

Algal blooms in the seas around India – Networking for research and outreach

S. R. Bhat* and S. G. Prabhu Matondkar

The ever-growing reports on harmful algal blooms (HABs), their adverse consequences on economy and the pace with which consortia of institutes are being formed globally to understand their dynamics, prompted us to view the situation in India. Unlike the 70s, when blooms were phenomena mostly restricted to the temperate waters, the 90s have been witnessing their spread to tropical and sub-tropical regions as well^{1,2}. We examined the Aquatic Sciences and Fisheries Abstracts world database of FAO, Rome to which the National Institute of Oceanography, Goa provides inputs for the whole of India. This database holds research publication details on aspects regarding marine, brackish water and freshwater³. Patchy and scattered efforts on bloom research in Indian waters were discernible. Most of the investigations seemed only to fulfil academic pursuit, without any real link to human health concerns or economy. It is time to be alert as HABs are unpredictable and have implications that extend beyond isolated locations. Networking of various institutions for co-ordinated research and of voluntary citizens to interface between the research institutions and the community at large, all along our coast is an inevitable requirement.

It is amazing that tiny, microscopic, free-floating aquatic (marine in this context) plants, phytoplankton so vital as first link in the food-web as primary producers, at once bloom to cause adverse consequences on human health and catastrophic loss of cultured and wild fish. Although use of the term 'bloom' or 'red tide' conjures up an image of algal populations so dense as to be visible, this is not always the case with harmful algal blooms (HABs). Concentrations of only a few cells per litre may produce harmful toxic effects. About 300 of the estimated 4100 phytoplankton species, some predominant dinoflagellates, silicoflagellates, raphidophytes and diatom species produce 'red tides', and about 60–80 species are actually harmful or toxic as a result of their bio-toxins, physical damage, anoxia, etc.⁴.

Spread of HABs

A question that one would ponder is: 'Are HABs spreading and would our waters be affected?' Growing evidence the world over affirms this, but we need to check whether that should really worry India? In seas around the United States, for example, over the last 25 years, HAB expansion has reached a different scale, more areas are being affected, more toxic species observed and a heavy recurring economic loss suffered. But citizens here, realizing the potential human health effects, have formed groups to

alert the general public, particularly fish and shellfish-eaters about the paralytic, neurotoxic and diarrhoeic effects due to the consumption of bloom-affected fish and shellfish⁵. The volunteers also assist marine research institutes with actual observed data and information. The research institutions who have shared their research efforts according to the available expertise, respond in issuing appropriate advisories and research in understanding various aspects of bloom of both planktonic and cyst forms. The unpredictability of HABs still remains; so also the threat to the ecosystem and public health.

The foremost cause attributed to the triggering and spread of blooms is increasing pollution. Though pollution is not always an obvious factor, it cannot be ignored. The nutrients that reach coastal waters by natural processes and due to increased anthropogenic activities stimulate the growth of 'background' population of blooming species⁶. Another possible cause for the increasing bloom is transport of exotic species through ballast water from ships. The invasion can cause profound changes in biodiversity. According to Carlton and Butman⁷, on a typical day more than 3000 species of marine animals and plants are in silent motion around the world, travelling in ballast water in ships. The instance of ballast water carrying a Japanese dinoflagellate released in Australian waters, has led to the closure of shellfish beds⁷. Steve Raaymakers, Chief Technical Adviser to the International Maritime Organization (IMO), who was part of the First South Asia Regional Meeting on Ballast Water Control and Management held in Goa in May 2004, puts this strongly as: 'Alien invaders are ordinary marine organisms, often harmless in their

The authors are in the National Institute of Oceanography, Dona Paula, Goa 403 004, India.

*For correspondence. (e-mail: bhat@darya.nio.org)

home environment, but assuming the role of natural terrorists when they are transported to another ecosystem'⁸. India has been one of the active pilot countries among the six identified by IMO since the year 2000, for Global Ballast Water Management Programme. Under this, port areas of Mumbai and adjacent coastal waters are being monitored for various invading species, including HAB-forming species⁹. Improved methods of detection also have enabled better and increased observations and therefore, more occurrences of blooms have come to light (Figure 1).

Hong Kong, for instance, had witnessed only four incidents of red tides of potentially toxin-producing species during 1975–97, but a major and extensive HAB outbreak caused by *Gyrodinium* species occurred in 1998, covering an area > 100 km² along its coast and south China. It killed over 80% (3400 tonnes) of mariculture fish and caused a loss of over US\$ 40 million^{10,11}. Malaysia had few instances of toxic blooms, but it was badly hit in 1976 by *Pyrodinium bahamense* var. *compressum*, victimizing 202 people and killing seven children¹². In 2002, an intense HAB of *Alexandrium catenella* occurred south of Chile. The area was forced to be closed, declaring it as catastrophic by the President of that country¹³.

