Red tides in the sunset

Robin Raine

‘Red tides’ are one type of harmful algal bloom. Robin Raine describes how the blooms are formed and the unpleasant effects they can have on marine life and its human consumers.

Marine phytoplankton are the microscopic, single-celled algae that inhabit the surface few tens of metres of the sea. They are found across all oceans in concentrations of several thousands of cells per litre. Their existence is critical to virtually all the other organisms found in the sea, as they are the primary producers of organic material and are right at the very start of the marine food chain. When there is sufficient light and nutrients they can proliferate into enormous concentrations of up to millions of cells per litre. These events are referred to as blooms. Most blooms are extremely beneficial to the marine ecosystem, either for the filter-feeding bivalve shellfish such as oysters, mussels, scallops and clams, for the larvae of commercially important crustaceans and finfish, or for other marine food chains.

About 5,000 species of marine phytoplankton are known to exist, a number that is still rising with recent advances in technology. A very small number of these species are potentially harmful. These can either contaminate seafood with toxins, cause serious human health problems, proliferate and kill fish, or otherwise alter ecosystems in ways that we perceive as harmful. The scientific community refers to these events with the generic term ‘harmful algal blooms’, or HABs. In the popular press they are often called ‘red tides’ (see Fig. 1), but this is a misnomer as it refers to only one particular form of potentially harmful event. The term HAB is likewise not at all precise, as a bloom implies a massive proliferation of phytoplankton cells, yet some species contain toxins so potent that only a small number need be present to seriously contaminate shellfish.

BELOW:
Fig. 1. An example of a ‘red tide’.
COURTESY BILL BACHMANN / SCIENCE PHOTO LIBRARY

We recognize two basic types of harmful algal blooms.

1. Large blooms of species that cause water discolorations, that can result in foams or scums, or that indiscriminately kill fish and other fauna due to oxygen depletion.
2. Species which produce toxins. These chemicals can either be directly toxic to fish and invertebrates, or have an indirect mode of action when, though harmless to filter-feeding shellfish, they can find their way through the food chain into humans causing a range of extremely unpleasant gastrointestinal and neurological illnesses.

