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Climate change, dinoflagellate blooms and sardine in the southern Benguela Current Large Marine Ecosystem

C.D. van der Lingen [a,b,*], L. Hutchings [b], T. Lamont [c,d], G.C. Pitcher [a,b]

[a] Fisheries Management, Department of Agriculture, Forestry and Fisheries, Private Bag X2, Rogge Bay 8012, South Africa
[b] Marine Research Institute and Department of Biological Sciences, University of Cape Town, Private Bag X3, Rondebosch 7700, South Africa
[c] Oceans and Coastal Research, Department of Environmental Affairs, P.O. Box 52126, Cape Town 8002, South Africa
[d] Marine Research Institute and Oceanography Department, University of Cape Town, Private Bag X3, Rondebosch 7700, South Africa

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ABSTRACT

The incidence of harmful algal blooms (HABs) caused by dinoflagellates may be increasing as a consequence of climate change. The southern Benguela Current Large Marine Ecosystem (LME) has experienced extensive dinoflagellate blooms in recent years, one of which occurred during 2011. We analysed *in situ* and remotely-sensed data collected at that time to characterise the bloom, investigate its possible causes, and assess its impacts on small pelagic fish species. The bloom was dominated by *Gonyaulax polygramma*, and the spatial extent of the bloom coincided with near-shore aggregations and wash-ups in some localities of sardine *Sardinops sagax*. Sardine in the bloom area were in poor condition compared to those elsewhere, whereas variation in the condition of anchovy *Engraulis encrasicolus* and west coast round herring *Etrumeus whiteheadi* did not appear to be linked to the bloom. High-salinity South Atlantic surface water covered much of the south coast during the bloom and is considered to have suppressed the normal diatom community and promoted the dinoflagellates. We hypothesise that sardine were negatively impacted by the bloom because this species possesses a fine-meshed branchial basket that can retain the dinoflagellates, whereas the other two species have coarse-mesh branchial baskets and cannot retain small particles. We speculate that the retention of these dinoflagellates on sardine gill rakers "irritated" the fish in some way such that they ceased feeding and lost condition. This hypothesis suggests an indirect impact of dinoflagellate blooms on sardine as opposed to a direct effect such as death from toxin ingestion or hypoxia.

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1. Introduction

Benguela sardine (*Sardinops sagax*) is an economically and ecologically important small pelagic fish that is distributed in the Benguela Current LME around southern Africa between southern Angola and the South African/Mozambique border (Beckley and van der Lingen, 1999). This species is the main target of the South African purse-seine fishery, with average annual catches of ca. 130 000 t since 1950 (van der Lingen et al., 2015), and is also ecologically important as it is the

* Corresponding author at: Fisheries Management, Department of Agriculture, Forestry and Fisheries, Private Bag X2, Rogge Bay 8012, South Africa.
E-mail addresses: CarlVDL@daff.gov.za, Carl.vanderlingen@gmail.com (C.D. van der Lingen).

