Data for informing the choice of a prior for the contribution of South Coast spawner biomass to West Coast recruitment

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

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

Background

Miller *et al.* (2006) employed a particle-tracking individual-based model (IBM) coupled with a 3-D hydrodynamic model (known as PLUME; Penven *et al.,* 2001) to investigate how spatial variability in spawning and nursery grounds may influence transport and retention of sardine (*Sardinops sagax*) eggs and larvae in the southern Benguela ecosystem.

Key features of the PLUME 3-D hydrodynamic model include:

- PLUME consists of a curvilinear, pie-shaped grid located at the southwestern portion of South Africa from 28°S to 40°S and from 9°E to 24°E.
- Horizontal model resolution ranges from 9 km along the coast and increases linearly to 16 km offshore, and there are 20 vertical levels, with high resolution near the surface and a gradually decreasing resolution towards the bottom.
- The PLUME grid has three open (seaward) boundaries and an active open boundary scheme to estimate horizontal velocities in the vicinity of the boundaries; features produced within the model are transferred to the open ocean following a radiation condition and inputs from the surrounding ocean are forced by seasonal time-averaged outputs of the Agulhas As Primitive Equations (AGAPE) basin-scale ocean model.
- The model itself is forced by heat and salinity fluxes from the COADS ocean surface monthly climatology and the ERS1/2 wind stress scheme, a real weekly wind field with 1°×1° resolution from the actual years simulated by the PLUME model (8 years representing the period July 1991 to June 1999).
- Output data for each grid point were stored every two simulated days.
- Although the model is forced by repeated climatology (i.e. no interannual variability in the forcing fields) there are pronounced interannual differences between individual years, with intrinsic mesoscale activity considered to be the major contributor to interannual variability.
- The model was qualitatively validated via comparison of outputs with observed data both at the surface (e.g. SST) and at deeper levels.

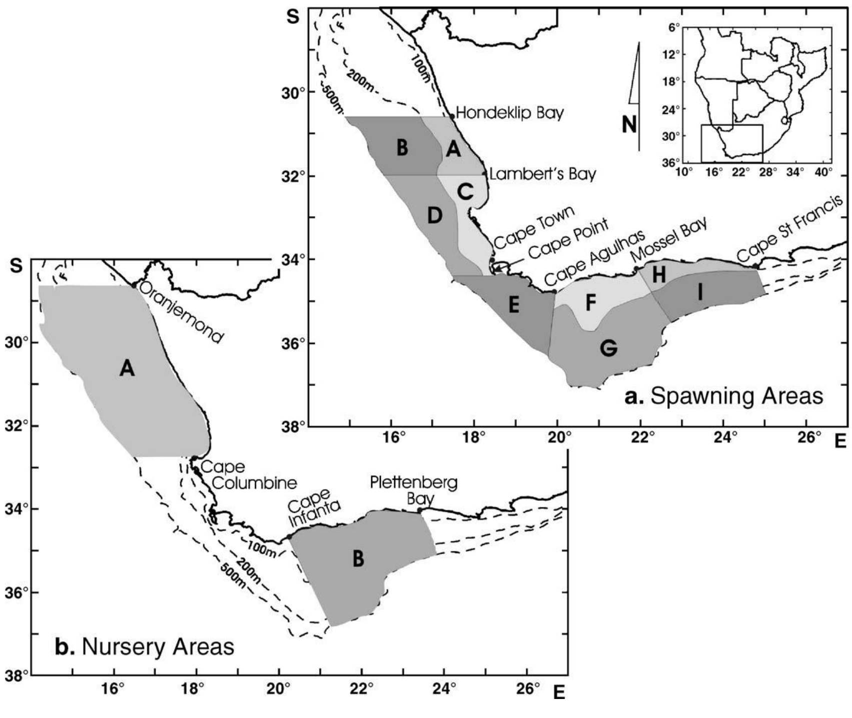
Key features of the IBM include:

- A temperature-dependent development model was used to determine the duration of one egg and two (yolk-sac larvae and early larvae that can swim) larval stages. Particles exposed to water of 13°C or less died and were removed from simulations.
- Particles representing eggs were released in each of nine spawning areas covering the shelf between Hondeklip Bay and Cape St Francis and divided into inshore and offshore regions

(by the 125m depth contour on the Agulhas Bank and 200m off the West Coast), and their movements tracked for 60 days.

