Evolution of coastal SST in the northeast subtropical Atlantic and distribution patterns of small pelagic fish from Mauritania to Morocco

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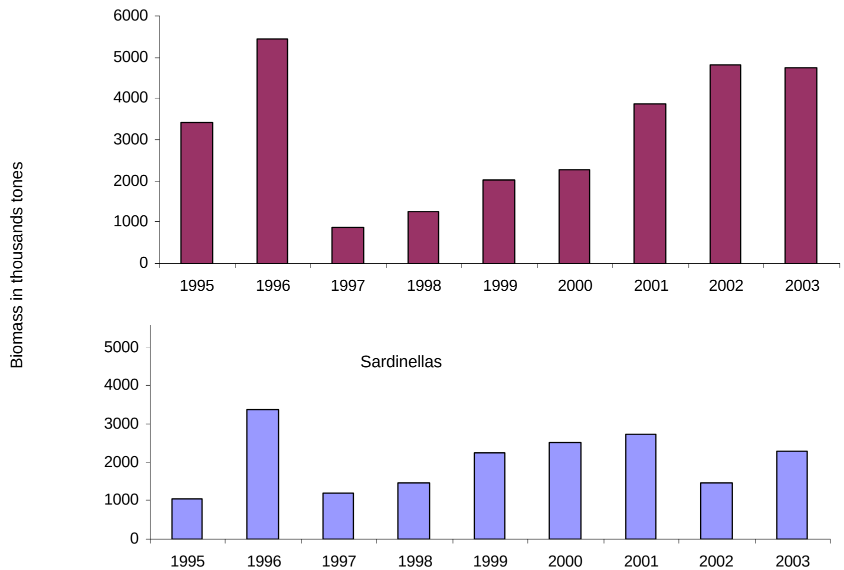

Figure 1. The biomass estimates of Sardine and Sardinellas between 16° and 29°N from acoustic surveys with R/V Dr. Fridtjof Nansen during November 1995-2003.

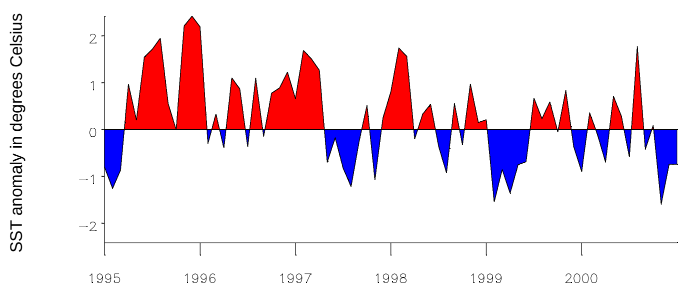

Figure 2. The evolution of SST monthly anomaly off Cape Blanc (20°50'N, 17°30W), 1995-2000, from remotely sensed AVHRR data, (EU SRD project, ICA4-CT-2001-10029). Note the shift of this figure with respect to Figure 1. This is to demonstrate the fact that the abundance estimate took place by the end-of the year, while SST evolution includes a continuous record, including the eleven months prior to each survey.

Two major oceanographic phenomena culminate around Cape Blanc (21ºN) off the northwest Africa: the hydrographic front separating the sub-tropical North Atlantic from the the tropical ocean (Zenk et al. 1991) and the northwest Africa's coastal upwelling (Mittlestaed, 1991). The fisheries in this area are characterized by the overlap in the concentrations of the two pelagic species: the sub-tropical sardine (*Sardina pilchardus*) in the north and the tropical sardinellas (*Sardinella spp.*) in the south. We describe the variations in the biomass of these species and in their distribution patterns during 1995-2003, and investigate links to environmental change during the same period.

Figure 1. Demonstrates the trends in abundance for an area between 16º and 28ºN. A dramatic decrease in the sardine stock estimate was recorded by the end of 1997 (FAO, 2001). A significant drop in the biomass of sardinellas was also observed during the same period. For the sardine, the adult component of the stock had vanished from the region and only the juvenile fish remained in 1997. The estimates in the subsequent years revealed a rebuild of the biomass and gradual maturation of the sardine stock. The distribution pattern of fish has changed, following the collapse, with both species more concentrated around the Cape Blanc and the sardine distribution exhibiting a broader meridional extent (Figure 3).

The coincidence between the 1997 abundance collapse and the anomalous temperature conditions (Figure 2) is apparent. Figures 1 and 2 indicate that the biomass had increased during the first two warm years, 1995 and 1996, and it collapsed in 1997, when the warm conditions were about to subside.

