THE UNUSUAL 1999-2000 SUMMER SEASON IN THE SOUTHERN BENGUELA: IMPLICATIONS FOR ANCHOVY RECRUITMENT

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Two unusual oceanographic events occurred during the 1999-2000 summer season off the West Coast of South Africa (Roy *et al.* 2001). The first was a strong and sustained warming that occurred in mid-December and lasted for two weeks. The second was an enhanced cooling that lasted from mid to late summer. Both events were the result of fluctuations in wind-induced upwelling. A period of moderate upwelling separated the two events.

The chronology and magnitude of these major oceanographic events affected the water mass over the continental shelf from Cape Point to Hondeklip Bay during the 1999-2000 upwelling season (Fig. 1). The warm event had a comparable magnitude along the Cape Peninsula and the West Coast, with Sea Surface Temperature (SST) anomalies reaching +2.0°C during the third week of December. The cold episode appeared to be more pronounced in the vicinity of Cape Columbine where the SST anomaly in early April reached -2.0°C. The time-series of alongshore wind and the cumulative divergence at Cape Columbine, illustrated the succession of events that triggered the fluctuations in upwelling off the West Coast (Fig. 2).

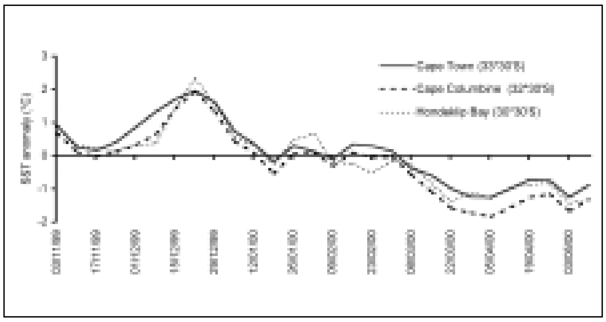

Fig. 1

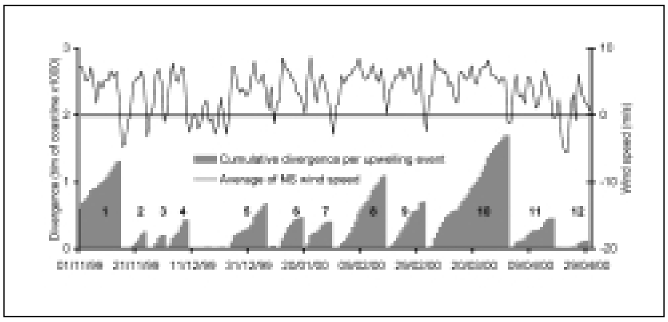

Fig. 2

Using SST data from ships of opportunity, the whole 1999-2000 upwelling season was placed within the long term climatic context by examining the averaged SST anomalies and SST standard deviation from November through to the following April for the last 30 years (Fig. 3). The 1999-2000 season appeared to be 0.58 °C cooler than the average conditions recorded over the last 30 years, with the 1999-2000 summer ranked as the third coolest summer over this period, and the seventh largest in terms of absolute amplitude of the anomaly. A different picture emerged from the SST standard deviation data, however. The SST standard deviation can be interpreted as an index of the variability in oceanographic conditions during the summer season. During the 1999-2000 summer, it reached 1.36°C, which was 50% higher than the previous maximum recorded during the 1993-1994 summer season (Fig. 3). This indicated that the succession of both extreme cold and warm events observed during the 1999-2000 summer was highly unusual and has not been recorded with such intensity during the past 30 years.

There were indications of a direct response in plankton abundance to the alternation of weak and strong upwelling episodes (see Fig. 10 in Roy *et al.* 2001). The chlorophyll *a* concentration off the West Coast, derived from SeaWiFS ocean colour images, suggested that plankton abundance was low during the

