

Algal blooms can suddenly colour the ocean waters. The rash of blooms and poisoning has dramatically increased in the last 30 years and scientists are trying to understand why.

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Algal Bloom

Boon or Bane?

LANDSCAPES are generally marked by seasonality. The change in seasons is discernible in temperate locales, but subtler in the tropics. Even so, the onset of a tropical summer is obvious with the burst of flowers, fruits and faunal migration. What may not be very obvious is that the seascape undergoes a similar seasonality.

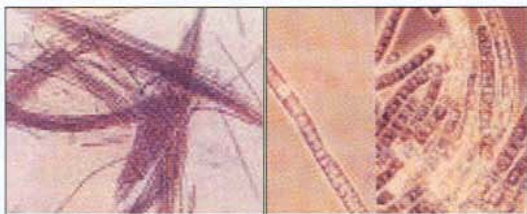
The interactions between physical, chemical, geological and biological processes that determine the structure and functioning of oceanic ecosystems are the essence of oceanography. The layering of water masses due to density differences caused by heating and cooling of water and evaporation and precipitation and the seasonal heating

and cooling of surface waters are just a few of the physical processes that give shape and structure to the ocean, which in turn dictate its chemistry and biology. In addition, the seasonal changes in the winds and current patterns bring with them alterations in the way plants and animals in the sea respond to their environment.

Many of us may not know that it is commonplace for the plants in the sea to burst forth into a dense growth – a phenomenon commonly referred to as “algal or phytoplankton blooms”. This process happens when deeper nutrient-rich waters rise to the top replacing surface waters. With the bright sunlight in the surface waters, along with nutrient enrichment, the scenario is set for a quick cascade of events that trigger the minute floating plant cells to just “float forth and multiply”. Most of these plants are moved by the winds and the waves – hence their name phytoplankton or floating plants. This process of upwelling, which brings up nutrient-rich water, creates the most biologically productive regions in the world ocean.

The upwelling blooms are strong, long-lasting events that continue as long as upwelling persists. They have been noted during the southwest monsoon off Somalia, Oman and India as a result of coastal alongshore winds. Alternatively, blooms also form when surface waters get enriched with land run-off or by anthropogenic (man-induced) influences. These are blooms in response to a nutrient replete condition. The waters turn soupy thick with plankton that are generally benign, only at times harming the fauna at the upper end of the trophic echelon.

Besides upwelling blooms there are the detrainment blooms. These are intense short-lived events that develop when the mixed layer thins abruptly, thereby increasing light intensity available for phytoplankton growth. They occur during the fall in the central Arabian Sea, and during the spring throughout most of the basin. On the west coast of Goa, blooms occur from February to May. When winds are calm, conditions are favourable for blooms that occur during nitrogen deplete conditions.



Trichodesmium

Algal blooms of *Trichodesmium* have been a regular phenomenon along the west coast of India especially just before the summer monsoon. *Trichodesmium erythraeum*, a blue-green alga, blooms along the northwest coast of India in response to the drier winds of the winter monsoon, reaching a peak by the end of March before declining by the end of April. These blooms are in response to a nutrient deplete or oligotrophic conditions when the ambient concentrations of nitrate are extremely low. Recent results suggest strongly its quantitative role in supplying nitrogen to the upper water column of the world's nutritionally poor oligotrophic seas may be much greater than previously thought.

The blooms could be either predictable or sporadic. The predictable ones are associated with eastern boundary currents of the world where major upwelling is associated with large fisheries. Blooms are marked by high density but low diversity. Nevertheless, they support highly productive zooplankton population, which in turn spell good fishery potential. The California sardine industry, the Peruvian anchovy industry and the Benguelan fishery are good examples of fisheries supported by blooms due to upwelling. Similarly,



Dinophysis (left)
Modis (below)



the linkage of larval haddock survival off the east coast of Nova Scotia, Canada to local spring blooms of phytoplankton over several years have been recently verified by remotely sensed ocean colour data. In contrast

the western boundary currents are sporadic.

