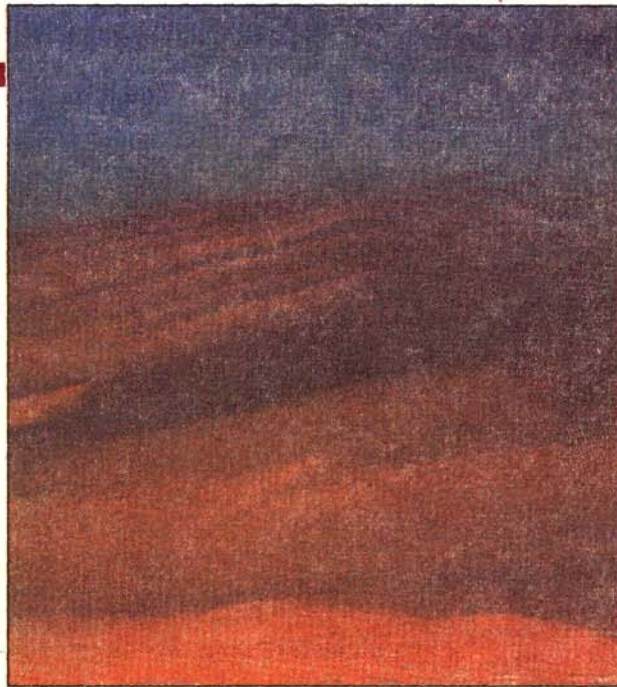


A poisonous red tide off the coast of Yucatan, Mexico in 1980 (Courtesy: *Nature & Resources*)



and discolours the water. In the above case, for instance, it was the *Gymnodinium* sp. that turned out to be the culprit. Certain killer red tides have even caused widespread losses to human life and to the fishing industry at several places. Measures adopted to control these harmful events have either proved ineffective or are economically unviable.

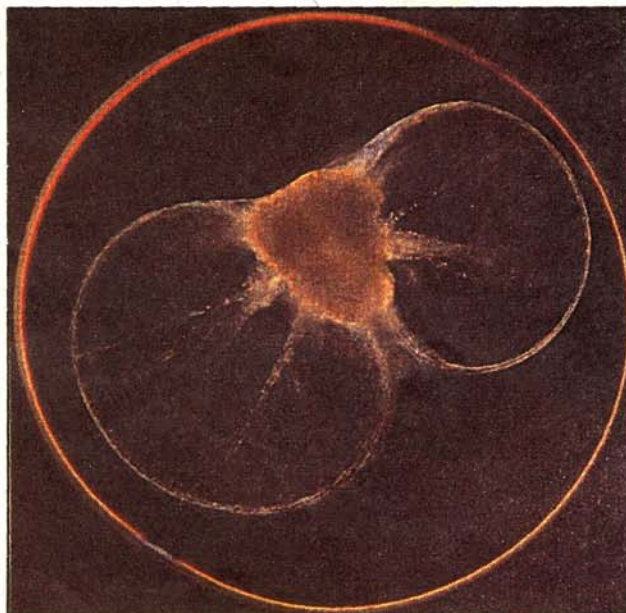
The phenomenon has been puzzling oceanographers for several years. It is still not clearly understood as to why any planktonic species should suddenly start blooming. Red tides generally break out under favourable environmental conditions such as calm sunny weather and gentle breeze, or when two dissimilar water masses meet, or when

THE KILLER TIDES

When the pristine blue of the sea suddenly turns a deadly red it could be a disaster in the offing. Tiny microorganisms that unleash these red tides poison marine life and are fatal to humans who feed on them. **V.P. DEVASSY** and **S.R. BHAT** explain the curious phenomenon of these red tides

IN 1972, on the southeast coast of Japan, bathers on the beaches suddenly felt the presence of a mysterious gas, bubbling out of the sea, that caused difficulty in breathing and irritated their eyes and nose. And as a sequel to this strange phenomenon thousands of dead fish were found heaped up on the resort area beaches. Several other marine organisms died as their oxygen supply was cut off. The deadly 'red tide' had once again unleashed an ecological disaster off the coasts of Japan.

