PREDICTING SPAWNING HABITAT LOCATION OF ANCHOVY AND SARDINE IN THE SOUTHERN BENGUELA USING REMOTELY-SENSED DATA

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A multivariate model developed to predict the probability of finding eggs of either anchovy (*Engraulis encrasicolus*) or sardine (*Sardinops sagax*) in the southern Benguela from four remotely-sensed environmental variables (Twatwa *et al*., 2004) was tested by comparing predicted spawning habitat with observed spawning habitat in 2000 and 2001. These years were not used in construction of the predictive model and therefore provide an independent test to assess model validity. The multivariate model was based on quotient curves of anchovy/sardine egg abundance and four environmental parameters, namely water depth, wind speed, SST and ocean colour (Fig. 1). These quotient curves were considered as references for defining ranges of each environmental parameter that were suitable for spawning, with a quotient value above 1 considered to indicate selection.

Predicted spawning habitat was derived from 3-day "moving average" (to account for daily cloud cover) satellite images of SST (AVHRR), ocean colour (SeaWiFS), satellite-derived daily measurements of wind speed (Quickscat), and from measured water depth (ETOPO 2). These temporal composite data were then combined to provide a spatial composite of the surveyed area using a Dirichlet tessellation algorithm based on the survey track. Such spatio-temporal composite images are considered to provide the most realistic illustration of actual environmental conditions observed during the survey. The environmental parameter ranges identified from the quotient analysis as suitable spawning habitat were then applied individually to the spatial-temporal composites to provide spatially explicit visualisations of suitable spawning habitat over the duration of the survey.

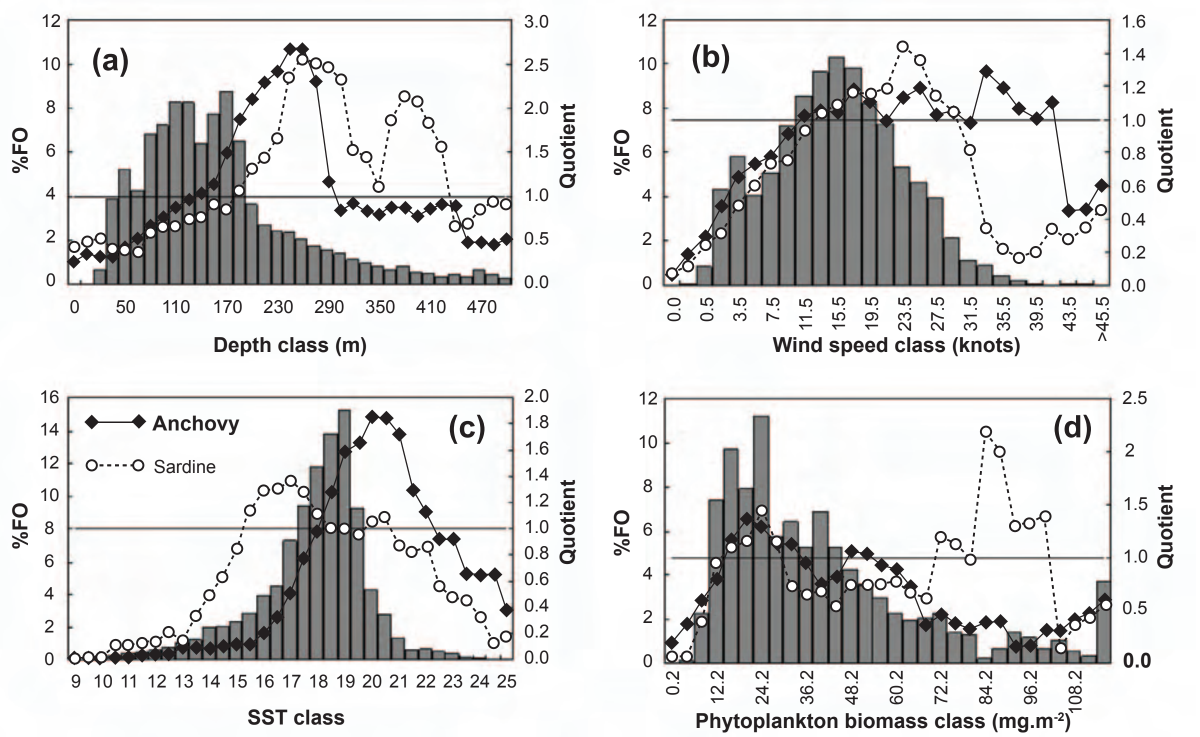


Figure 1. Results of single parameter quotient analyses for egg abundance and environmental parameters for anchovy (diamonds and solid lines) and sardine (circles and dashed lines) in the southern Benguela, for (a) water depth, (b) wind speed, (c) SST and (d) phytoplankton biomass. Frequency distributions of the environmental variables are shown as histograms, and the horizontal line indicates a quotient value of 1. After Twatwa *et al.* (2004).