- Particles were released every month using PLUME hydrodynamic model output from July 1991 to June 1999 (covering 8 spawning seasons).
- Particles were released in one of three depth ranges (0-25, 25-50 and 50-75m) but their vertical positions were dependent on the vertical velocity field of the 3D hydrodynamic model.
- Particles were released randomly within each spawning area and each depth range, typically leading to a uniform distribution within each.
- Transport to or retention within either of the designated nursery areas (a West Coast nursery area and a South Coast nursery area; Fig. 1) was recorded and expressed as a percentage of particles from each spawning area that reached each nursery area, and particles were only considered to have "successfully" reached a model nursery area if they were in the late-larval stage. Once a particle "successfully" reached a nursery area it was removed from the simulation.
- Three viable recruitment "systems" were identified: (i) eggs spawned and retained on the West Coast (WC to WC); (ii) eggs spawned and retained on the South Coast (SC to SC); and (iii) eggs spawned on the South Coast and transported to the West Coast (SC to WC). The third of these is of interest here as the "effective spawner biomass" for the western stock includes the proportion of eggs spawned on the South Coast (east of Agulhas) that are transported to the West Coast nursery area.
- A GLM analysis of the SC to WC area (excluding spawning on the WAB) indicated that *Spawning Area* explained most of the variance (36%), followed by *Month* (15%), *Month*Year* (10%), and then *Spawning Area*Month* (7%).

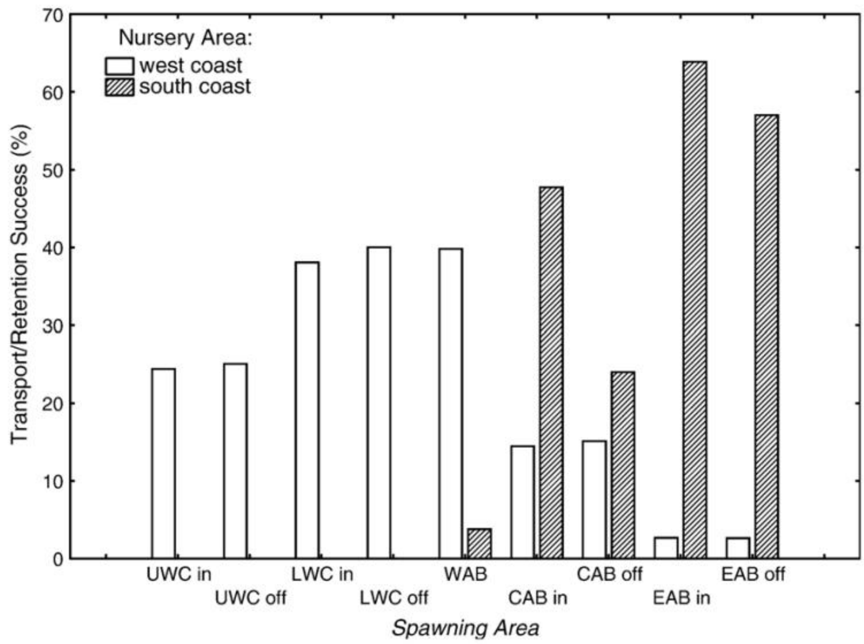
Figure 1: The nine spawning areas (A to I, upper plot) and two nursery areas (A and B, lower plot) used in Miller et al's (2016) IBM simulations.



