ by month (and irrespective of Year, Depth or Trial – see van der Lingen *et al.* 2016) were obtained from the simulation outputs of the coupled 3D-IBM model used by Miller *et al.* (2006). Monthly frequency distributions of transport success were used to generate (i) an equally-weighted (across all months; *i.e.* no spawning seasonality with data from each month weighted by 1/12 or 0.083), and (ii) a weighted (using GSI data for sardine caught off the South Coast; *i.e.* with spawning seasonality) annual frequency distribution of modelled transport success to the West Coast nursery area. Given that sardine spawn year round, relative mean monthly GSI ($GSI_{Month\_n}/GSI_{Sum\ all\ months}$; range 0.029-0.128) was used to weight each monthly frequency distribution in (ii). A comparison of equally- and GSI-weighted annual frequency distributions of successful transport from spawning on the CAB and EAB to the West Coast nursery grounds is shown in Figure 2.

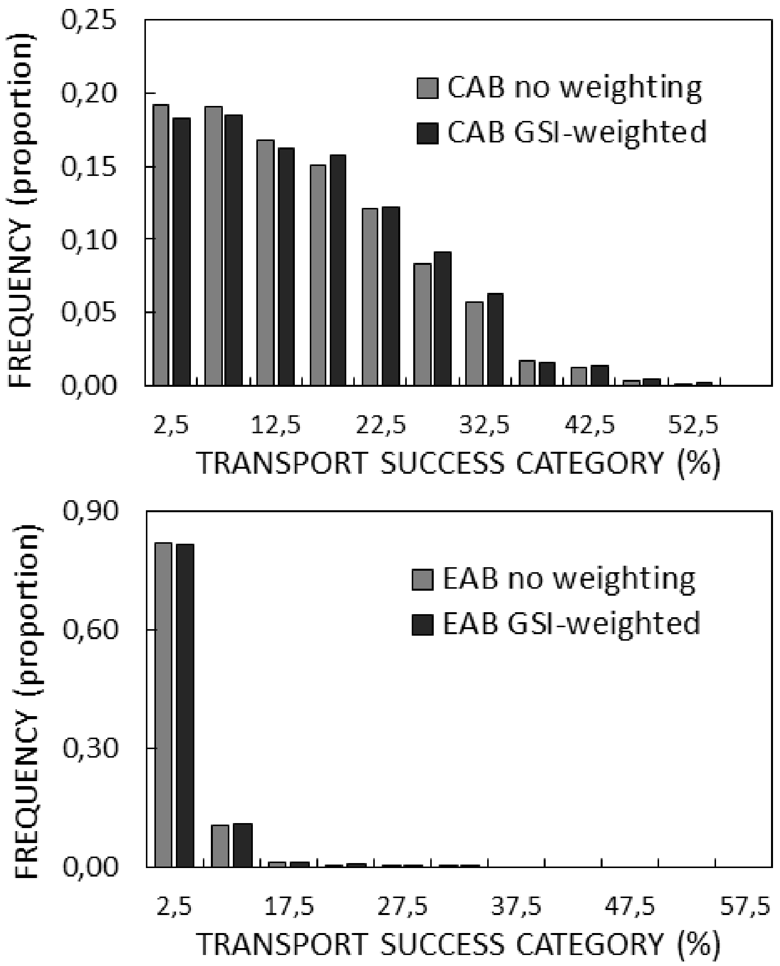

Figure 2: Frequency distributions (all simulated data irrespective of *Year, Depth* or *Trial*) of modelled transport success to the West Coast nursery area from the $CAB_{Combined}$ (upper plot) and $EAB_{Combined}$ (lower plot) for all months equally-weighted (light histograms) and months weighted by relative GSI (darker histograms).

Discussion

Weighting monthly frequency distributions of modelled transport success to the West Coast nursery area from spawning off the South Coast by monthly gonado-somatic values of sardine from the South Coast made relatively little difference to the overall frequency distributions of modelled transport success. The frequency distribution was shifted slightly to the right for the CAB when compared to that when months were equally-weighted, but very little difference was seen for the EAB (Fig. 2). Simulations are presently underway using a higher resolution 3D hydrodynamic model and transport success to the West Coast of particles spawned off the South Coast will be compared between IBMs run using low and high resolution 3D hydrodynamic models. In addition, the spatial extent of the South Coast spawning and nursery grounds will be expanded eastwards compared to the low resolution model to more accurately reflect sardine egg and larval distributions (McGrath MSc). Results from these analyses will be reported on during 2017.

References

Butterworth DS, van der Lingen CD, Coetzee JC, de Moor C. 2016. The present agreed hypothesis for South African sardine stock structure. FISHERIES/2016/NOV/SWG-PEL/69 (also MARAM/IWS/DEC16/Sardine/P7, 3pp.

Coetzee JC. 2016. Estimation of the effective proportion of sardine biomass contributing to putative western stock recruitment by including the proportion of eggs transported to the West Coast nursery area from South Coast spawning areas. FISHERIES/2016/AUG/SWG-PEL/37, 10pp.

Dunn A, Haddon M, Parma AM, and Punt AE. 2016. International Review Panel Report for the 2016 International Fisheries Stock Assessment Workshop 28 November – 2 December, UCT. MARAM/IWS/Dec16/General/7, 17pp.

Miller DCM, Moloney CL, van der Lingen CD, Lett C, Mullon C, and Field JG. 2006. Modelling the effects of physical–biological interactions and spatial variability in spawning and nursery areas on transport and retention of sardine *Sardinops sagax* eggs and larvae in the southern Benguela ecosystem. *Journal of Marine Systems* 61: 212–229.

van der Lingen CD, Coetzee JC, and McGrath A. 2016. Data for informing a choice of prior for the contribution of South Coast spawner biomass to West Coast recruitment. FISHERIES/2016/NOV/SWG-PEL/58, 6 pp.

van der Lingen CD and Huggett JA. 2003. The role of ichthyoplankton surveys in recruitment research and management of South African anchovy and sardine. In: *The Big Fish Bang. Proceedings of the 26th Annual Larval Fish Conference*. H. Browman and AB Skiftesvik (Eds). IMR, Bergen, Norway, 303-343.