How are organizations responding?

Realizing the need, three premier institutions in the US, viz. the Woods Hole Oceanographic Institution, Marine Biological Laboratory and the Massachusetts Institute of Technology together have formed a Center for Oceans and Human Health (COHH) at Woods Hole to serve as a focal point for research on issues of human health, HAB being a major one¹⁴. Three more centres are in the offing. Similarly, researchers from the University of California, California State Laboratories, Colorado State University and NOAA's Seattle and Charleston Laboratories regularly collect water and fish samples to analyse domoic acid content to create a database, as some blooms emit toxic

domoic acids in aerosols as they decompose and cause health hazards. In one major instance in 1995–96, beach-goers and seaside residents in South Africa's largest False Bay, faced discomfort of coughing, burning of nasal passages, difficulty in breathing, stinging eyes and skin irritation due to release of toxins in the sea-spray aerosols by the blooms of *Gymnodinium* species¹⁵. Hong Kong has formed an exclusive Red Tide Task Force to direct and oversee red tide management. It has also established an operational technical team to facilitate communication to improve coordination during HAB events¹⁰. The Brunei Darussalam recently formed the National Red Tide Response Team that comprises experts from Fisheries, Medical and Health Services, Municipal Board and District Offices¹⁶. Fiji, known for its frequent and widespread fish poisoning called 'ciguatera', carries out research on ciguatera and associated marine toxins through the Ministry of Fisheries and Forests¹⁷.

Intergovernmental Oceanographic Commission of UNESCO promotes international programmes such as Global Ecology and Oceanography of Harmful Algal Blooms to foster and promote cooperative research directed towards the prediction of harmful algal bloom events⁵. It often organizes open science meetings and regional training courses in taxonomy of harmful microalgae, besides transmitting lot of information through its newsletter *Harmful Algae News* and its website: <http://ioc.unesco.org/hab>.

Response of citizens

The US Food and Drug Administration, the Maine Department of Marine Resources (DMR), and the University of Maine Cooperative Extension/Maine Sea Grant have developed the Maine Phytoplankton Monitoring Program for the coast of Maine. This is a citizen-volunteered programme in which community members and students use plankton nets and field microscopes to monitor HABs and provide data to the DMR in real-time for biotoxin monitoring and issue advisories to shellfish consumers. About

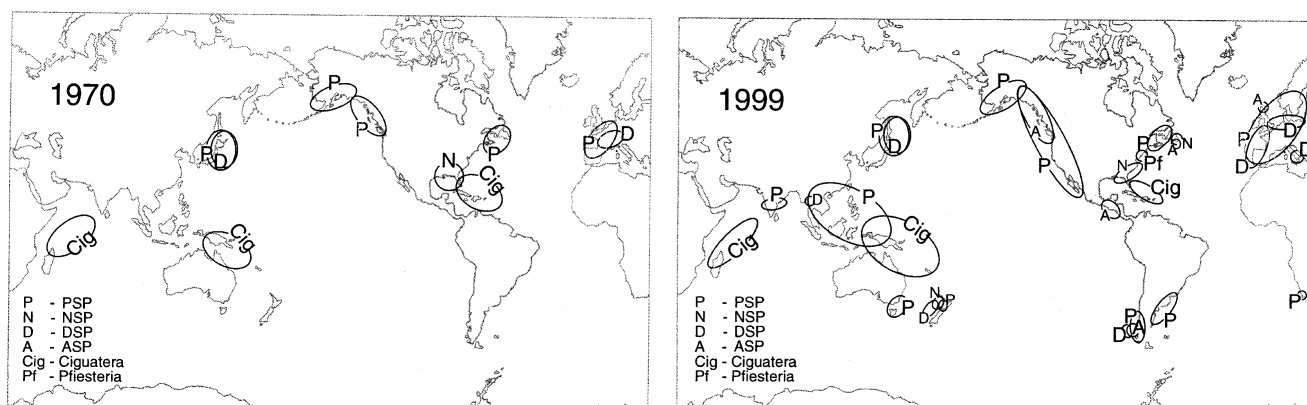


Figure 1. Spread of HABs during the last three decades (adapted from Hallegraeff²).

eighty volunteers monitor 35 sites coast-wide on a weekly basis, from April to October every year⁵. Residents of Delaware, realizing the environmental and potential human health effects of HABs when *Pfiesteria* was implicated in fish kills from North Carolina to New Jersey in the mid to late 90s, formed citizen volunteer groups. The volunteers, who are taught to identify phytoplankton, collect and evaluate samples from the bloom-hit areas and assist the University of Delaware in issuing health alerts through the State department. The volunteers also supply algal samples for culture, since collecting samples by the university alone from far-off sites is logistically difficult.

