Potential indicators of the effective spawning biomass derived from the proportion of eggs transported to or retained in either a west coast or south coast nursery area

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Introduction

The two-stock sardine hypothesis that has been agreed on for use in the development of a two-stock assessment model allows for the movement of age-1 fish only from the "West Stock" to the "South Stock" and caters for no movement of fish or their spawning products from the area to the east of Cape Agulhas back to the west (Smith et al. 2011). Outputs from this two-stock model suggests that the "West Stock" is substantially more productive than the "South Stock" and that the biomass of sardine on the South Coast is more dependent on good recruitment from the "West Stock" than on local South Coast recruitment (de Moor and Butterworth in review).

Recently questions have been raised regarding the potential contribution of sardine from the South Stock to recruitment measured in the area to the West of Cape Agulhas. The only available analyses which may assist in quantifying such contribution (Miller et al. 2006) suggests that whereas some eggs released to the East of Cape Agulhas can be transported to the west coast nursery grounds, eggs spawned on the South Coast are predominantly retained on the South Coast. Their results indicated that over a period of 8 spawning seasons 15% of eggs spawned between Cape Agulhas and Mossel Bay and ~3.5 % of eggs spawned to the east of Mossel Bay are successfully transported to the west coast on average (Annexure A, [fig.4] and Table 1). This success rate is considerably lower than that estimated to have been retained on the south coast following south coast spawning. The averages transported to the west coast were similar for both inshore and offshore areas but differed for south coast spawning where retention tended to be higher for inshore areas. Seasonal differences in transport success of eggs spawned in the area between Cape Agulhas and Mossel Bay were, however, evident with transport success increasing to above 20% in spring and summer and declining to below 10 % in winter. Only slight transport success variability with season was noted for the area to the east of Mossel Bay.

Methods

To include this information in development of alternative 2-stock hypotheses, particularly that spawning on the south coast may contribute appreciably to west coast recruitment, aggregation of the proportion of eggs transported to/retained in each of the nursery areas is needed as the biomass estimates cannot be disaggregated into an inshore and offshore component.

The proportion of eggs transported/retained is summed (successful transport/retention for spawning inshore and offshore combined/ total number of eggs released inshore +offshore) for the area between Cape Agulhas and Mossel Bay and Mossel Bay and Port Alfred. These aggregated proportions, weighted by the relative proportion of biomass in each of these two strata results in a varying combined percentage of eggs potentially transported to the west/retained on the south coast each year. The same aggregation and weighting procedure was applied to combine the smaller

spawning areas into a west and east component coinciding with the west stock/south stock division off Cape Agulhas. Spawning areas A to E were combined for the west stock aggregated proportion transported/retained within each nursery area and areas F to I for the south stock. In this instance weighting of the proportion transported to/retained in each of the nursery areas was weighted by the model estimated biomass.

Furthermore, because the original IBM from which these results are obtained was structured in such a way that eggs were only successfully transported to/retained in predefined nursery areas with the balance being "lost" to the system, a further weighting of the transport/retention success rates was performed after ignoring the proportion of eggs lost. In this case the proportions transported/retained on the west coast and that transported/retained on the south coast summed to 1 for each spawning area.

Results

The aggregated (inshore and offshore strata on the south coast combined) proportion of eggs transported to the west coast nursery area (Table 2) from spawning in the area between Cape Agulhas and Mossel Bay (0.148) is considerably higher than that from spawning to the east of Mossel Bay (0.027), whereas the aggregated proportion of eggs retained in the south coast nursery area from spawning in the area to the east of Mossel Bay is higher (0.590) than that from spawning to the west of Mossel Bay (0.379). Overall the proportion of eggs retained on the south coast from south coast spawning is higher than the proportion off eggs transported to the west coast nursery grounds (for both strata).

The aggregated proportion of eggs transported to/retained in each of the in each of the nursery areas from spawning in the larger combined spawning areas (west and east of Cape Agulhas, Table 3) indicates that eggs spawned to the west of Cape Agulhas are mainly retained on the West Coast with very few being transported to the south coast nursery area. Eggs spawned to the east of Cape Agulhas are, however mainly retained on the south coast (0.459) with much reduced transport to the west coast nursery area (0.102). The percentage of eggs lost to the system is substantially higher for eggs spawned on the west coast (71%) compared to those spawned on the south coast (44%).