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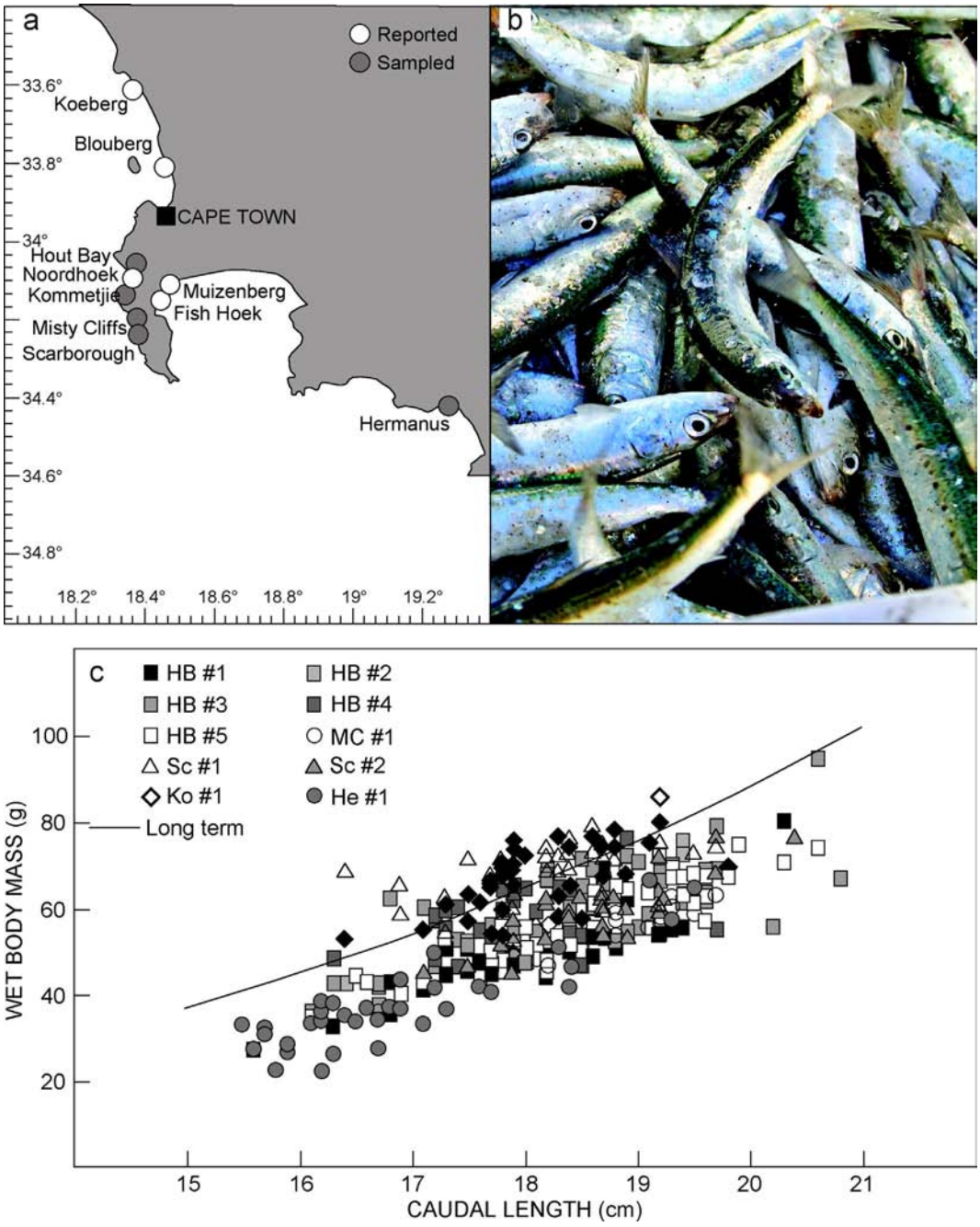

Fig. 1. (a) Map showing the localities where sardine were reported as either being washed up on beaches and/or concentrated in the near-shore zone (dark and light circles) and where samples were collected (dark circles) during the November/December 2011 Cape Town sardine run and subsequently; (b) photograph of sardine caught using a throw-net off Hout Bay beach on 04/12/2011 (courtesy Rob Tarr, DAFF); and (c) scatterplot of *WBM* (g) against *CL* (cm) for sardine collected from the near-shore zone off Hout Bay (HB #s 1–5), Misty Cliffs (MC #1), Scarborough (Sc #s 1–2) and Kommetjie (Ko #1) during the Cape Town sardine run of November/December 2011, and off Hermanus (He #1) in early February 2012. The solid line shows the fitted long-term length-mass regression for sardine reported by van der Lingen et al. (2006a); $WBM = (1.1639 \times 10^{-5}) * CL^{3.03155}$; $p < 0.001$).

dominant prey of many species of piscivorous fish, marine mammals and seabirds (Beckley and van der Lingen, 1999). Sardine was previously abundant in the northern Benguela Current LME off Namibia where it supported a large purse-seine fishery, but that population has shown a substantial reduction in biomass since the 1980s, attributed principally to overfishing (see Roux et al. (2013) and references therein).

During November and December 2011, shoals of sardine were observed very close inshore and/or washed up on several beaches around Cape Town, South Africa, predominantly on the western side of the Cape Peninsula (Fig. 1a). This event

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