Algal blooms in Indian waters

The red tide is not an unknown phenomenon in Indian waters. Until 1973, sporadic blooms of *Noctiluca scintillans*, *Trichodesmium erythraeum*, *Rhizosolenia* sp., etc. have been reported, but none were of HAB type. However, since 1981, cases of paralytic shellfish poisoning (PSP) from coastal Tamil Nadu, Karnataka and Maharashtra were reported with adverse effects¹⁸. In 1981, PSP resulted in the hospitalization of 85 people and death of three persons due to the consumption of bloom-affected mussel *Meretrix casta* in Tamil Nadu. A similar incidence took place in Mangalore in 1983, but in both the cases causative species were not identified⁸. In 1996, Godhe *et al.*¹⁹ reported *Gymnodinium catenatum*, a potent PSP species both as planktonic cells and cysts in sediment, in the coastal waters of Karnataka (off Mangalore); but the low number of cells had no toxic effect. In September 1997, an outbreak of PSP was reported in three villages of Kerala, resulting in the death of seven persons and hospitalization of over 500, following consumption of mussel, *Perna indica*²⁰. During a reconnaissance cruise in 2001, on the coastal vessel *Sagar Shukti*, a toxic algal bloom by hitherto unreported dinoflagellate *Cochlodinium polykrikoides* was reported by the NIO team²¹. Though this species is a fish-killer in Korea, the cause for fish mortality noticed off Goa could not be confirmed (Lata Raghukumar, pers. commun.). These few examples underline the unpredictable nature of the bloom and perhaps answer the query regarding whether India should really worry about the blooms.

Algal bloom research in India

Despite the fact that India has a fairly good spread of institutions dealing with marine research, technology and teaching, interest in bloom research could translate into about 300 scientific papers over a period of 48 years³. Some of the publications were due to instant response to the bloom episodes, but research interest did not persist further. The obvious reasons for this are: (i) Indian waters were never seen as potential sites for recurring blooms of

temperate type and hence investigations were restricted to fulfil academic pursuits. (ii) *Trichodesmium* and *Noctiluca* species were most dominant members of the blooms reported. The blooms of these non-toxic species therefore were not a cause for worry. (iii) The concept of blooms either in terms of their real extent or composition for a discernible consequence remained obscure. The blooms that discoloured the waters or the occurrence of even 'miniblooms' as a response to nutrient pulses, normally to be ignored, were speculated to be harmful. Some even raised warning flags based on circumstantial fish mortality or fall in their catch without actually collecting scientific data. Among 300 abstracts that we went through, only 80 (20%) dealt with bloom aspects and only a handful on extensive blooms as perceived now. (iv) A lack of clear distinction on the kind of blooms was obvious, as descriptors such as 'toxic', 'noxious' and 'nuisance' have been synonymously used, at times misplacing their real potency and vice versa. (v) Universities and research institutions have limited sea observation and laboratory facilities, and therefore explorations and studies were sporadic.

Monitoring and networking

Fishing is one of the largest industries in India. It provides employment or gainful economic activities to nearly 10 million people²². There are around 3638 fishing villages along the Indian coastline²³. Nearly 34,000 mechanized boats and 20,000 non-mechanized boats operate along the 7000 km coastline of India²². Fish production (capture and culture) is of the order of 3 million tonnes per year (C. T. Achuthankutty, pers. commun.). In the last 30 years, India has emerged as one of the foremost exporters of seafood in the world, with the exported value reaching more than Rs 6000 crore per annum. These statistics only highlight the fact that commercial and artisanal fishing in India is a source of income and a way of life for many. Though our coastal waters and sea around are claimed to be cleaner compared to adjacent waters and elsewhere, unpredictable blooms allow no complacency. Therefore, regular monitoring of our waters is a societal requirement. Clearly, the vastness of our coast and sea area demands a large resource beyond those available to any single institution, both for an efficient outreach and in understanding different aspects of blooming and bloom-forming species. This can only be done through strong partnerships with marine research institutions, fishery technology and education-imparting universities and academies, industries, fishery cooperatives, Block development offices and volunteering citizens. The networking of such partners will not only provide a good factual description and observational data of a large area on regular basis, but also help to rapidly alert the citizens on the likely consequences of HAB episodes. This would also help in the development