As the upwelled water is further transported offshore, the same sequence of events occurs – Phytoplankton bloom, zooplankton bloom, the things that eat the zooplankton bloom (and so on) deplete the waters of nutrients, the bloom shuts down, and the upwelled water eventually warms and mixes, and biological productivity ends. Because upwelling brings cold nutrient-rich water to the surface, biological productivity in these regions is very high. In fact, productivity in upwelling regions is the highest of any region in the ocean, with the exception of kelp forests and coral reefs. Nonetheless, upwelling productivity is the highest of all oceanic ecosystems and that is why most major commercial fisheries are centered around upwelling regions.

Polar oceans typically experience only one phytoplankton bloom in the summer because of the low surface irradiance in all seasons except summer. However, polar phytoplankton blooms lead to the highest concentrations of phytoplankton (and chlorophyll) found anywhere in the ocean (with the exception of some bays and estuaries). As ice melts, it creates a lens of fresher water on top of the saltier ocean water. This melting creates stratification. Along with stratification induced by warming of the surface waters, the water column next to an ice edge becomes stratified very quickly. In addition, the melting of sea ice releases large quantities of diatoms and other phytoplankton. The result is fast stratification and "seeding" of the water column, all of which adds up to one massive phytoplankton bloom. So famous are these blooms of phytoplankton in the sea that many whales, especially grey whales and humpback whales, return to polar waters in the summer to feed on the rich organic soup.

These floating plants come in all sizes ranging from



Phytoplankton in the North Sea

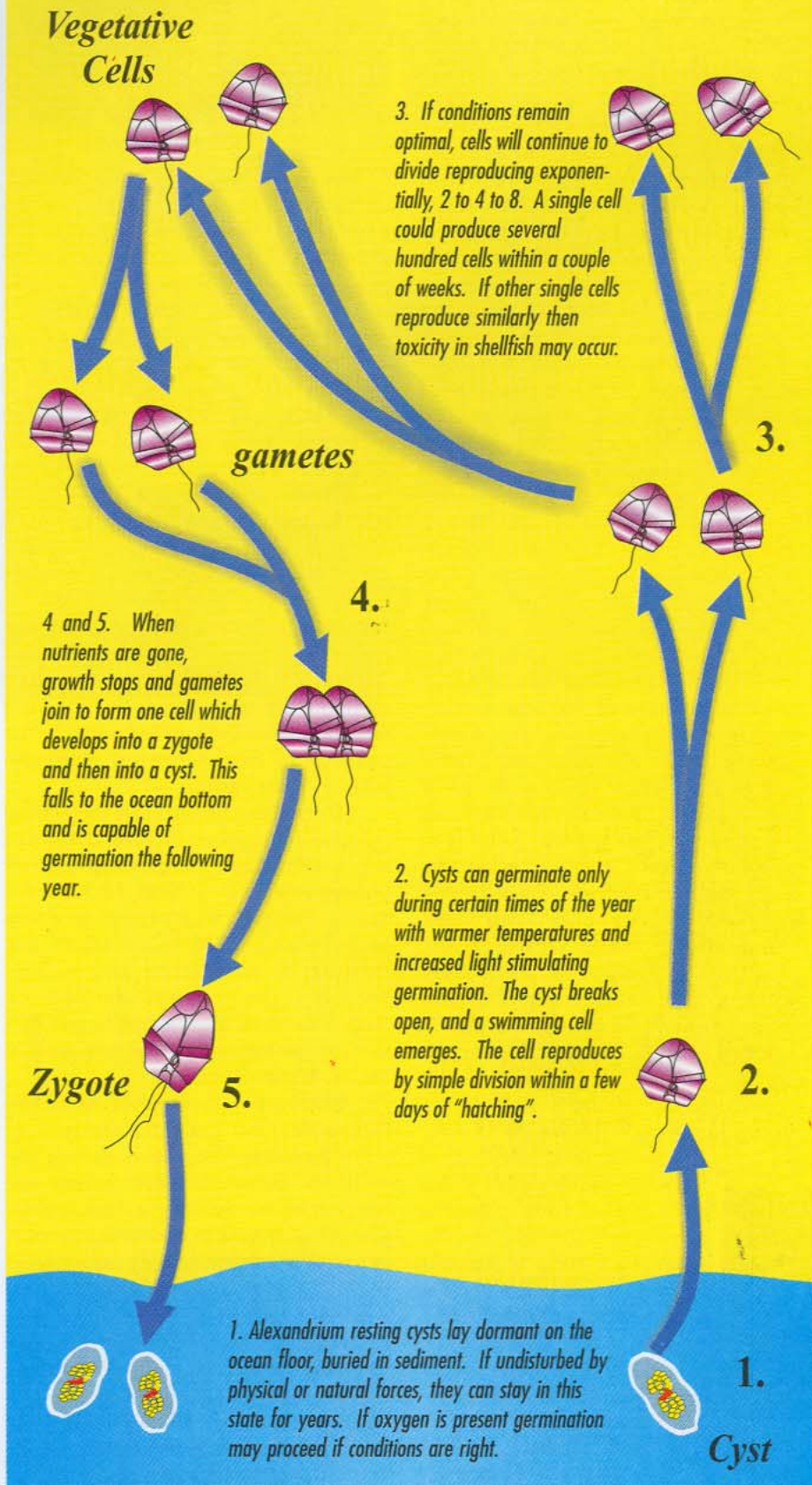
1/1000th of a millimeter to 2 mm and shapes from the mundane globules to ornate forms all with specks of chlorophyll to aid them in photosynthesis. Some live as single cells while others form chains or colonies. The ocean plant life may not only be influenced by climate changes but may also play a part in causing the change itself. With their propensity to fix carbon dioxide over wide stretches of the ocean, these plant forms are known to play a key role in controlling the temperature of our planet. Without their activity, the greenhouse gas would just accumulate and warm our surroundings to uncomfortable temperatures. Like the glass in a green house, carbon dioxide and other greenhouse gases like methane are transparent to incoming radiation from the sun but impede the passage of heat reflected from the surface of the earth.