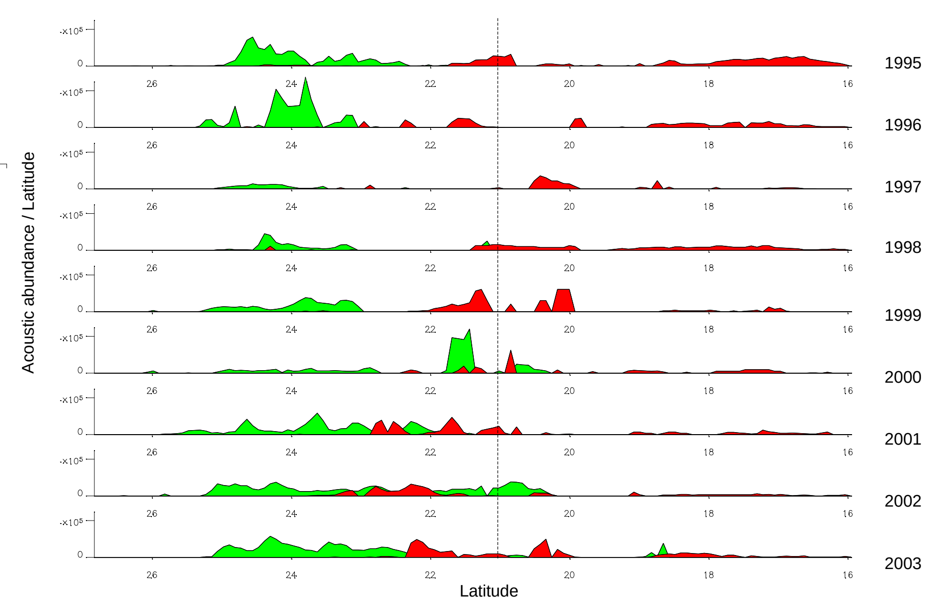

Figure 3. The meridional distributions of the main pelagic stocks off northwest Africa from the November surveys 1995-2003. Sardine and sardinellas are marked with green and red color, respectively. The Y-axis denote the area scattering coefficient integrated over the zonal extents of the stocks. The Sardinellas values are multiplied by 2 to elucidate the spatial change. An approximate

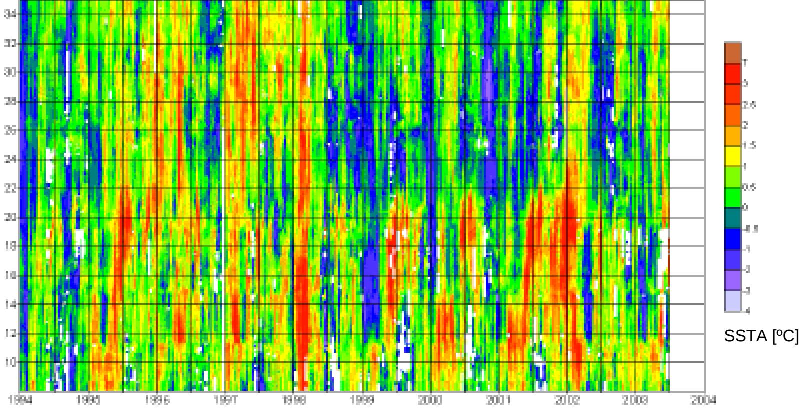

Figure 4. Evolution of SST anomally off northwest Africa using the 9km, the 8-day average daytime SST global datatabase. The anomaly is computed relative to a 5-day JPL climatology 1985-1997 datasets. Both datasets are available from Physical Oceanography Distributed Active Archive Center (http://podaac.jpl.nasa.gov/). The data were extracted at the pixel nearest to the coast except of Banc d'Arguin and south of Cape Verde, where the data were extracted at the shelf break.

Figure 4 demonstrates a SST time series, describing the SST climate change off the entire northwest Africa. Note the warm period 1995-1997, which includes both the North and tropical Atlantic domain and the period 1998-2002, when the warm anomaly continued only in the tropical domain, south of 20ºN.

Hydrographic data collected with Dr. F. Nansen during the abundance surveys, indicate seasonal intrusions of the nutrient-rich South Atlantic Central Water (SACW) in November. This water penetrates the inshore areas of the Dakhla shelf to the north of 23ºN. (Figure 5). While a part of this water is uplifted locally by upwelling from the poleward current carrying SACW along the slope, the shallow water hydrographic sections exhibit an alongshore continuity with the Cape Blanc cell, which suggest a direct alonshore current close to the coast. The interannual variability in timing and intensity of the SACW intrusion events may play a pivotal role in the enrichment in this region inhabited the southern sardine stock, hence affect their abundance and distribution patterns.

The November intrusion of SACW forms a cross shelf front with a strong meridional temperature gradient at the sea surface. It is thus possible to combine the remotely sensed sea surface data (SST) with hydrography and examine the interannual variability of this phenomenon.