The red tide is a disastrous phenomenon often encountered in the seas. A certain species of plankton suddenly starts blooming (rapid increase in population), attains astronomical proportions



A dinoflagellate (Courtesy: *Seashore Life*)

factory effluents, domestic sewage or agricultural fertilizers are released into the sea. It is also observed that in the spring, the seas having been stirred by winter storms, bring to the surface a supply of nutrient-rich water. This, with the increasing hours of sunlight, rouse certain species of plankton to life which then multiply at an astonishing rate spreading a living carpet over large areas of the sea. Hundreds of square kilometres of the sea are tinged pink, red, brown, orange, even green. It is perhaps to this phenomenon that the Red Sea owes its name, as in the early days, sailors passing through this sea during certain seasons observed a blood-red colour imparted to the water over long stretches due to a red tide.

FOR a red tide to form, a seed population must be present to act as an inoculum. This is effected by the planktonic population present on the seabottom. However, red tides may originate from a discrete water mass (autochthonous) or originate elsewhere and get transported to another area (allochthonous) by winds and currents. Normally blooms last for 2-3 weeks and may die down as a result of biological degradation or due to the formation of cysts which sink to the bottom sediments. Also, as the upwelling of rich sea-bed water ceases, the supply of minerals dwindles leading to a decline in the population. The bloom may also come to an end as the weather changes from calm, sunny conditions to turbulent mixing of the water column.

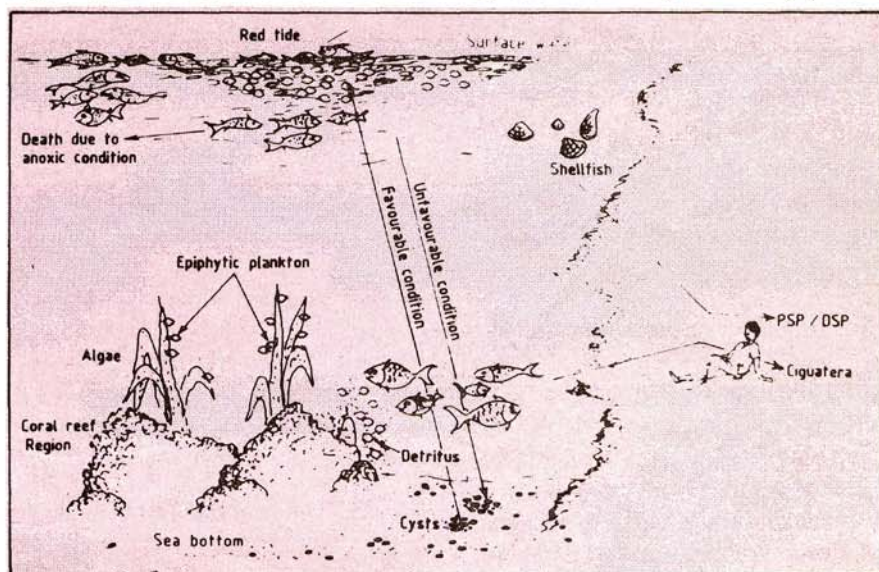
Though by and large red tide events are harmless, under exceptional conditions they do have detrimental effects. For, though the bloom may die down in a few weeks time, but not until after the marine life has gulped in, what could sometimes turn out be, poisonous species of plankton.

The red tides of a blue-green alga *Trichodesmium*, have been widely reported from tropical and subtropical regions. In the Indian Ocean, its occur-

rence from February to May is a regular feature and is very evident due to the fact that a vast expanse of surface water exhibits sawdust-sprinkled appearance. Extensive red tides spreading over large areas varying from 40,000 sq. km. to 52,000 sq. km. have been reported from different regions of Australia, Java, the westcoast of India and Lakshadweep. At times the population explosion is so high that the red tide cuts off supply of oxygen to marine animals which eventually perish. For instance, in New York Bight during 1972, a red tide caused by the dinoflagellate *Ceratium tripos* is believed to have killed fish and

mals. Under normal circumstances the concentration of toxic species in the total phytoplankton population is not heavy enough to cause trouble, it is only when their number suddenly increases astronomically, that the real danger arises.