Weighting these proportions by the relative proportion of the observed biomass in each of these two spawning areas (west and east of Cape Agulhas) results in a varying combined percentage of eggs potentially transported to the west/retained on the south each year (Figure 1). On average over the 30 year time-series, these results suggest that 8.3% of eggs spawned to the east of Cape Agulhas may be successfully transported to the west coast and contribute to recruitment in that area. The weighted proportion transported to/ retained on the west coast and south coast from spawning on either coast (by model predicted biomass) is shown in Figures 2a and 2b respectively. These generally suggest that on average 20% of eggs reach the west coast and 20% reach the south coast and these proportions closely mirror the proportion of biomass observed on each coast. The proportion retained or transported to the south coast is somewhat higher and closer to 25% over the period 2007-2011.

The above results are repeated below with disregard for the proportion of eggs lost to the system. The aggregated (inshore and offshore strata on the south coast combined) proportion of eggs transported to the west coast nursery area (Table 4) for the (inshore and offshore strata on the south coast combined) from spawning in the area between Cape Agulhas and Mossel Bay doubles to 0.281

and remains considerably higher than that from spawning to the east of Mossel Bay (0.043). The aggregated proportion of eggs retained in the south coast nursery area from spawning in the area to the east of Mossel Bay is also much higher (0.957) than that from spawning to the west of Mossel Bay (0.719). Overall the proportion of eggs retained on the south coast from south coast spawning is higher than the proportion off eggs transported to the west coast nursery grounds (for both strata) but particularly for the area to the east of Mossel Bay.

The aggregated proportion of eggs transported to/retained in each of the nursery areas from spawning in the larger combined spawning areas (west and east of Cape Agulhas, Table 5) indicates that eggs spawned to the west of Cape Agulhas are mainly retained on the West Coast (0.982) with very few being transported to the south coast nursery area (0.018). Eggs spawned to the east of Cape Agulhas are, however mainly retained on the south coast (0.819) with much reduced transport to the west coast nursery area (0.181).

Weighting these proportions by the relative proportion of the observed biomass in each of these two spawning areas (west and east of Cape Agulhas) and disregarding the number of eggs lost to the system results in a varying combined percentage of eggs potentially transported to the west/retained on the south each year (Figure 3). On average over the 30 year time-series, these results suggest that 15.3% of eggs spawned to the east of Cape Agulhas may be successfully transported to the west coast and contribute to recruitment in that area. This average is slightly higher for the past five years (17.0%). The weighted proportion transported to/ retained on the west coast and south coast from spawning on either coast (by model predicted biomass) is shown in Figures 4a and 4b respectively. These generally suggest that on average 65% of eggs reach the west coast and 35% reach the south coast. This result differs from that for which the proportions included eggs lost to the system. On balance, almost double the amount of eggs reach or are retained in the west coast nursery grounds compared to the south coast nursery ground.

Conclusion

These results may potentially contribute towards the further development of hypotheses regarding mixing rates and mechanisms for such mixing between the two stocks (de Moor et al. 2014). Together with further refinement of recruitment indices for the “South Stock” which include taking account of winter spawning on the South Coast and subsequent downward adjustment of the adult biomass estimate in that area in November each year, the current perceived dependence of the “South Stock” biomass on recruitment from the west, may not be as pronounced.

Acknowledgements

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References

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Table 1. The numbers of eggs and proportion transported/retained (in each of the nurseries) and lost within each of the spawning areas. See annexure A for spawning area naming convention.

Spawning Area	Eggs released	Eggs (n) transported to/retained in WC nursery	Eggs (%) transported to/retained in WC nursery[1]	Eggs (n) transported to/retained in SC nursery	Eggs (%) transported to/retained in SC nursery[2]	Eggs (n) lost to the system	Eggs (%) lost to the system
A	1441729	351092	0.244	0	0.000	1090637	0.756
B	1861286	467263	0.251	1	0.000	1394022	0.749
C	259595	98341	0.379	4	0.000	161250	0.621
D	273508	108913	0.398	4	0.000	164591	0.602
E	590546	235708	0.399	22500	0.038	332338	0.563
F	1528492	221989	0.145	729649	0.477	576854	0.377
G	1079128	163430	0.151	258506	0.240	657192	0.609
H	426108	11384	0.027	271713	0.638	143011	0.336
I	1170968	31044	0.027	669836	0.572	470088	0.401

Table 2. The aggregated numbers of eggs and proportion transported/retained (in each of the nurseries) and lost when spawned within each of the larger spawning areas. See annexure A for spawning area naming convention.