Model results

Miller *et al.* (2006) reported that whereas some eggs from all nine spawning grounds reach the West Coast nursery grounds the further east eggs are released the less likely they are to do so. Overall average transport success from the CAB inshore (spawning area F) and CAB offshore (spawning area G) to the west coast was 15.1% and 14.4%, respectively, whereas transport success from the EAB inshore and EAB offshore was about 2.5% each (Fig. 2).

Figure 2: Modelled transport/retention success to the West and South coast nursery areas from each of the nine spawning areas.



Developing relative probabilities for transport for the proportions of sardine eggs spawned on the South Coast that are successfully transported to the West Coast nursery grounds

Butterworth (2016) suggested that probabilities to alternative assumptions concerning the contribution of sardine spawning on the South Coast to recruitment on the West Coast (*p*) could be assigned by combining information from the coupled 3D hydrodynamic and individual-based models with fits to stock-recruitment relationships. Whilst overall values of *p* have been provided in Miller *et al.* (2006), no information on the uncertainty associated with these values was provided. Butterworth (2016) showed a probability histogram for *p* calculated under a normal prior distribution with a mean of 0.083 and a standard deviation of 0.3 (the first of these values being the *qs* value reported by Coetzee [2016] and representing the average, biomass-weighted proportion of eggs transported to the West Coast from the South Coast; the second is presumably an assumed value).

Simulation outputs of the coupled 3D-IBM have been received from D. Miller and analysed to assess the distribution of *p*. Ten categories of *p* (each category being of equal width and selected to cover the full distribution of simulated *p* values in each case for each spawning area) were calculated for each of the South Coast spawning areas from all simulations (irrespective of *Year*, *Month*, *Trial* and *Depth*) and are presented in Figure 3.

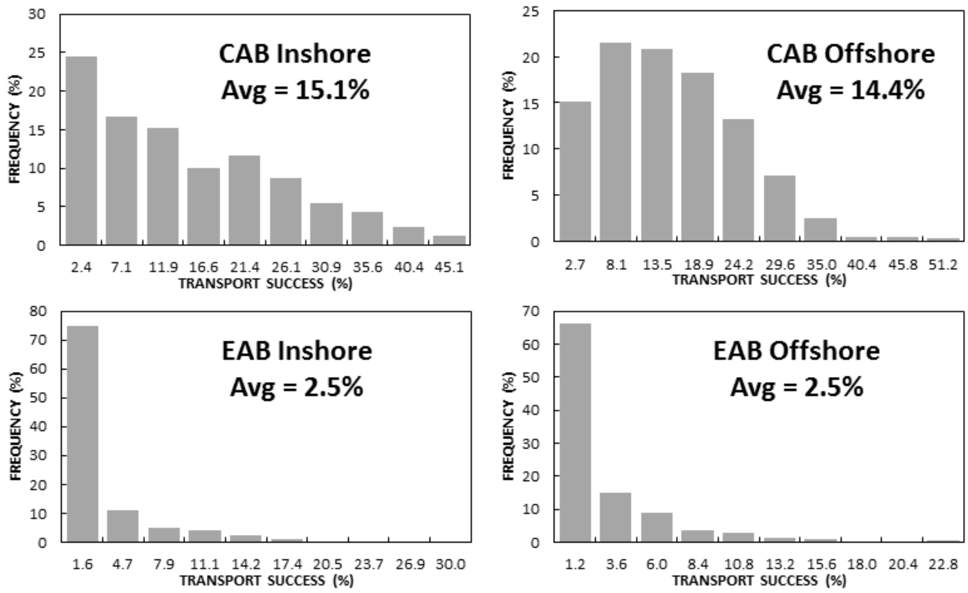


Figure 3: Frequency distributions (all simulated data irrespective of *Year, Month, Depth* or *Trial*) of various categories of modelled transport success to the West Coast nursery area from each of the four spawning areas on the South Coast (overall average values are shown). Note that the categories are not the same across spawning areas and that the y-axes also differ.