Dinoflagellates are found in all aquatic bodies. However, a bizarre variety are met with in tropical seas. Some species such as *Noctiluca scintillans*, *Pyrodinium bahamense* var. *compressa*, and *Gonyaulax polyedra*, are well known for their spectacular display of luminescence. They, as any other algae, reproduce asexually or sexually (known



The pathway of human intoxication through ingestion of toxic red tide organisms

shellfish due to prolonged paucity of oxygen in the bottom waters over an area of 13,000 sq. km.

Marine fauna are more commonly killed by blooms of certain toxic dinoflagellates. Though only 23 of the 2000 extant species are known to be toxic, the widespread notoriety of the intoxication and the serious problems associated thereby, have propelled various government bodies and research organisations the world over to find a solution to this recurring phenomenon. It has been estimated that about 2,000 cases of poisoning occur each year following ingestion of toxic marine ani-

only in a few species) and form cysts under unfavourable conditions. The persistent cyst population also contributes in a significant manner to the intoxication of the fauna. Although the toxins present in the cysts are not presently known, they are thought to be very potent.

TOXIC dinoflagellate red tides are known to cause three types of sea food poisoning. Paralytic shellfish poisoning (PSP) and diarrhetic shellfish poisoning (DSP) are very common and recurring ones. The third type of poisoning is called Ciguatera, the origin of which was a mystery for a long time.

Ciguatera is caused due to the consumption of fish feeding on toxic dinoflagellates. The species known to produce ciguatoxins is the benthic *Gambierdiscus toxicus* found in coral reef areas. The fishes implicated in this type of food poisoning are mainly moray eels, red snapper (*Lutjanus bohar*) and *Barracuda* (*Sphyracna barracuda*), which mostly occur in the Caribbean and Pacific coasts. The toxin produced by these species is apparently not harmful to fishes feeding on the dinoflagellates. But several cases of intoxication of people feeding on these fishes have been reported from Florida and Hawaii. In one such incident in 1982 in the Bahama region, a *Barracuda* fish weighing 12 kilogrammes was captured and eaten by twenty two members of the Italian supertanker *Corragio*. Eighteen of them were intoxicated, and were so severely affected that they had to be air-lifted to Miami for treatment.

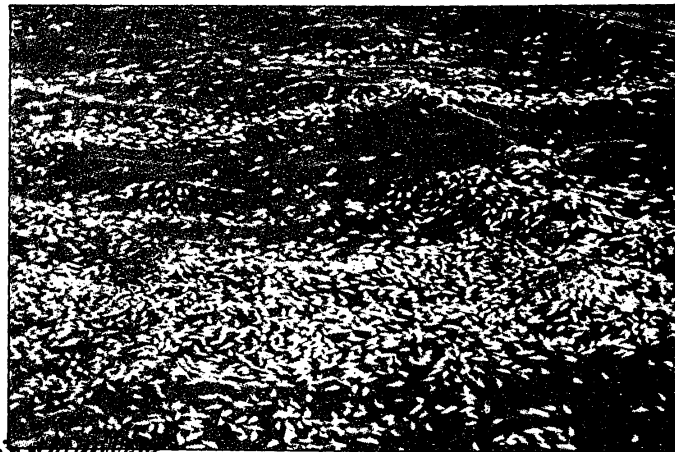
While ciguatera is caused by the consumption of fish feeding on toxic dinoflagellates on the sea bed, PSP and DSP largely occur due to the consumption of shellfishes such as clams, mussels, and scallops. Shellfishes being filter-feeders, pump in large volumes of water containing plankton. If the ingested mass comprises largely the toxic dinoflagellates, then the toxin present in these organisms enters the digestive system of the shellfish and gets accumulated in the body tissue with hardly any harmful effect on them. However, the degree to which the filter-feeders become toxic depends on the concentration and duration of the toxic red tide, rate of feeding and the quantity of toxin accumulated. No instance of direct kills of shellfish by PSP have been reported so far. Some clams mysteriously maintain the toxin

year round in their siphon, despite the apparent absence of the causative organisms in the surrounding waters.