Spawning Area	Eggs released	Eggs (n) transported to/retained in WC nursery	Eggs (%) transported to/retained in WC nursery	Eggs (n) transported to/retained in SC nursery	Eggs (%) transported to/retained in SC nursery	Eggs (n) lost to the system	Eggs (%) lost to the system
A+B	3303015	818355	0.248	1	0.000	2484659	0.752
C+D	533103	207254	0.389	8	0.000	325841	0.611
E	590546	235708	0.399	22500	0.038	332338	0.563
F+G	2607620	385419	0.148	988155	0.379	1234046	0.473
H+I	1597076	42428	0.027	941549	0.590	613099	0.384

Table 3. The aggregated numbers of eggs and proportion transported/retained (in each of the nurseries) and lost within each of the major spawning areas. See annexure A for spawning area naming convention.

Spawning Area	Eggs released	Eggs (n) transported to/retained in WC nursery	Eggs (%) transported to/retained in WC nursery	Eggs (n) transported to/retained in SC nursery	Eggs (%) transported to/retained in SC nursery	Eggs (n) lost to the system	Eggs (%) lost to the system
A-E	4426664	1261317	0.285	22509	0.005	3142838	0.710
F-I	4204696	427847	0.102	1929704	0.459	1847145	0.439

[1] These are the percentages plotted as white bars in Figure 4 of Miller et al 2006 (see annexure A)
[2] These are the percentages plotted as black bars in Figure 4 of Miller et al 2006 (see annexure A)

Table 4. The aggregated numbers of eggs and proportion transported/retained (in each of the nurseries) and lost when spawned within each of the larger spawning areas when eggs lost to the system are disregarded. See annexure A for spawning area naming convention.

Spawning Area	Eggs released	Eggs (n) transported to/retained in WC nursery	Eggs (%) transported to/retained in WC nursery	Eggs (n) transported to/retained in SC nursery	Eggs (%) transported to/retained in SC nursery
A+B	3303015	818355	1.000	1	0.000
C+D	533103	207254	1.000	8	0.000
E	590546	235708	0.913	22500	0.087
F+G	2607620	385419	0.281	988155	0.719
H+I	1597076	42428	0.043	941549	0.957

Table 5. The aggregated numbers of eggs and proportion transported/retained (in each of the nurseries) and lost within each of the major spawning areas when eggs lost to the system are disregarded. See annexure A for spawning area naming convention.

Spawning Area	Eggs released	Eggs (n) transported to/retained in WC nursery	Eggs (%) transported to/retained in WC nursery	Eggs (n) transported to/retained in SC nursery	Eggs (%) transported to/retained in SC nursery
A-E	4426664	1261317	0.982	22509	0.018
F-I	4204696	427847	0.181	1929704	0.819