A Bayesian approach was then used to predict the probability of suitable spawning habitat by combining the maps derived from individual parameters, weighted according to their perceived importance in controlling selection of spawning habitat (Twatwa *et al*., 2004). Predicted spawning habitat was then compared with observed spawning habitat, as indexed by egg abundance and distribution data collected from CalVET net samples taken during the surveys. The CalVET net is considered to provide a better representation of abundance and distribution patterns of anchovy eggs than of sardine eggs, due to the highly patchy distribution of sardine eggs. This problem appears to be resolved by sampling for sardine eggs using the CUFES (van der Lingen and Huggett, 2003).

Maps showing the overlap between predicted and observed spawning habitat for anchovy and sardine are shown in Plate 2 (page xi), and show better mesoscale correspondence between predicted and observed spawning habitat for anchovy than for sardine. High anchovy egg concentrations were generally found in areas predicted as being suitable (*i.e.* probability >0.5) for spawning in both years, and areas of a low suitability (*e.g.* inshore regions of the west coast in both years and inshore on the south coast in 2001) tended to have low observed anchovy egg densities. Relatively high densities of sardine eggs were occasionally observed in areas predicted as having a low suitability for spawning, such as on the south coast between 20-23°E in 2000, and between 22-24°E in 2001. However, regions on the west coast with a high-predicted suitability for sardine spawning were associated with high egg densities, particularly in 2001.

The percentage match and mismatch between predicted and observed spawning habitat for each parameter individually, and all four parameters combined, are given in Table 1. These indicate a higher match than mismatch between predicted and observed spawning habitat for anchovy and sardine, both for individual parameters and when they were combined, which provides some validation of the model. Additionally, percentage match levels were generally higher for anchovy than for sardine. When the parameters are considered individually, sardine showed a higher percentage match for SST than did anchovy, most likely arising from their broader quotient curve for this parameter, but not for the other parameters.

Table 1. Percentage match (% +) and mismatch (% -) between predicted and observed spawning habitats of anchovy and sardine in the southern Benguela for 2000 and 2001. The table shows the percentage of eggs that were observed in areas having a predicted spawning suitability >0.5 (*i.e.* a match), and the percentage of eggs that were observed in areas having a predicted spawning suitability <0.5 (*i.e.* a mismatch), for each of the four parameters individually and from the combined analysis. Values >50% are shown in bold and italic.

Year	Species	SST		Bathymetry		Chlorophyll *a*		Wind speed		Combined parameters	
		%+	%-	%+	%-	%+	%-	%+	%-	%+	%-
2000	Anchovy	***54***	46	49	***51***	***78***	22	***62***	38	***75***	25
	Sardine	***82***	18	***64***	36	***53***	47	42	***58***	***55***	45
2001	Anchovy	***56***	44	***58***	42	***68***	32	***83***	17	***65***	35
	Sardine	***82***	18	16	***83***	26	***74***	***63***	37	***61***	39

The higher percentage match between the predicted and observed spawning habitat of anchovy compared to sardine suggests that using the predictive model to demarcate potential anchovy spawning habitat when egg abundance data are not available would provide meaningful information. This could be useful in monitoring spatio-temporal variability in potential spawning habitat throughout the entire anchovy-spawning season. The relatively low percentage match for sardine is surprising, given that this species appears to be less specific in their selection of spawning habitat than are anchovy (Twatwa *et al*., 2004). However, this difference may be due to less-efficient sampling of sardine eggs than anchovy eggs by the CalVET net, and comparisons between predicted sardine spawning habitat and observed spawning habitat from CUFES samples will be conducted.

Relating the variability in potential spawning habitat to subsequent recruitment success will contribute to an evaluation of the hypothesis that climate-induced changes in the spatio-temporal extent of suitable spawning habitat of small pelagic fishes cause observed productivity changes. Additionally, comparisons between predicted and observed egg distributions would permit tuning of the model through changing input parameter weightings. Future research will focus on temporal shifts and extent quantification of predicted spawning habitat in order to relate these changes to observed productivity changes as well as integration of others relevant environmental parameters as ocean currents and salinity, which can be obtained from modelling approaches.

References

van der Lingen C.D. and J. A. Huggett. 2003. The role of ichthyoplankton surveys in recruitment research and management of South African anchovy and sardine. In: H.I. Browman and A.B. Skiftesvik (Eds). The Big Fish Bang. Proceedings of the 26th Annual Larval Fish Conference, Institute of Marine Research, Bergen, Norway. p.303-343.

Twatwa N.M., C.D. van der Lingen, L. Drapeau, C.L. Moloney and J.G. Field. Submitted. Characterizing and comparing the spawning habitats of anchovy (*Engraulis encrasicolus*) and sardine (*Sardinops sagax*) in the southern Benguela upwelling ecosystem. African Journal of Marine Science 27(2): 487-499.