Frequency distributions (irrespective of *Year*, *Month*, *Trial* and *Depth*) have also been derived for the entire CAB (*i.e.* $CAB_{Inshore}$ and $CAB_{Offshore}$ combined) and EAB (*i.e.* $EAB_{Inshore}$ and $EAB_{Offshore}$ combined) so as to match the survey strata from which the observed relative sardine biomasses were calculated by Coetzee (2016), as well as for all four South Coast spawning areas combined. These are shown in Figure 4.

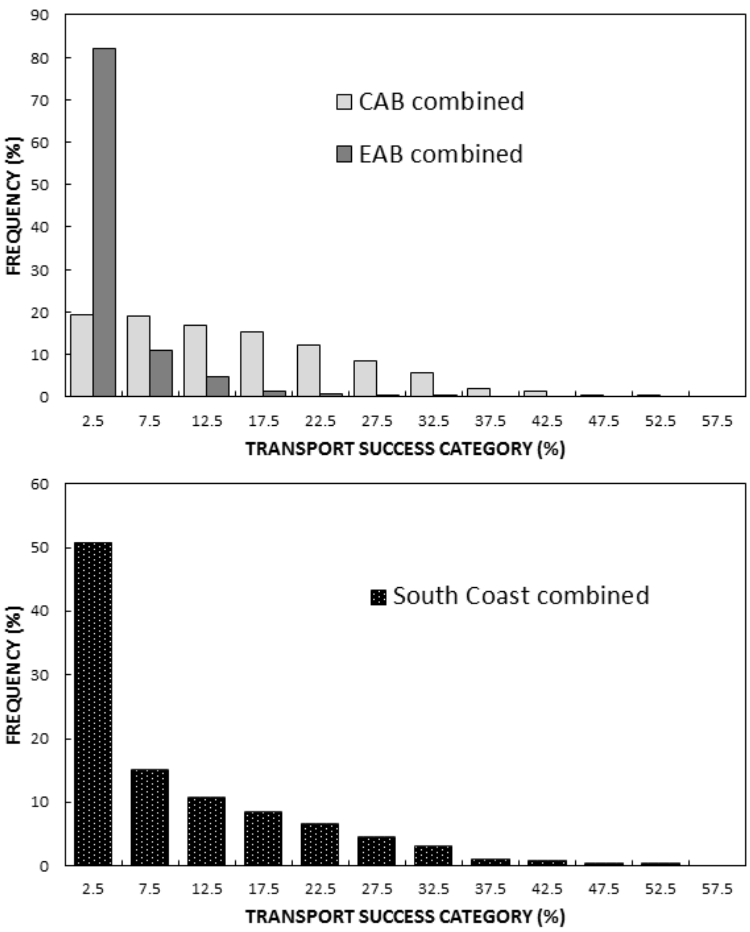


Figure 4: Frequency distributions (all simulated data irrespective of *Year, Month, Depth* or *Trial*) of various categories of modelled transport success to the West Coast nursery area from the $CAB_{Combined}$ and $EAB_{Combined}$ (upper plots), and for all four spawning areas on the South Coast combined (lower plot).

Fitting appropriate distribution functions to each of the $CAB_{Combined}$ and $EAB_{Combined}$, and also to that for all four South Coast (*i.e.* east of Cape Agulhas) spawning areas combined will allow for a more objective estimate of the mean and standard error for use as a prior for the contribution to West Coast recruitment from South Coast spawning.

References

Butterworth DS. 2016. A draft framework for assigning probabilities to alternative assumptions concerning the contribution of sardine spawning biomass on the south coast to recruitment on the west coast. FISHERIES/2016/OCT/SWG-PEL/47rev, 11pp.

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

Penven P, Roy C, Brundrit GB, Colin De Verdière A, Fréon P, Johnson AS, Lutjeharms JRE, and Shillington FA. 2001. A regional hydrodynamic model of upwelling in the southern Benguela. *South African Journal of Science* 97(11/12): 472-475.

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.