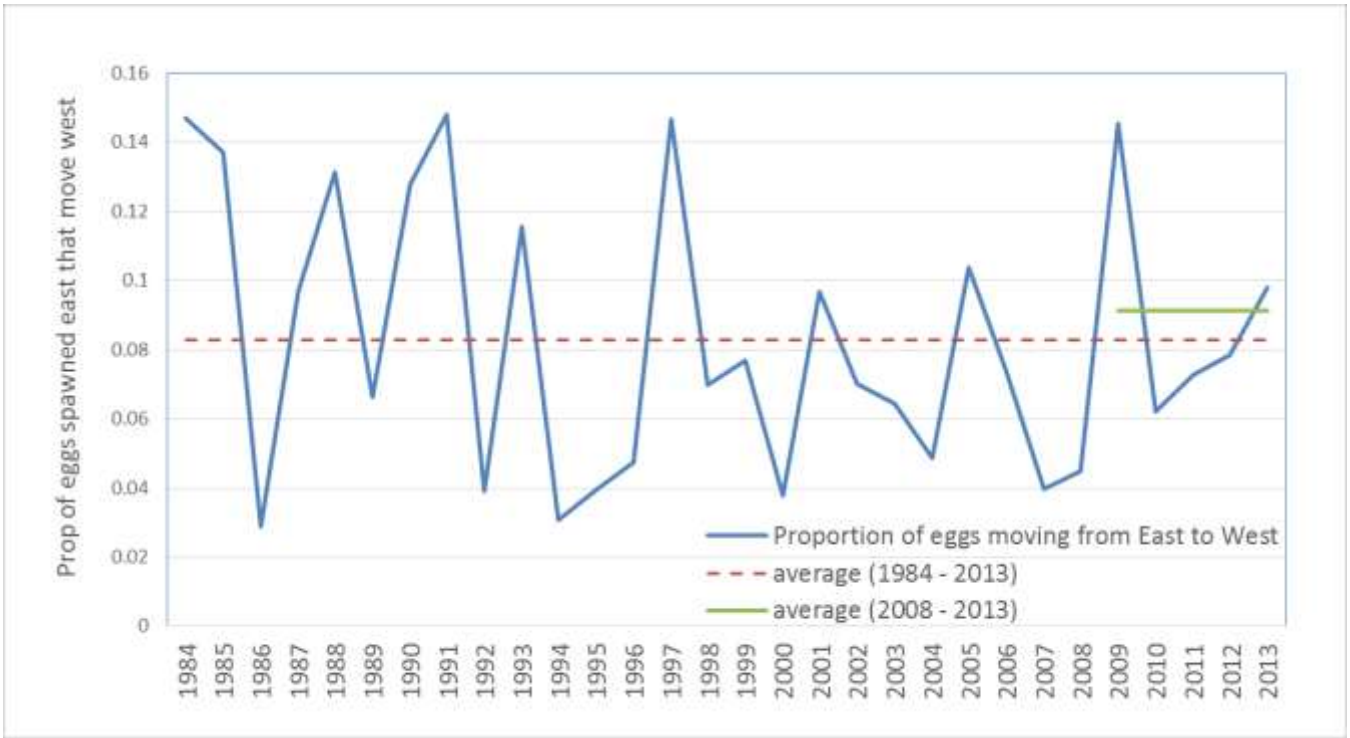


Fig 1. The weighted (by survey estimated biomass) proportion of eggs spawned on the south coast that is transported to the West Coast nursery ground.

Fig 2a (Left); the weighted proportion (by model estimated biomass) of eggs that are either retained or transported to the west coast nursery ground from spawning across the entire distribution. Fig 2b (right); the weighted proportion (by model estimated biomass) of eggs that are either retained or transported to the south coast nursery ground from spawning across the entire distribution.

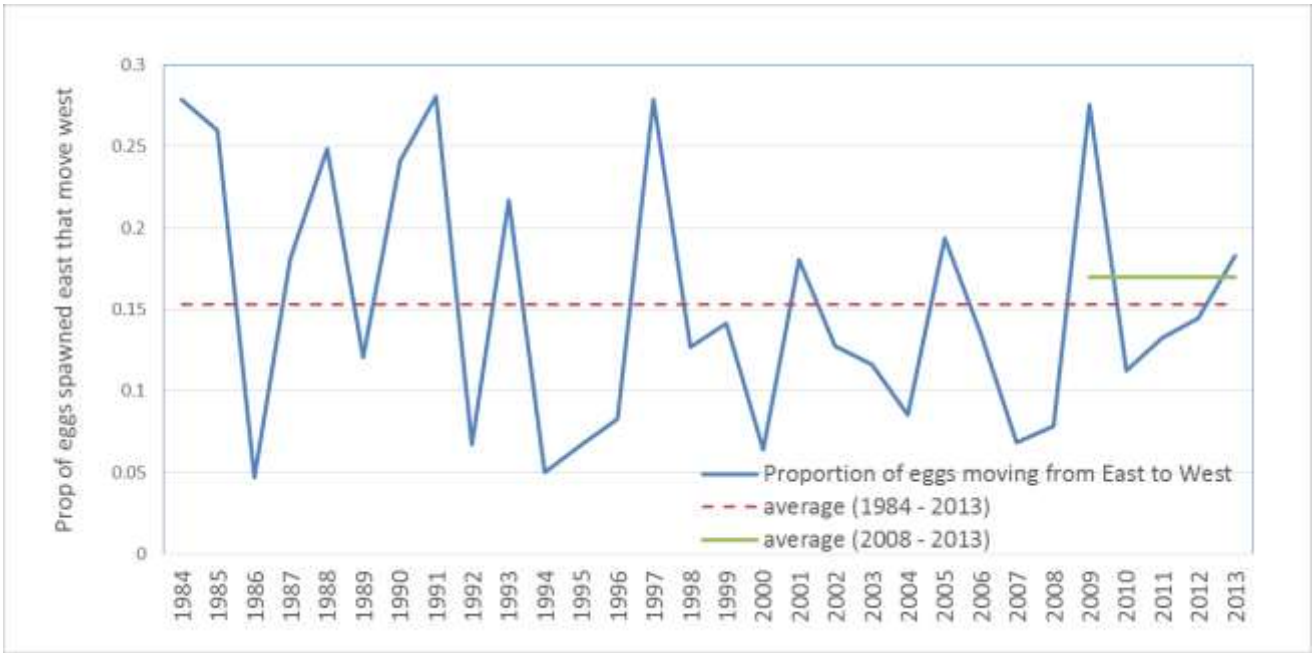
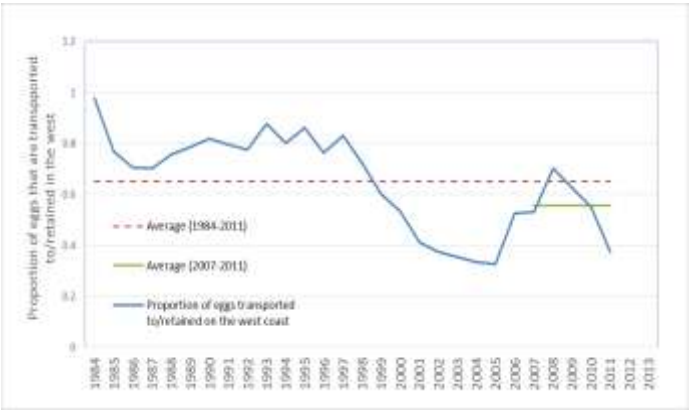