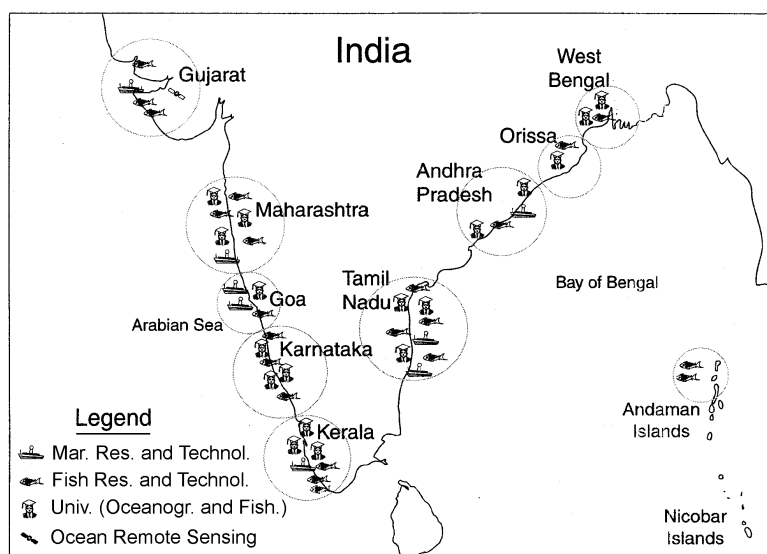
Table 1. Some major ocean research and academic institutions along the Indian coast²⁴.**West coast**

Central Salt and Marine Chemicals Research Institute, Bhavnagar
 Gujarat Fisheries and Aquatic Science Research, Port Okha
 Space Application Centre, Ahmedabad
 Central Marine Fisheries Research Institute, Veraval
 Central Marine Fisheries Research Institute, Mumbai
 National Institute of Oceanography, Regional Centre, Mumbai
 Fishery Survey of India, Mumbai
 Central Institute of Fisheries Technology, Mumbai
 Taraporevala Marine Biological Research Station, Mumbai
 Central Institute of Fishery Education, Mumbai
 College of Fisheries, Ratnagiri
 National Centre of Antarctic and Ocean Research, Vasco-da-Gama
 Goa University, Panjim
 National Institute of Oceanography, Dona Paula, Goa
 Central Marine Fisheries Research Institute, Karwar
 PG Centre of Karnataka University for Marine Biology, Karwar
 Central Marine Fisheries Research Institute, Karwar
 Central Marine Fisheries Research Institute, Mangalore
 Fisheries College, Mangalore
 Central Marine Fisheries Research Institute, Thiruvananthapuram
 Central Marine Fisheries Research Institute, Kochi
 Central Institute of Fisheries Technology, Kochi
 National Institute of Oceanography, Kochi
 University of Kerala, Thiruvananthapuram
 Cochin University of Science and Technology, Kochi
 College of Fisheries, Kochi

East coast

Central Marine Fisheries Research Institute, Mandapam
 Central Marine Fisheries Research Institute, Chennai
 Centre of Advanced Study in Marine Biology, Parangipettai
 Fisheries College and Research Institute, Tuticorin
 Fishery Survey of India, Chennai
 Central Institute of Fisheries Technology, Sambalpur
 Berhampur University, Berhampur
 Department of Marine Science, Kolkata
 Zoological Survey of India, Kolkata

The list does not include coordinating organizations such as Department of Ocean Development, Ministry of Environment and Naval Research.

**Figure 2.** Marine institutions along the Indian coast.

of a bloom prediction model. In short, observational data in the right places, at the right times, and at rates and scales that can be compared are a must if we have to successfully devise a mechanism to safeguard our lives.

India is in much better position to establish a network, as its long coastline is dotted with institutions that deal with ocean research, fishery education, fishery technology and ocean science, besides fisheries cooperatives and State fisheries departments (Table 1 and Figure 2)²⁴. We also have a dedicated ocean satellite IRS-P4 for ocean studies, including bloom monitoring, with another version due for launching. New ocean technologies such as autonomous underwater vehicles, sensors on platforms, and coastal observatories are also emerging²⁵. The means to understand blooms in coastal waters and beyond are already at our disposal. We will now have to put them in use through cooperative venture. The behaviour of these tiny blooming organism needs to be understood to ensure safety of our life along the water's edge.