Thus, these blooms can impact the marine ecosystem in four different ways. With their accelerated rate of photosynthesis they form the basis for marine food web. Such blooms generally attract a swarm of zooplankton, the floating or wandering animal life. Secondly, they control atmospheric carbon dioxide, a greenhouse gas that in turn can influence heat retention in the earth's atmosphere.

Chlorophyll concentration, an indicator of the density of phytoplankton, sometimes during the peak is about 100-500 times the concentration during the rest of the year. This process is now being mooted as a method of sequestering carbon from the atmosphere as a palliative to global warming. Thirdly, by multiplying to high densities, they deplete the nutrients and oxygen. When this happens fish can suffocate and die, thus leading to mass mortality. Finally, some of them can contribute substantially to the nitrogen economy of the sea.

How a Toxic Algal Bloom Occurs

The life cycle of one cell



Poisonous algae contaminated shellfish toxin

Harmful Algal Blooms

When algal blooms are caused by toxic algal species they are referred to as HABs or harmful algal blooms. Though there are about 5000 species of marine phytoplankton, only a small percentage 6% of the species that proliferate in high numbers discolour the surface of the oceans. A still smaller percentage, that is, < 0.02% or so could actually produce potent toxins that can harm humans through fish or shell fish.

The scale and development of HABs may vary considerably. Shellfish such as clams, mussels, oysters and scallops can accumulate algal toxins to levels that are potentially lethal when ingested by larger fish, mammals and humans. It is the lack of effect on fish and shellfish that we consume that makes marine biotoxins so dangerous, since there is no outward sign that can forewarn the consumer. On a global scale, nearly 200 incidents of human poisoning including mortality in 15% of the cases are reported annually. Even porpoises and whales are not exempted from poisoning through the food chain.