Fig 3. The weighted (by survey estimated biomass) proportion of eggs spawned on the south coast that is transported to the West Coast nursery ground when eggs lost to the system are disregarded.



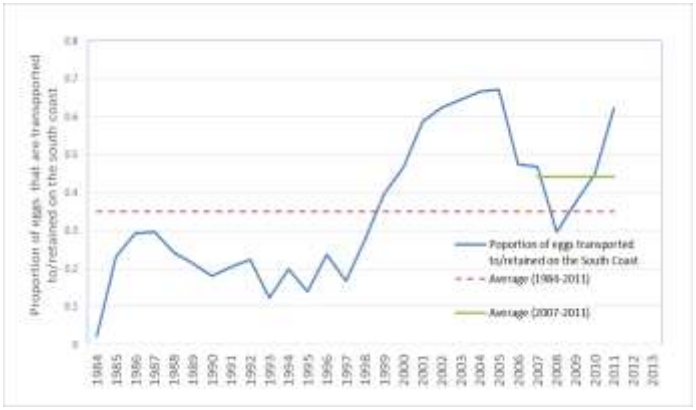
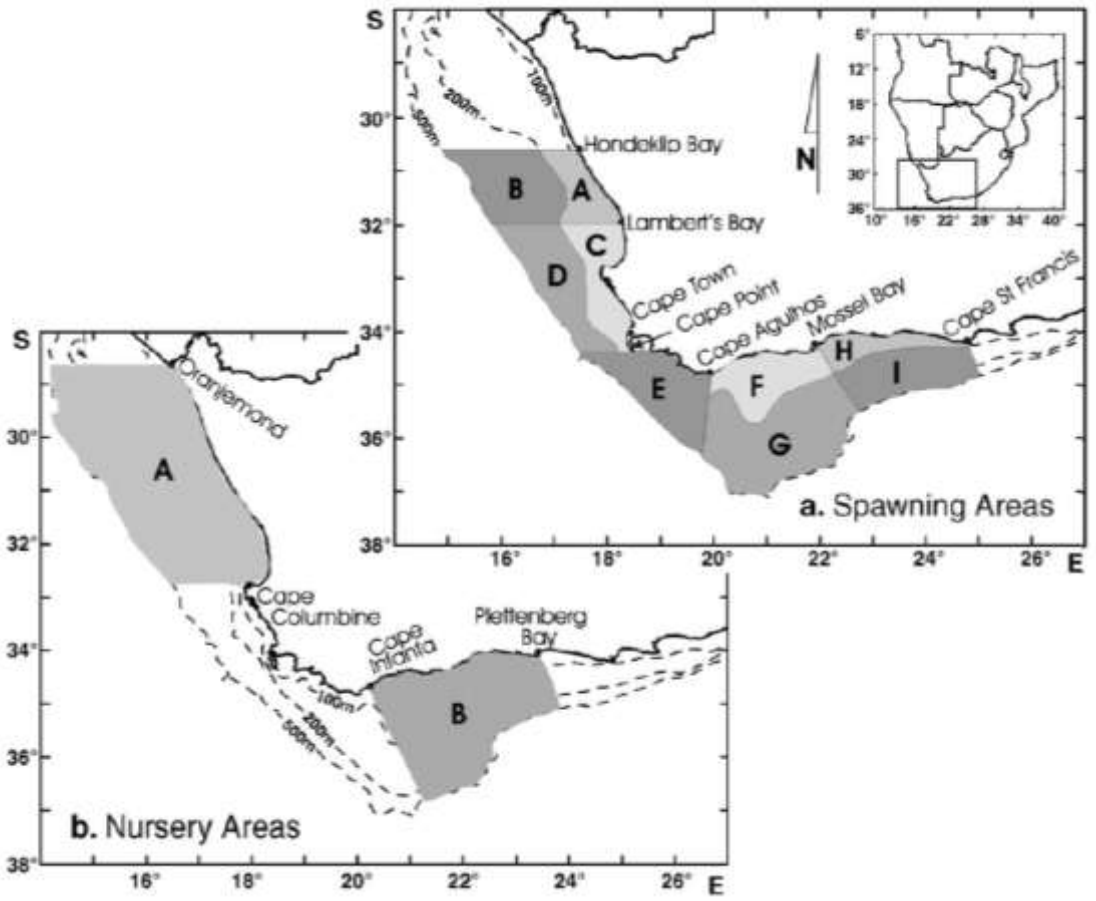