Red tides and other exceptional blooms

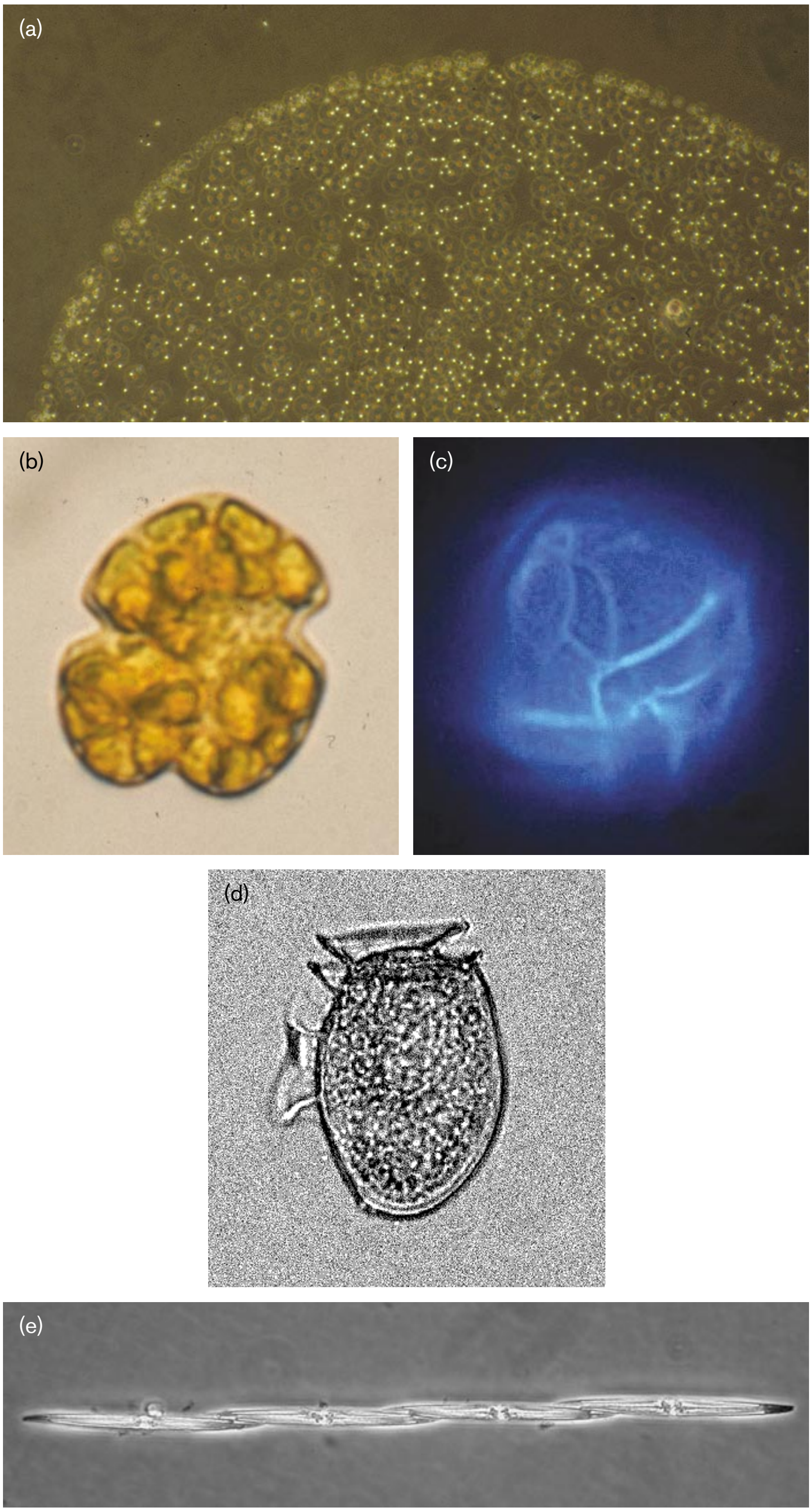
It is believed that the first written reference to a harmful algal bloom appears in the Bible as one of the plagues of Egypt (Exodus 7, 20–21): ‘*…all the waters that were in the river were turned to blood. And the fish that was in the river died; and the river stank, and the Egyptians could not drink of the water of the river…*’. This has been interpreted as a non-toxic bloom-forming alga which became so densely populated that it generated anoxic conditions resulting in indiscriminate kills of fish and other fauna. Oxygen depletion can be due to high respiration by the algae, particularly at night, but more commonly is caused by bacterial respiration during decay of the bloom.

Water discolorations caused by algal blooms can be quite spectacular and spread over a wide area. For the most part these are caused by a group of phytoplankton called dinoflagellates. On these occasions, the sea becomes coloured red-brown, as dinoflagellates contain a pigment known as peridinin which is brick red. Hence the term ‘red tide’.

A common bloom-forming phytoplankton species in European coastal waters is known as *Phaeocystis*. This is a tiny flagellate cell, about 3 µm in diameter, which has the ability to form dense colonies embedded in mucus (Fig. 2a). Colonies are commonly 5–10 mm across and are visible to the naked eye. *Phaeocystis* blooms in May and is often associated with the accumulation of foam on beaches along the North Sea and Irish Sea. The colonies also give an odour to the sea, which can become quite evil if they are washed ashore. Another aspect of *Phaeocystis* blooms is that post-bloom sedimentation can lead to deoxygenation near the sea bed. One such event in 2001 killed 10 million kg of mussels (worth Euro 20 million) in the western Oosterschelde, Holland.

Toxic blooms

Although a number of phytoplankton species have direct toxic effects on marine organisms, these events are in practice difficult to observe. They are most likely to be observed at fish farms where fish are contained in cages and cannot escape. *Karenia mikimotoi* is a dinoflagellate that not only forms red tides but also contains toxins



LEFT:
Fig. 2. (a) *Phaeocystis*. Thousands of tiny cells are embedded in mucus in each colony. (b) *Karenia mikimotoi*, a red tide organism. (c) *Alexandrium*, a genus which produces PSP toxins. (d) *Dinophysis*, a genus responsible for much DSP. (e) *Pseudo-nitzschia* – a diatom which produces domoic acid, an amnesic shellfish poisoning toxin. COURTESY ROBIN RAINE (a); CAROLINE CUSACK (b); GERT HANSEN (c); GEORGINA MCDERMOTT (d); ROBIN RAINE (e)

(Fig. 2b). It is known to kill fish, but it is extremely toxic to lugworms, and the disappearance of worm casts in an intertidal mud is highly indicative of the presence of this species. A massive bloom of a flagellate called *Chrysochromulina polylepsis* in 1988 spread over some 75,000 sq. km of the Skaggerak and Kattegat and up the Norwegian coast. It indiscriminately killed large numbers of seaweeds, invertebrates and fish.