Plate 1

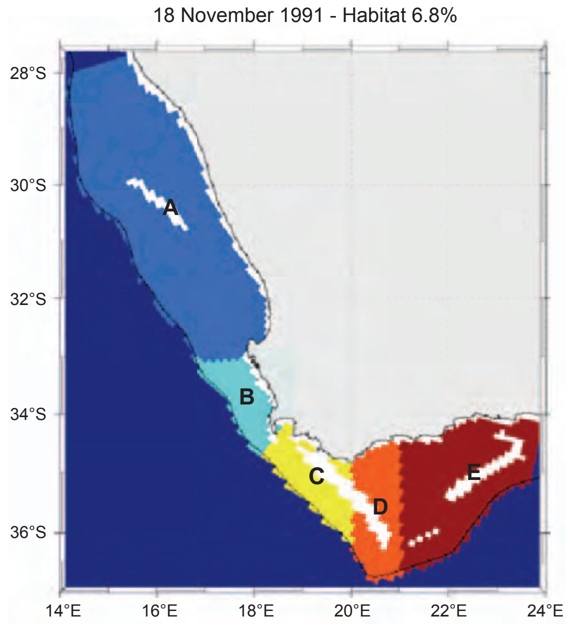


Plate 2

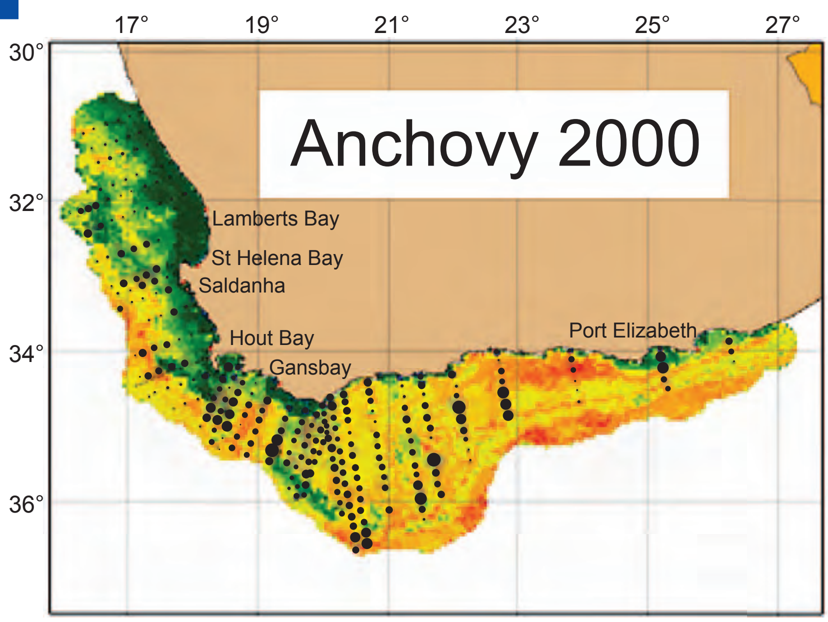
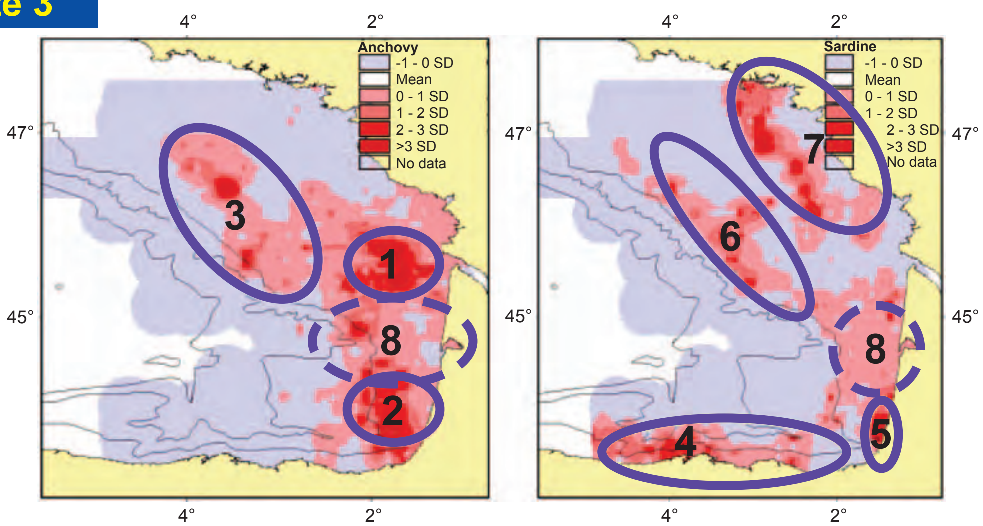


Plate 3



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