1. Maclean, J. L. and White, A. W., Toxic dinoflagellate blooms in Asia: A growing concern. In *Toxic Dinoflagellates* (eds Anderson, D. M., White, A. W. and Boden D. G.), Elsevier, New York, 1985, pp. 517–520.
2. Hallegraeff, G. M., A review of algal blooms and their apparent global increase. *Phycologia*, 1993, **32**, 79–99.
3. Aquatic Science and Fisheries Abstracts, ASFA Databank of international literature on marine, brackish and natural freshwater environments, maintained by NICMAS Centre, NIO (Goa) for FAO, Rome.
4. Sournia, A., Red tide and toxic marine phytoplankton of the world ocean: An inquiry into biodiversity. In *Harmful Marine Algal Blooms*. Proceedings of the 6th Conference on Toxic Marine Phytoplankton, pp. 103–112.
5. <http://ioc.unesco.org/hab>.
6. Kirkpatrick, B., *et al.*, Literature review of Florida red tide: Implications for human health effects. *Harmful Algae*, 2004, **3**, 99–115.
7. Carlton, J. T. and Butman, C. A., Understanding marine biodiversity. *Oceanus*, 1995, **38**, 4–7.
8. Alien invaders threaten Goa's waters? *Gomantak Times*, Panjim, Goa, 13 May 2004.
9. Anil, A. C. and Venkat, K., Ballast water risk assessment in India. First South Asia Regional Meeting on Ballast Water Control and Management, Goa, 13 May 2004.
10. Paul, K. S. and Lam, P. K. L., Red tides/harmful algal blooms in Hong Kong. Regional Training Workshop on Marine Toxins, Suva, Fiji, 17–22 June 2002.
11. Yong, Z. B. and Hodgkiss, I. J., Hong Kong's worst red tide causative factors registered in a phytoplankton study at Port Shelter station in 1998. *Harmful Algae*, 2004, **3**, 149–161.
12. Choo, P. S., A review of red tide occurrences in Malaysia. Regional Training Workshop on Marine Toxins, Suva, Fiji, 17–22 June 2002.
13. Rodriguez, C. V. and Arancibia, J., Application of remote sensing of ocean color to forecast HAB events in Chile. *Harmful Algae News*, 2002.
14. Woods Hole Oceanographic Institution, News release, New Centre for Oceans and Human Health Woods, Hole, 2004.
15. Pitcher, G. and Matthews, S., Noxious *Gymnodinium* species in South Africa waters. *Harmful Algae News*, 1996, 1–2.
16. Metali, D. H. J., The status of red tides occurrence and its management in Brunei Darussalam. Regional Training Workshop on Marine Toxins, Suva, Fiji, 17–22 June 2002.
17. Leewai, A. and Yakub, N., Regional Training Workshop on Marine Toxins, Suva, Fiji, 17–22 June 2002.
18. Devassy, V. P. and Bhat, S. R., The killer tides. *Sci. Rep.*, 1991, 16–19.
19. Godhe, A., Indrani and Karunasagar, I., *Gymnodinium catenatum* on west coast of India. *Harmful Algae News*, 1996, **15**.
20. Karunasagar, I. *et al.*, Another outbreak of PSP in India. *Harmful Algae News*, 1997, **16**.
21. Fish kills due to algal blooms, NIO Press release, 29 October 2001.
22. Qasim, S. Z., Ocean based industries in India. *J. Indian Ocean Stud.*, 2000, **7**, 191–200.
23. Sinha, P. C., India's coastal law-problems and prospects. *J. Indian Ocean Stud.*, 2000, **8**, 170–185.
24. *Indian National Directory of Marine Scientists*, National Institute of Oceanography, Goa, 1993.
25. Mantondkar, S. G. P., Bhat, S. R., Dwivedi, R. M. and Nayak, S. R., Indian satellite IRS-P4 (OCEANSAT) monitoring algal blooms in the Arabian Sea waters. *Harmful Algae News*, communicated, 2004.

ACKNOWLEDGEMENTS. We thank Dr Satish R. Shetye, Director, NIO, Goa and Dr D. Chandramohan, Head, Biological Oceanography for encouragement and support. Our thanks to the Publication Committee and Prof. Karl Banse (University of Washington) for scrutinizing the manuscript. We acknowledge the help of DTP Section for tracing work.

Received 7 August 2004; accepted 23 August 2004