Fig 4a (Left); the weighted proportion (by model estimated biomass) of eggs that are either retained or transported to the west coast nursery ground from spawning across the entire distribution. Fig 4b (right); the weighted proportion (by model estimated biomass) of eggs that are either retained or transported to the south coast nursery ground from spawning across the entire distribution. Both are for the case when eggs lost to the system are disregarded.

Annexure A

IBM simulation setup used by Miller et al. Eggs spawned within each of 9 sub regions, were either retained within a nursery area on the west coast or south coast, transported to a nursery area on the west coast or south coast, or lost to the system (did not make it to either nursery area).



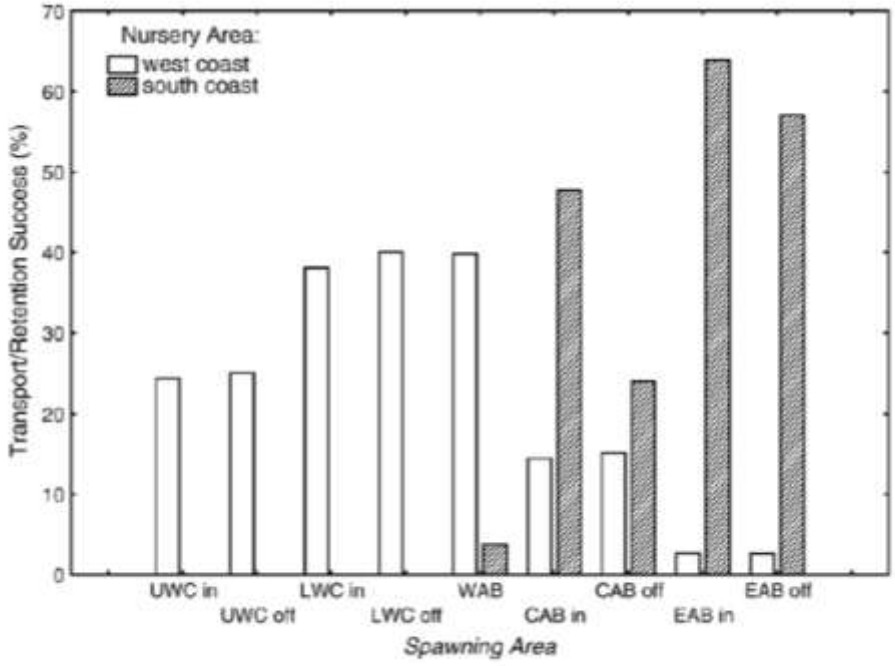


Fig. 4. Modelled transport/retention success to the west and south coast nursery grounds from the nine spawning areas.