AN EMPIRICAL MODEL OF ANCHOVY RECRUITMENT VARIABILITY IN THE SOUTHERN BENGUELA

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From the mid-1980s to the late 1990s, anchovy recruitment variability in the Southern Benguela has been relatively moderate for a small pelagic fish population when compared with other regions. This changed in 2000, when a record high level of anchovy recruitment was observed, estimated in May/June 2000 as being four times higher than the previous historical record over the last 15 years. This exceptional recruitment was confirmed later in the season during the spawner biomass survey which showed an adult biomass of more than 2 times the previous highest level observed since the start of the time-series in 1984 (van der Lingen *et al.* 2001).

Environmental conditions recorded off South Africa's West Coast during the 1999-2000 summer season were highly unusual, being characterized by a pronounced warm event in mid-December 1999, followed by a moderate upwelling in January 2000 and an enhanced upwelling from mid to late summer 2000 (Roy *et al.* 2001a). The extreme oceanographic variability recorded during the 1999-2000 summer may have significantly contributed to the record high level of anchovy recruitment observed in 2000. It has been proposed that the succession, within a short period of time, of contrasting oceanographic events during that summer and their respective timing relative to the anchovy reproductive strategy might represent the canonical pattern of environmental conditions for anchovy recruitment success (Roy *et al.* 2001b, Barlow *et al.* this volume):

- Relaxed upwelling in December along the Cape Peninsula, following the November peak anchovy spawning, might limit offshore loss of eggs and larvae during the transport phase from the spawning to the nursery grounds;

- Moderate upwelling off the West Coast in January might have enhanced retention and provided food for the larvae; and

- Enhanced upwelling later in the season and the development of secondary production may have enhanced food availability for late larvae and early juveniles.

The validity of this assumption is tested using an empirical approach. Two environmental indices (Sea Surface Temperature anomalies) are used as surrogates for upwelling intensity off the Cape Peninsula in December and off the West Coast (Hondeklip Bay) in January. These indices were selected in order to describe the pattern of upwelling variability following the anchovy's peak spawning that occurs in November over the Agulhas Bank. SST anomalies off the Cape Peninsula during December are considered to represent the modification of the transport process from the spawning to the nursery grounds caused by variations in upwelling, whilst SST anomalies of the West coast in January represent the effect of upwelling once the larvae have arrived on the nursery grounds. These two environmental indices are individually related to anchovy recruitment strength estimated from winter hydroacoustic surveys (Barange *et al.* 1999) for the first two-thirds (1985-1994) of the anchovy recruitment strength time-series. Scatterplots show that anchovy recruitment increases as the SST anomaly off the Cape Peninsula in December (designated CT4) increases (Fig. 1), suggesting that weak upwelling promotes successful recruitment. A dome-shaped relationship between recruitment and SST anomaly (and hence upwelling intensity) off the West Coast in January (designated HB4) indicates that both weak and strong upwelling are detrimental to recruitment success whilst moderate upwelling promotes recruitment (Fig. 1).

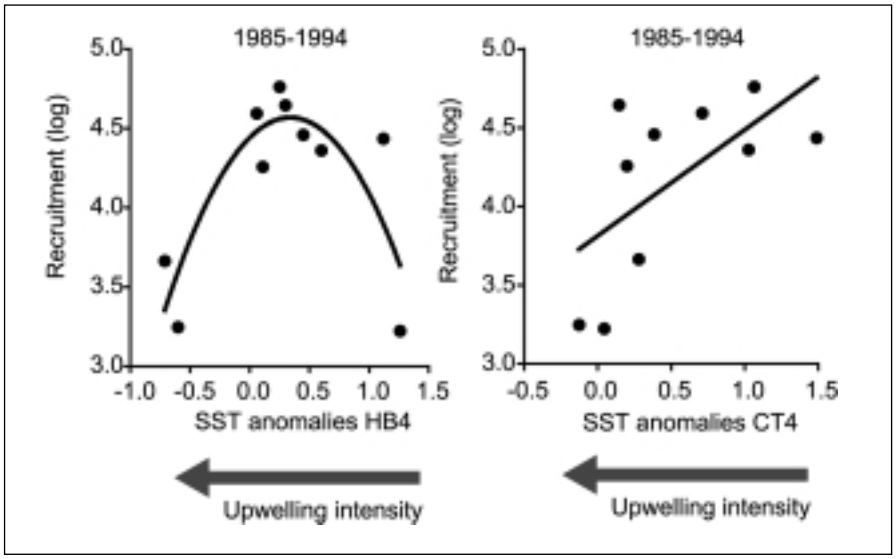

Fig. 1

These observed relationships are combined into an empirical model that is used to hindcast anchovy recruitment success for the remaining part (1995-2000) of the time-series. The empirical model suggests that weak upwelling off the Cape Peninsula in December followed by moderate upwelling off the West Coast region in January generally contribute to favour anchovy recruitment success over the whole time series. A reasonable fit between hindcast and observed recruitment strength is observed (Fig. 2), with 1998 and 2000 outlying points where the model underestimated subsequent recruitment. Further development of this empirical model using GAM is underway.

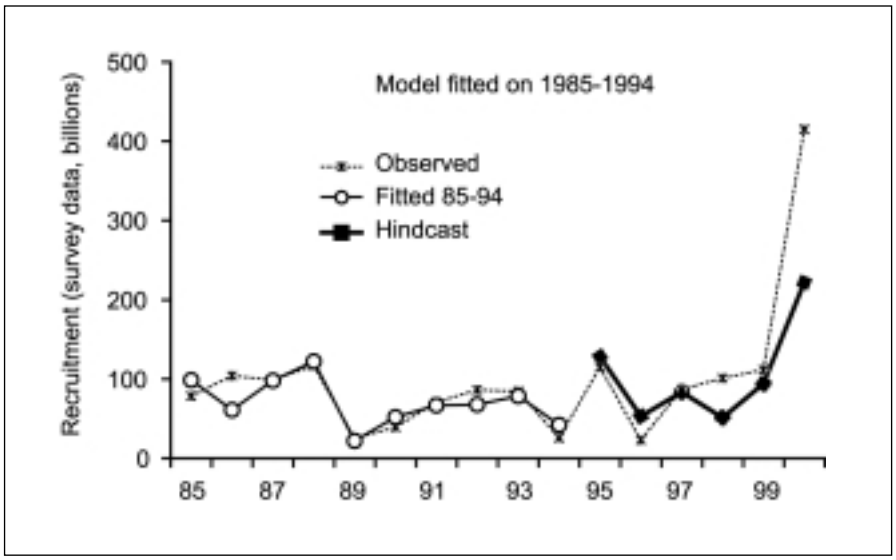

Fig. 2

Anchovy recruitment in 2001 was of the same order of magnitude as in 2000 (Coetzee *et al.* 2001); our model failed to predict this high anchovy recruitment. However, with an adult biomass well above the average level measured during the period over which the empirical model was calibrated, processes other than just environmental control of egg and larval survival may have become important as determinants of recruitment success.

Acknowledgements
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Figure Legends

Figure 1. Scatter plots of anchovy recruitment and SST anomalies in December off the Cape Peninsula (CT4; right panel) and anchovy recruitment and SST anomalies in January off the West Coast (HB4; left panel).

Figure 2. Observed and modelled anchovy recruitment time-series in the Southern Benguela.