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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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.
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 depleted 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, 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 $1/1000^{th}$ 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

1. Alexandrium resting cysts lay dormant on the ocean floor, buried in sediment. If undisturbed by physical or natural forces, they can stay in this state for years. If oxygen is present germination may proceed if conditions are right.

2. Cysts can germinate only during certain times of the year with warmer temperatures and increased light stimulating germination. The cyst breaks open, and a swimming cell emerges. The cell reproduces by simple division within a few days of "hatching".

3. If conditions remain optimal, cells will continue to divide reproducing exponentially, 2 to 4 to 8. A single cell could produce several hundred cells within a couple of weeks. If other single cells reproduce similarly then toxicity in shellfish may occur.

4 and 5. When nutrients are gone, growth stops and gametes join to form one cell which develops into a zygote and then into a cyst. This falls to the ocean bottom and is capable of germination the following year.

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 discolor 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 shellfish.

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
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 species 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 fish, birds, marine mammals and even humans that feed either directly or indirectly on them.

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 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 domaioic 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 diarrhea. 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 monilis, Thracidium sp. and Amphidinium carterae. They produce ciguatoxin/

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

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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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