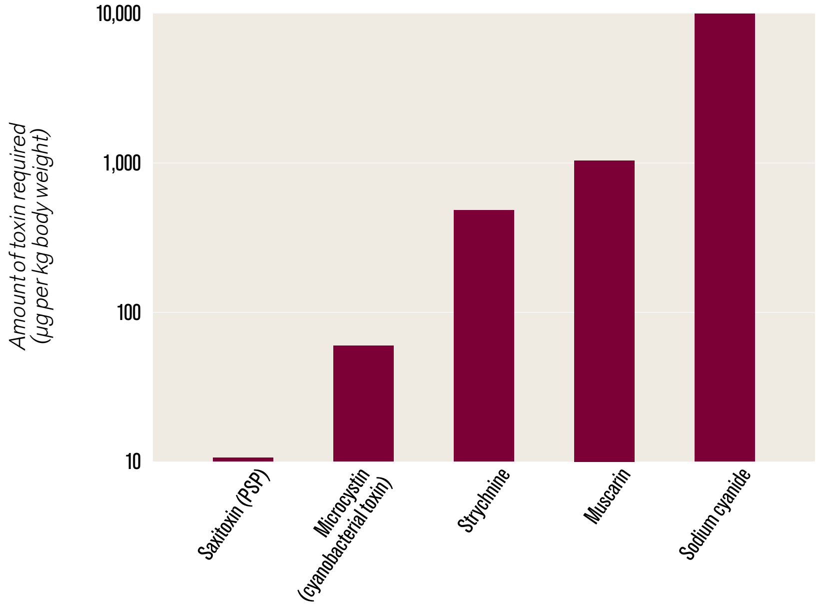
HAB events caused by toxicity resulting from eating contaminated shellfish have been with us for a long time. An event which occurred during the surveying of British Columbia by Captain George Vancouver in 1793 was one of the first ever recorded. A landing party went ashore, at an area now known as Poison Cove, and ate shellfish contaminated with dinoflagellate toxins. On their return, there was much '*sickness, giddiness and numbness*' among them. One, John Carter, died and Vancouver named the bay Carter Bay to mark this tragic episode. Interestingly, he also noted that it was taboo for local Indian tribes to eat shellfish when the seawater was phosphorescent, an indication that dinoflagellates are present.

The causative alkaloid toxins were what we now know as saxitoxins which give rise to a syndrome known as paralytic shellfish poisoning (PSP). These are so potent that less than a pinhead quantity, which can easily accumulate in a 100 g helping of shellfish, can be fatal (Fig. 3). Fortunately, the dinoflagellates which contain these toxins (Fig. 2c) are in general terms infrequent around the coast of Northern Europe. More commonly, particularly in summer, one finds species that contain toxins which give rise to diarrhoea and in more extreme cases nausea, vomiting and abdominal pain (diarrhoeic shellfish poisoning or DSP). The dinoflagellate genus *Dinophysis* contains many species with this group of toxins (Fig. 2d).

Until the late 1980s, dinoflagellates were considered as the cause of toxic events arising from shellfish poisoning. However, a new type of poisoning occurred in Prince Edward Island, Canada when over 100 people became ill after eating cultured mussels. The importance of this event was that the toxin involved, domoic acid, was produced by a diatom known as *Pseudo-nitzschia* (Fig. 2e). Diatoms had hitherto been regarded as either totally harmless or even extremely beneficial to the marine ecosystem. Contamination of some types of shellfish with domoic acid now occurs regularly in Europe. The toxin has also found its way via the marine food chain into seabirds such as cormorants, and even sea lions along the Californian coast with lethal results.