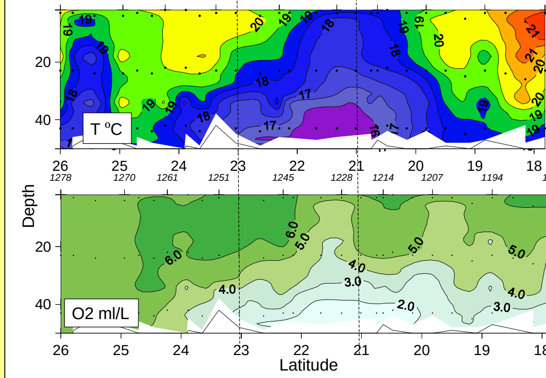

Figure 5. Alongshore vertical distributions of temperature and dissolved oxygen along a 50 depth contour between 18º and 26ºN. The cold water dome at 21º N marks the location of Cape Blanc upwelling cell. The core of cold low-oxygen water below a 40 m depth to the north of 22 ºN indicates the SACW intrusion into the Dakhla shelf. The data were collected in November 1993. The dotted lines denote the location of control points selected for the frontal index estimation (see Figure 6).

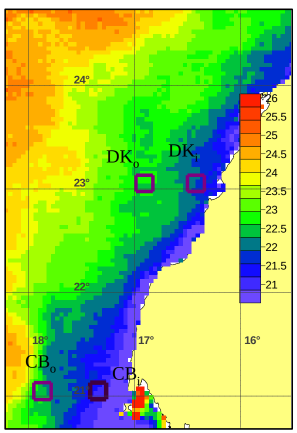

Figure 6. Definition of the control points used in the analysis. The background SST image depicts a monthly composite SST for November 1997.

Four control points were established in order to extract the time series from the remotely sensed SST. These are depicted in Figure 6. The points CB_i and CB_o were located in the center of the Cape Blanc upwelling cell. The points DK_i and DK_o were selected at 23ºN on the northern boundary of the observed November SACW front. The distance between the offshore and inshore points used in the upwelling computations was about 100km. The following parameters have been computed:

The upwelling index at Cape Blanc

$$(?T)_{CB} = (T_{CBi} - T_{CBo})$$

The upwelling index at 23ºN

$$(?T)_{DK} = (T_{DKi} - T_{DKo})$$

The frontal strength index between Cape Blanc and 23ºN.

$$(?T)_{?} = (T_{DKi} - T_{CBo})$$

The results are depicted in Figures 7, 8, and 9. Note that the negative values denote the high intensity, while the positive ones denote a blockage (or downwelling).

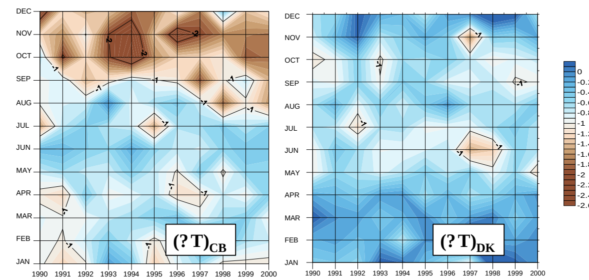

Figure 7. Variability of the upwelling indices $(?T)_{CB}$ and $(?T)_{DK}$, 1990-2000. The X- and Y-axis denotes years and months, respectively.

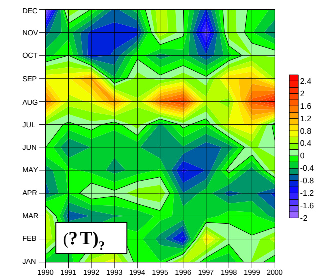

Figure 8. Variability of the frontal strength index $(?T)_{?}$. See Figure 7 for the axes description.

The computed indices (Figure 7), indicate a continuous upwelling condition at both locations. However, only the Cape Blanc undergoes the seasonal intensification, taking place between October and December. Since 1997, a regime appears to occur, with a shift towards the longer strong upwelling periods. The 23ºN location displays a considerably weaker upwelling index and no seasonal variation. It must be noted though, that this analyses does not capture the upwelling filament and the shelf-break front variability, which are intensive in this area (Kostianoy and Zatsepin, 1996).

The frontal strength index (Figure 8). exhibits a distinct relaxation period from July to September, but no clear pattern and a strong interannual variations during the remaining months. Interestingly, the year of the strongest front appears to have occurred during 1997 (Figure 9), during the same year, which marked the collapse of the southern sardine stocks.

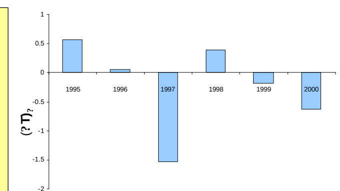

Figure 9. Variability of the frontal strength index $(?T)_{?}$ during November 1995-2000.

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Acknowledgements

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