These toxins can only be detected through laboratory analyses. However, sometimes blooms of *Trichodesmium erythraeum* have been reported to have adverse effect on oil sardine fisheries. These marine biotoxins are some of the most potent chemical compounds known – some of which are more lethal than sodium cyanide. Toxins can be transferred through successful levels of food chain, sometimes having lethal effects. The lethal effects are not destroyed even after cooking, and efforts to develop antidote have met with little success. However, administration of enema and laxatives are recommended for immediate relief.

Though algal blooms are natural processes, in the past two decades, the

impacts of such phenomena have increased in frequency, intensity and coverage plausibly due to growing scientific awareness of toxic species. The other possible reasons attributed to the increased HABs include natural mechanisms of species dispersal (currents and tides) – to a host of human-related phenomenon such as nutrient enrichment, climate shifts, and transport of algal species via ship ballast water. In some countries like USA, virtually all the coastal regions are now subject to a variety of harmful algal blooms.

Marine waters are characteristically blue or green, but under certain conditions, a single algal species can increase in abundance until they dominate and reach high concentrations and change the colour of the water. Although commonly referred to as the “red tide”, the hue of the waters can range anywhere from milky white to yellow, green or brown.

Only a few dozen of the many thousands of species of microscopic and macroscopic algae are repeatedly associated with toxic or harmful blooms. Some species, such as the dinoflagellate *Alexandrium tamarense* and diatom *Pseudonitzschia australis*, produce potent toxins which are liberated when the algae are eaten.

Many cyanobacteria produce potent neurotoxins and when massive accumulation of cyanobacteria occurs, animals ingesting them may succumb. Fortunately, the massive accumulation needed to cause death does not occur extensively.

Tracking Blooms

Now remotely sensed data are used to detect and track down the flow of blooms in oceanic and coastal water bodies. The advanced, very high-resolution radiometer (AVHRR), coastal zone colour scanner (CZCS) image and sea-viewing wide field-of-view sensor (SeaWiFS) could monitor the development of blooms. However, we still need surface-based measurements to pin point harmful parts of the algal blooms and which are benign bloom of diatoms.

For most part, when we have a good fish catch, healthy and benign bloom would have been ultimately responsible. In our own waters, coastal upwelling of nutrients during and after the southwest monsoon has been

Algal Bloom Caution!

DURING a cyanobacterial bloom, the water looks and smells bad, although there are no reports of people getting sick from blue-green algae bloom. To minimize the risk of direct contact, people should follow some practical precautions:

- Don't wade or swim in water containing visible blooms, and avoid direct contact with dense mats of algae. Boating is less risky than swimming or wading.
- Limit exposure to water where blue-green algae are readily visible, walking on the shore or fishing from a dock is less risky than being out on the water.
- Don't drink untreated water or let children, livestock or pets get into or drink the untreated water. In addition to possible health risks from algal blooms, other gastrointestinal illnesses can also be contracted by drinking untreated water, such as giardiasis, cryptosporidiosis, hepatitis A viral infection or *E. coli*-related diseases.
- People who are prone to hay fever and asthma from environmental triggers should avoid algal bloom areas.
- Make sure children are supervised at all times when they are near water. Drowning, not exposure to algae, remains the greatest hazard of water recreation.
- If you do come into contact with the algae or the water around a bloom, simply rinse off with fresh water as soon as possible.
- Because of the potential for local irritation from direct skin contact, it is recommended that water-resistant gloves be used in handling and removing unwanted algae that may build up or wash up on shores and surfaces.

Red Tides

RED tide is a naturally occurring estuarine or marine algal bloom that grows very fast and accumulates into dense, visible patches near the surface of the water. “Red Tide” is a common name for such a phenomenon where certain phytoplankton species contain reddish pigments and “bloom” such that the water appears to be colored red. Red tide is caused by species of dinoflagellates, often present in sufficient numbers (thousands or millions of cells per milliliter) to turn the water red or brown. They are usually not harmful; and those species that are harmful may never reach the densities required to discolor the water.

