SATELLITE IDENTIFICATION OF HYDROGEN SULPHIDE EMISSIONS

Scarla J. Weeks[1], Bronwen Currie[2], Andrew Bakun[3] and Ray Barlow[4]
[1]Ocean Space CC and IDYLE associate, UCT, Cape Town, South Africa
[2]National Marine Research and Information Center, Swakopmund, Namibia
[3]IRD, Oceanography Department, UCT, Cape Town, South Africa
[4]Marine and Coastal Management, Cape Town, South Africa

Introduction

Outbreaks of toxic hydrogen sulphide toxic gas are a recurrent feature in the near-coastal shelf environment off Namibia. These outbreaks have a significant economic and societal relevance because of their effects on the biota in one of the world's largest upwelling regions, fisheries being the third largest source of revenue for Namibia. Until recently, hydrogen sulphide events were considered to be of local geographical extent and forced by a combination of high biological productivity and reduced advection of oxygenated ocean water. New evidence from remote sensing suggests a far larger geographical distribution than previously assumed, and ship-borne surveys in 2000 suggest a significant contribution by eruptions of biogenic gas accumulations in organic-rich diatomaceous oozes on the shelf.

Background

Strong upwelling off Lüderitz results in massive downstream primary production. Dead and decaying phytoplankton cells accumulate on the sea bottom in a metres-deep muddy diatom ooze, which is exceptionally thick and azoic. The "azoic zone" bottom water suffers from chronic hydrogen sulphide concentrations, and is devoid of fish life, although copious fish remains are present. In the sediment, anaerobic sulphate-reducing bacteria convert sulphates to sulphides, ultimately producing hydrogen sulphide. During an hydrogen sulphide event, hydrogen sulphide gas is liberated into the water column. While some gas escapes into the atmosphere, hydrogen sulphide in the water column oxidises to microgranules of elemental sulphur, giving the surface a milky-green discoloration.

In addition to its direct toxic impact, hydrogen sulphide has the secondary effect of stripping oxygen from the water, so that extensive surrounding areas suffer from severe anoxia and hypoxia. The catastrophic loss of two billion young Cape hake, *Merluccius capensis*, during austral summer of 1992-93, was blamed on an anoxic outbreak (Woodhead *et al*. 1998a). About half of the recruit population of Namibian Cape hake was estimated to have died as a result of being trapped by widespread anoxia in shelf bottom waters, with cumulative mortality of surviving hake in 1994 being estimated at 84% (Woodhead *et al.* 1998b).

Satellite identification of hydrogen sulphide emissions

Recently, a potential boon to the scientific study and eventual management of the possible effects of hydrogen sulphide outbreaks has emerged. We are now able to detect and monitor such anoxic phenomena via satellite remote sensing. An example is shown of an episode, observed over a two-week period during March–April 2001 (Plate 3), that affected an area of ocean surface exceeding 20,000 km^2. Plate 3 displays a series of visible-band, quasi-true colour images from the OrbView-2 SeaWiFS satellite during this episode. On 18th March (image a), a massive sulphide emission event was evident in the turquoise-coloured patch stretching northwards more than 200 km along the Namib Desert coast from the vicinity of Lüderitz almost to Conception Bay. Images for 12th and 13th March showed only small isolated spots of milky coloration localized against the coast between Ichaboe Island and Hollams Bird Island, indicating that minor precursory eruptions seem to have commenced at that time.

Fortunately, NATMIRC personnel were on the scene during the major outbreak, taking measurements and collecting samples for analysis. They were able to demonstrate the presence of intense hydrogen sulphide emissions in that zone, and to confirm that the peculiar milky turquoise colouration of the water occurred simultaneously as viewed from the satellite. This discoloration consistently occurs during hydrogen sulphide events along the Namibian coastline, and is due to the highly reflective microgranules of sulphur (oxidised sulphide) suspended in the water column. Oxygen samples from surface waters showed very low concentrations (<0.7ml l^{-1}; K. Noli-Peard, NATMIRC, unpublished data) indicating that a knock-on impact of sulphide is widely felt throughout the water column.

In the days to follow (images b-f), the feature was advected further northward and offshore in the prevailing equatorward geostrophic current, as well as exhibiting some spreading due to turbulent diffusion. Finally, in the image of 3rd April (image f), even while the earlier offshore feature continued to maintain a coherent identity, another totally new hydrogen sulphide emission event was observed to have abruptly commenced within the coastal upwelling zone north of Lüderitz. "Milky turquoise waters" were again reported from Ichaboe Island, which is amongst Namibia's most important lobster fishing grounds. Dive surveys showed dissolved oxygen levels to be exceptionally low, forcing the lobster stock right inshore (C. Grobler, NATMIRC, personnel communication).

Additional recent episodes have likewise been definitively associated with coastal sulphide emissions and associated anoxia, although the possibility of some degree of involvement of coccolithophores in the offshore signatures cannot be discounted at this point. If so, such a relationship to sulphide/anoxia is previously unreported and in itself would be of great ecological significance. The conventional view has been that the sulphide emissions that are recurrently observed from the shore in this region are very local features, and thus must have only rather limited ecosystem-scale consequences. The recent satellite observations appear to dramatically overturn that view. In the case of the March-April episode, the initial coastal outbreak can be seen (Plate 3 image a) to stretch continuously along nearly two and one half degrees latitude. The zone of rather intense coloration in the later images (images b-f) extends over an expanse of sea surface more than 20,000 square kilometers in total area.

Conclusions

Hydrogen sulphide occurrences are seen to be far larger in spatial extent, and more frequent and longer lasting, than was previously supposed. Implications of these phenomena to the local ecology may be profound, and the relevance to the valuable but extremely variable fishery of the region is likely to be high. This capability for identifying and monitoring from satellite the incidence, position and extent of ocean areas affected by toxic hydrogen sulphide emissions and associated anoxic/hypoxic conditions promises to be a major asset for fisheries management in the Namibian waters.

References

Woodhead, P.M.J., Hamukuaya, H., O'Toole, M.J., Stromme, T., Saetersdal, G. and M.R. Reiss. 1998a. Catastrophic loss of two billion hake recruits during widespread anoxia in the Benguela Current. Paper presented and distributed at the BENEFIT Scientific Programme Formulation Workshop, Swakopmund, Namibia, 1-4 April, 1998.

Woodhead, P.M.J., Hamukuaya, H., O'Toole, M.J., Stromme, T. and S.S. Kristmannsson. 1998b. Recruit mortalities in Cape hake following exclusion from shelf habitat by persistent hypoxia in the northern Benguela Current. Paper presented and distributed at the BENEFIT Scientific Programme Formulation Workshop, Swakopmund, Namibia, 1-4 April, 1998.

Acknowledgements

We wish to acknowledge the contributions of all the members of the NATMIRC "Sulphide Team", the French-South African IDYLE Project and the regional BENEFIT Project. We also wish to express special thanks to Dr. Gene Feldman of NASA (USA) for his continuing generous interest and assistance in affording the benefits of SeaWiFS technology to southern Africa.