Monitoring for harmful species

Monitoring for phytoplankton and their toxins in shellfish plays a vital role in aquaculture. The increasing use of the coastal zone for this industry demands that every precaution is taken to avoid contaminated product



ABOVE:
Fig. 3. Comparison of doses of algal toxins (PSP and a cyanobacterial toxin) necessary to kill humans compared with other known poisons.
ADAPTED FROM E. GRANELI *ET AL.* (1999) EUROHAB – SCIENCE INITIATIVE, EUROPEAN COMMISSION, BRUSSELS

being released into the market. Indeed, under the EC directives 91/492 and 2002/225, member states are required to '*check the possible presence of toxin-producing plankton in production and relaying waters, and biotoxins in live bivalve molluscs*'. The actual cost of this is quite a burden. Water and shellfish sampling together with subsequent analysis for phytoplankton and toxins amounts to approximately 5 % of turnover of the shellfish industry in Ireland. However, this figure can be trebled if trade losses due to harvest closures and other health costs are added on. Comparable figures are found in most states involved in shellfish production. The price of monitoring is, however, worthwhile as shown by the extremely high quality of shellfish available on the market today.

The future

The number of recorded instances of HAB events is on the increase. It is at present difficult to discern whether this is a true reflection of a changing marine environment or simply a result of the increase in monitoring of a globally expanding industry. Attempts have been made to link the increase in HABs with climate variability and global warming, yet there is no evidence whatsoever to show this as yet. One potentially serious way an HAB species can be introduced is in the ballast water of ships, returning from long distances after off-loading their cargo. Evidence that toxic species had been introduced into Australian waters in this way was gathered in the 1980s. Many phytoplankton have dormant stages in their life cycle and can easily remain viable in ballast water for extended periods of time before being discharged in other parts of the world. Countries have been slow to respond to this threat, but at least there are now some controls on discharging ballast water near areas of aquaculture. It is up to us to remain vigilant in our activities so we may continue to enjoy the *fruits de mer*.

● *Dr Robin Raine is the Senior Researcher in Phytoplankton Ecology at the Martin Ryan Institute, National University of Ireland, Galway, Ireland.*
Tel. +353 (0)91 524411 ext. 2271
Fax +353 (0)91 525005
email robin.raine@nuigalway.ie

Micro Shorts

Foot-and-mouth disease inquiry

The 2001 foot-and-mouth disease (FMD) disaster highlighted the urgent necessity for a strategy based on the best science to be in place for dealing with future outbreaks in the UK and EU. The Royal Society inquiry *Infectious Diseases in Livestock*, commissioned by the government, reached some hard-hitting conclusions. Its wide-ranging recommendations were based on 400 written submissions of evidence, interviews with people involved in the outbreak and visits to affected areas. The report sets out policy measures to minimize the risk of a disease entering the country and, if it does get in, ensuring that the outbreak is localized and does not develop into an epidemic. It calls for properly funded and co-ordinated animal disease research, including the development of rapid tests, and controversially suggests that emergency vaccination should be considered as part of control strategy. The responsibility for taking most of the suggested actions is laid at DEFRA's door. The full text of the report and the evidence is available on the Royal Society website: **www.royalsoc.ac.uk**

Malaria genomes sequenced

The genomes of *Plasmodium falciparum*, the parasite that causes malaria, and its carrier, the *Anopheles gambiae* mosquito, have been sequenced by two international consortia. This information will aid the battle against malaria which kills millions each year.

Life Sciences in Transition

The June 2002 issue of *Journal of Molecular Biology* is dedicated to *European Molecular Biology Laboratory Essays on Science and Society: Life Sciences in Transition*. It includes 18 papers grouped under the following headings: Assessing the future of the biosciences; Biosciences and basic values; Genomics and the globalization of biology; Science (mis)communication; and Rethinking reproductive technologies. All the articles are available at **www.idealibrary.com**

LTSN activities

The Learning and Teaching Support Network Centre for Bioscience is running a professional development programme this autumn. Themes include: Diversifying assessment; Practical work and on-line assessment (see **http//:bio.ltsn.ac.uk/events/futureLTSNfeed.htm**). The LTSN Bioscience Image Bank is now open. It has a searchable catalogue of biological images for use within teaching and can be found at **http//:bio.ltsn.ac.uk/imagebankuploads**

Engaging Science grants

The Wellcome Trust has announced the launch of a new £3 million grants programme. Engaging Science is designed to support projects that inform, stimulate debate and address the issues that biomedical sciences raise. The scheme aims to make biomedical sciences accessible to wide audiences. There are two categories of awards: People Awards (<£30k) and Society Awards (>£50k). For further information see **www.wellcome.ac.uk/engagingscience**