The specie responsible for red tides on

the gulf coast of Florida is *Karenia brevis* (formerly *Gymnodinium breve*). It produces brevetoxins which produce respiratory irritation in humans. Algal blooms in lakes and rivers may be caused by greatly increased amounts of phosphorus or nitrogen entering an aquatic ecosystem from either sewage systems or agricultural fertilizers. Red tides also occur in places where there are no associated human activities. A small number of species produce potent neurotoxins that disrupt the proper function of neurons. These toxins even kill higher forms of life such as fishes, birds, marine mammals and even humans that feed either directly or indirectly on them.

considered to support rich fisheries off the west coast of India. However, with increasing anthropogenic influences these very processes that prove to be a boon could turn to be a bane. The causes of the increased incidence of these blooms worldwide are still debated. Some of these causative organisms may be opportunistic species newly introduced into the system and able to dominate it swiftly. Others may be around in small numbers all the time, but a certain combination of environmental parameters triggers their rapid growth and development.

Blooms can last anywhere from a few days to a few weeks, from highly localized area to vast stretches. Their appearance can be as dramatic as their disappearance. One of the reasons attributed is temperate phages. Some of these populations lyse or self-destruct due to the viruses that they

intrinsically carry with them, yet others dissipate due to drastic fall in nutrients. Whatever be the reason, it is now becoming apparent that it would be possible to predict blooms and their intensity by the abundance of spores in the sediment.

There are worldwide indications that the occurrence of harmful algal blooms is becoming frequent. However, the events leading to outburst is yet to be clearly understood. We have now begun to realize that there are not enough observations on the coastal waters to cover sufficient duration, space and resolution. Real time data, telemetry, assimilation and visualization could be used effectively to predict environmental changes. Satellite observations could help determine more accurately the distribution and density of blooms and resolve the

Health Risks

HUMANS are exposed principally to the naturally occurring toxins produced by harmful algae through the consumption of contaminated seafood products.

Amnesic Shellfish Poisoning (ASP): Causative organism is *Pseudo-nitzschia* sp. and the toxin produced is domoic acid. It can be a life-threatening syndrome. It is characterized by both gastrointestinal and neurological disorders. Gastroenteritis usually develops within 24 hours of the consumption of toxic shellfish; symptoms include nausea, vomiting, abdominal cramps, and diarrhoea. In severe cases, neurological symptoms also appear, usually within 48 hours of toxic shellfish consumption. These symptoms include dizziness, headache, seizures, disorientation, short-term memory loss, respiratory problems and coma.

Ciguatera Fish Poisoning (CFP): Causative organisms are *Gambierdiscus toxicus*, *Prorocentrum* spp., *Ostreopsis* spp., *Coolia monotis*, *Thecadinium* sp. and *Amphidinium carterae*. They produce ciguatoxin/

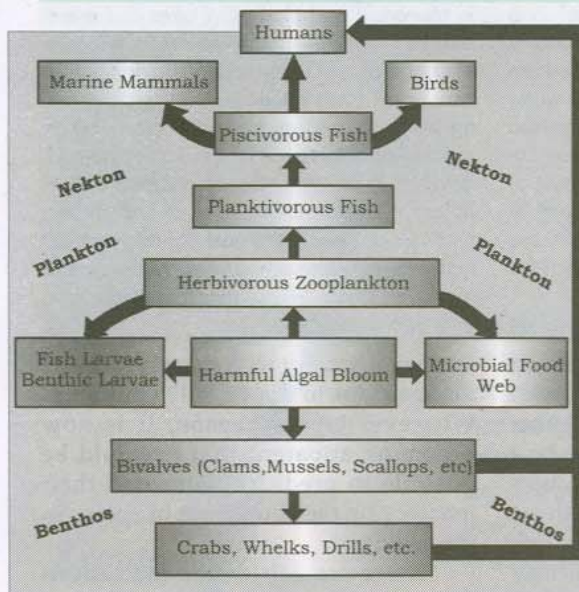
maitotoxin, which produces gastrointestinal, neurological, and cardiovascular disorders. Generally, diarrhoea, vomiting, and abdominal pain occur initially, followed by neurological dysfunction including reversal of temperature sensation, muscular aches, dizziness, anxiety, sweating, and numbness and tingling of the mouth and digits. Paralysis and death have also been documented. Recovery time is variable, and may take weeks, months, or years.