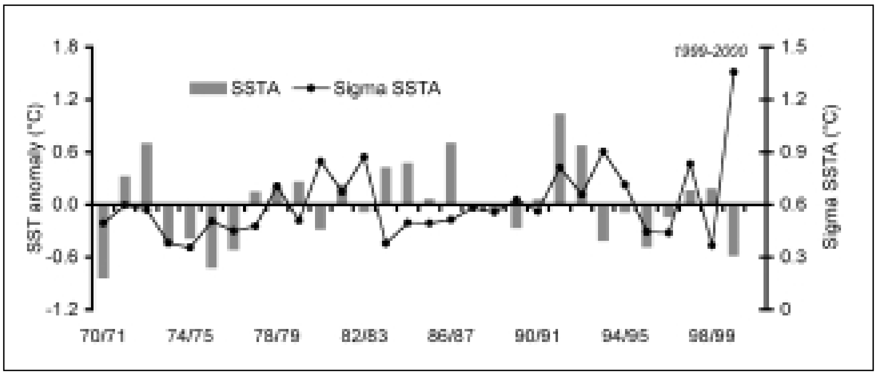

Fig. 3

relaxed upwelling episode in December 1999, and increased significantly later in the season.

One of the major ecological consequences of the unusual 1999-2000 upwelling season, might well be the record high level of anchovy recruitment observed in 2000 (the most successful anchovy recruitment recorded since the beginning of the time-series in 1985). Both wind and SST data indicated that, when averaged over the whole season, the 1999-2000 upwelling was greater than usual. Previous studies have suggested that there is a detrimental effect on anchovy recruitment during seasons of strong upwelling (Boyd *et al.* 1998). Surprisingly, the enhanced upwelling in 2000 appears to have favoured anchovy recruitment. By placing the timing of the warm and cold events in the context of anchovy reproductive strategy, it appears to be possible to reconcile previous findings with the exceptional recruitment recorded in 2000. In doing so, several facts need to be considered:

- Anchovy spawning peaks in late spring and early austral summer (October-December) on the Agulhas Bank. It is during the transport phase to the West Coast nursery ground that enhanced upwelling is thought to affect dispersal of eggs and larvae (Hutchings *et al.* 1998). In late summer and autumn (January-April), larvae and juveniles are located both on and offshore of the shelf along the West Coast.

- The collapse of the upwelling during the last two weeks of December 1999 might have drastically reduced the advective loss of eggs and larvae, and enhanced the number of larvae reaching the West Coast nursery area. Additionally, the elevated water temperatures recorded in December 1999 might have resulted in more rapid larval growth, which is likely to have reduced mortality rates.

- The moderate upwelling intensity that followed the December warm event may have favoured the development of an upwelling plume downwind of Cape Columbine. The associated eddy is thought to enhance transport and retention into the coastal environment (Penven *et al.* 2000).

- The following sustained episodes recorded later in the season probably resulted in increased primary and secondary production. Rather than being detrimental to the larvae, the upwelling regime recorded during the mid and late summer season might have enhanced food availability to the larvae population that previously reached the West Coast nursery during the December 1999 relaxed upwelling event. Enhanced food availability probably reduced mortality of anchovy post-larvae and young juveniles.

Considering the unusual characteristics of the 1999-2000 upwelling season, these observations suggest that, when investigating the linkage between anchovy recruitment and environmental factors, it might be more important to consider the temporal succession of events and their magnitude, than just the mean conditions over the whole season as has been done in previous studies. Further work is being conducted to determine if the succession of events during the 1999-2000 upwelling season represents the canonical pattern of environmental variability for maximizing anchovy recruitment (see Roy *et al.* this volume).

Acknowledgements
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Figure Legends

Figure 1. Weekly SST anomalies (°C) at three locations off the West Coast of South Africa from November 1999 to mid-May 2000 (source: OISST).

Figure 2. Daily time series of North-South wind speed ($m.s^{-1}$) at Cape Columbine from 1st November 1999 to 30th April 2000 (upper) and cumulative divergence ($t.m^{-1}$) per upwelling event (lower) for the same time period. The episode number is indicated for each major upwelling event. The calculation of cumulative divergence was performed on the October-June time-series. This explains why upwelling event number 1 does not start at 0 on 1st November 1999.

Figure 3. Seasonally averaged (November-April) time series of SST anomaly (SSTA) (°C) from 1970-1971 to 1999-2000 (column), and standard deviation of SST anomalies (Sigma-SSTA; °C; November-April) from 1970-1971 to 1999-2000 (line). Source: COADS dataset and Climate Diagnostics Centre.