A series of toxins and their derivatives such as saxitoxins, gonyautoxins, neosaxitoxins and brevetoxins have been isolated from shellfish and toxic dinoflagellates. These toxins are said

the whole of the Indo-pacific region. The toxin-producing ability of the dinoflagellates seems to be rather whimsical, and the function of the toxin produced and, for that matter how they are synthesised, remains a mystery. They are however believed to be synthesised *de novo* via a highly compartmentalised biosynthetic route.

PSP has long been known as a serious hazard in different regions of the world particularly Europe, North America, Pacific coast and Asia. On a global scale close to 2,000 cases of human poisoning through PSP and DSP occur annually. Even deaths have been reported from various parts of the world. India experienced its first PSP problem in 1981 when there were three deaths and 82 reported seriously ill after



Species like *Gymnodinium*, *Gonyaulax* and others produce red tides that kill many fishes

to be the most potent non-proteinaceous lethal materials known. Particularly the neurotoxins are the most notorious. Among the toxic dinoflagellates, *Pyrodinium bahamense* var. *compressa* is implicated as the number one danger in

eating toxic bivalves in Tamil Nadu. One death and seven cases of illness were again reported in 1983 from the Mangalore coast. However, the dinoflagellates responsible could not be identified.

Some important toxic red tide forming organisms

Species	Type of toxicity	Major distribution
<i>Gonyaulax</i> (<i>Protogonyaulax</i>) <i>catenella</i>	Paralytic Shellfish Poisoning (PSP)	North Pacific California British Columbia, Japan
<i>Gonyaulax tamarensis</i>	PSP	North Atlantic—Canada,
<i>Gonyaulax tamarensis</i> var. <i>excavata</i>		UK, North Sea, Japan, Argentina
<i>Gonyaulax monilata</i>	Ichthyotoxin	Florida coast
<i>Gambierdiscus toxicus</i>	Ciguatoxin	Tropical waters
<i>Dinophysis fortii</i>	Diarrhoeic Shellfish Poisoning (DSP)	Northern Japan
<i>Noctiluca scintillans</i>	PSP? Ichthyotoxin?	South China
<i>Gymnodinium</i>	Neurotoxin?	Gulf of Mexico
<i>Ptychodiscus breve</i>	Ichthyotoxin?	
<i>Prorocentrum micans</i>	DSP	North Sea—Netherlands
<i>Prorocentrum minimum</i>		
<i>Pyrodinium bahamense</i> var. <i>compressa</i>	PSP	South Pacific
<i>Gonyaulax acatenella</i>	PSP	British Columbia
<i>Chattonella marina</i>	Ichthyotoxin ?	Japan
<i>Chattonella antiqua</i>	Ichthyotoxin ?	Japan
<i>Polylepis chrysochromulina</i>	Ichthyotoxin ?	Norway, Sweden, Denmark

The symptoms caused by PSP and ciguatera are similar and occur within twelve hours of poisoning. Symptoms of PSP are very severe and sometimes fatal. The latent period may be as long as forty eight hours. The symptoms are diarrhoea, abdominal pain, nausea and vomiting. In more severe cases neurological abnormalities result, which often last several weeks. These include tingling of lips and tongue, numbness of legs, arms and neck. Muscular paralysis becomes more acute and death may result from respiratory failure. Other symptoms associated are joint pains, chills and headache, difficulty in breathing, etc. In many cases, the patient may not be able to coordinate his voluntary movements and looks as though he were drunk.

The magnitude of damage to fisher-

ies caused by toxic red tides was to the tune of US \$ 55 million in Japan during 1972. During a two-week ban on the consumption of mussels in some areas of Philippines during 1983, the loss was estimated to be around US \$ 25,000. And as recently as 1988 a Scandinavian killer alga created a sensation as it devastated marine life and caused a loss of US \$ 240 million to the fishing industry of Norway alone.