Diarrhetic Shellfish Poisoning (DSP): Causative organism of this disease is *Dinophysis* sp. and it produces the toxin okadaic acid. DSP produces gastrointestinal symptoms, usually beginning within 30 min to a few hours after consumption of toxic shellfish. The illness, which is not fatal, is characterized by incapacitating diarrhea, nausea, vomiting, abdominal cramps, and chills. Recovery occurs within three days, with or without medical treatment.

Neurotoxic Shellfish Poisoning (NSP): This is caused by *Karenia brevis* and the toxins produced are brevetoxins. It produces an intoxication syndrome nearly identical to

that of ciguatera. In this case, gastrointestinal and neurological symptoms predominate. Besides, formation of toxic aerosols by wave action can produce respiratory asthma-like symptoms. No deaths have been reported and the syndrome is less severe than ciguatera, but nevertheless debilitating. Unlike ciguatera, recovery is generally complete in a few days.

Paralytic Shellfish Poisoning (PSP): *Alexandrium* spp., *Gymnodinium catenatum*, *Pyrodinium bahamense* are the causative organisms producing saxitoxins. PSP, like ASP, is a life-threatening syndrome. Symptoms are purely neurological and their onset is rapid. Duration of effects is a few days in non-lethal cases. Symptoms include tingling, numbness, and burning of the perioral region, ataxia, giddiness, drowsiness, fever, rash, and staggering. The most severe cases result in respiratory arrest within 24 hours of consumption of the toxic shellfish. If the patient is not breathing or if a pulse is not detected, artificial respiration and CPR may be needed as first aid.



frequency and duration of bloom occurrence on a synoptic scale.

A pilot project to detect and forecast HABs in the northern Gulf of Mexico is already underway by the Environmental Protection Agency (EPA), US. The data needed include sea surface temperature, winds, currents and waves; precipitation and freshwater flows with discharges of sediment and nutrients; salinity, dissolved oxygen, and chlorophyll concentrations (*in vivo* fluorescence); and remotely-sensed

spatial images of sea surface chlorophyll concentrations. These data are provided via a mixture of discrete and autonomous *in situ* sensing with near real-time data telemetry, and remote sensing from space (SeaWiFS), aircraft (hyperspectral imagery) or land (high-frequency radar). With calibration across these platforms, the project is expected to provide a four-dimensional visualization of harmful algal bloom in time for resource managers responsible for protection of public health and aquatic resources.

From a practical viewpoint, the taxonomic diversity of HAB species complicates monitoring operations, which require a high degree of specialised expertise. The automatised detection of harmful species, for example, with specific molecular probes, seems an attractive approach that would increase monitoring efficiency.

Scientists are also exploring the possibility of containing the toxic effects of blooms by using naturally occurring viruses, as they have been known to dissipate certain blooms. The toxic alga *Phaeocystis globosa*, which

attacks the north sea coast each spring and summer, is decimated by viruses. The colonies are slimy with tens and thousands of brown algal cells. Strong winds whip up the slime into foam thick enough to choke filter-feeding animals like shellfish, herbivorous plankton and fish. Though the algae are not susceptible to viruses during rapid growth, they succumb when they weaken after nutrient depletion. Researchers foresee possibilities of controlling toxic algae with the help of viruses at least in enclosed bodies of water to begin with.

Observations of these events of blooms are few and far between in our waters. Scientists at the National Institute of Oceanography (NIO), Goa are putting in concerted efforts to monitor these phenomena on temporal and spatial scales either to be able to forecast potential fisheries or for timely intervention and mitigation of toxic blooms. However, an effort to network coastal marine institutions and government agencies to design and implement observation systems would be the need of the hour.

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