Efforts to develop an antidote to the toxins have been more or less unsuccessful. In some countries, for instance in the South Pacific region, the natives use certain medicines to cure the illness but the formulation of these medicines is a closely guarded secret. Even cooking the shellfish or fish does not destroy these toxins. However, as a first-aid measure toxin-control experts recom-

mend that stomach and bowels should be emptied as quickly as possible by first administering enema followed by a rapidly acting laxative. Breathing difficulty should be relieved by artificial respiration.

There does not seem to be any effective preventive measure once a red tide outbreak has occurred. The various chemical and biological methods that have been attempted have had mostly negative or short-term results. During one such outbreak in Florida, Copper Sulphate was sprayed from boats and planes over twenty five miles of infested offshore waters. This did reduce the organism temporarily in the treated area but the mass of dead red tide released endotoxins into the water and the decomposing mass created deleterious effects due to anoxic conditions. Moreover, most of these measures are very expensive. Many countries have already started monitoring vulnerable areas of shellfish and fish culture for toxicity by mouse assay. They have also introduced stringent control measures over the sanitary quality of shellfish meant for human consumption. Studies are also continuing on the identification of the triggering mechanisms, prediction of such outbreaks and to find an antidote to cure the illness. Since these outbreaks are sporadic and unpredictable, regular monitoring of the red tide areas, of their cyst population in the sediments and the associated seafood products along with the timely reporting of outbreaks of illness will improve the chances of avoiding these catastrophic events. But human contribution to the blooming of these red tides can also not be overlooked. There is a general belief that toxic red tide outbreaks are on the increase probably due to increasing urbanisation and discharge of sewage, organic pollutants, industrial wastes and agricultural fertilizers into the sea. This anomaly would have to be corrected.

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Some important events of red tide outbreaks

Country/Region	Causative organism	Estimated loss
Florida Gulf coasts (1946-47)	<i>Ptychodiscus brevis</i>	500 million fishes killed, airborne particles of the toxin became optic and respiratory irritant
Japan (1972)	<i>Gymnodinium</i> sp.	Contaminated nearly 100 miles of southeast coast, windrows of dead fish were heaped up on the resort area beaches and bathers complained of a mysterious gas which caused difficulty in breathing and irritated eyes and nose
Japan (1972)	<i>Chattonella</i> sp.	Heavy loss due to the death of yellow tail fish
Japan (1984)	<i>Gymnodinium nagasakiense</i>	Loss due to the death of yellow tail fish and shellfish
Massachusetts (1972)	<i>Gonyaulax catenella</i>	Hundreds of seagulls and ducks killed, scores of people sick and tremendous economic hardship due to the ban on harvest and sale of clams
Malaysia (1976)	<i>Pyrodinium bahamense</i>	7 human deaths, 195 ill due to PSP
Malaysia (1983-84)	-do-	5 human deaths and 20 severely ill
New York (1976)	<i>Ceratium tripos</i>	Heavy loss to the tune of US \$ 35,00,000 due to the death of caged fish
Philippines	<i>Pyrodinium bahamense</i> var. <i>compressa</i>	300 humans ill and heavy loss worth US \$ 2.2 million due to the ban on collection and sale of shellfishes
Hong Kong (1983)	<i>Ceratium furca</i> <i>Gymnodinium</i> sp. <i>Prorocentrum</i> sp.	More than 12 outbreaks during the year resulting in heavy loss of wild and cultured fishes
India (1981)	Unidentified	3 deaths, 82 showed neurotic symptoms due to the consumption of clam <i>Meretrix casta</i>
India (1983)	-do-	1 dead and 7 hospitalised due to consumption of clam <i>Meretrix casta</i>
Thailand (1983)	<i>Protogonyaulax</i> sp. <i>Gymnodinium</i> sp.	1 dead, 60 severely ill
Norway (1988)	<i>Chrysochromulina polylepis</i>	Heavy loss due to the death of fish worth US \$ 240 million