ASPECTS OF PHYTOPLANKTON BLOOMS IN RELATION TO MOLLUSCS AND MAN

Gudrun G. Thórarinsdóttir
Marine Research Institute, P.O. Box 1390, Skúlagata 4, 121 Reykjavík, Iceland

ABSTRACT

There is an apparent global spreading and increase in frequency of harmful and toxic phytoplankton blooms. These blooms are no longer limited to dinoflagellates and the list of highly toxic forms is growing. Filter feeding bivalves are no longer the only organisms causing shellfish poisoning. Gastropods and crustaceans can become toxic as well. The types of poisoning, the major species of microalgae involved, and the geographical distribution are reviewed.

INTRODUCTION

About 5,000 species of marine phytoplankton have been described from the world's oceans (Sournia *et al.* 1991). About 300 of these species can at times occur in such high numbers that they become harmful to man's interests, while 40 species are known to produce potent toxins that can find their way through fish, crustaceans, and molluscs to humans and cause so-called shellfish poisoning. Algal blooms, including those of harmful algae, are natural phenomena which have occurred throughout recorded history. It is believed that the first written reference appears in the Bible. It has been reviewed in international conference proceedings that public health and economic impacts of such events appear to have increased in frequency, intensity and geographical distribution the past two decades (Yasumoto *et al.* 1996). Consumption of fish or shellfish are now globally reported to cause many thousand cases of human poisoning with some mortality each year.

It is unknown if this increase is real increase, or just a result of the increased number of observations. Reports of harmful algal blooms associated with human illnesses and damage to aquaculture are receiving increased attention in the press and in the sciences. More and more researchers are surveying their local waters for the causative organisms. Aquaculture operations act as sensitive bioassay systems for harmful algae and can bring to light the presence in water bodies with problem organisms not known to exist there before. The increase in shellfish farming world-wide is therefore leading to more reports of shellfish poisoning.

Eutrophication from domestic, industrial and agricultural wastes can stimulate harmful algal blooms. Phosphate and nitrate concentrations in the sea are rising, causing altered nutrient ratios which may favour blooms of harmful phytoplankton as has been reviewed both from Europe (van Bennekom & Salomons 1981, Riegman & Noordeloos 1991) and Asia (Lam & Ho 1989, Okaichi 1989). Also global climate changes might increase bloom of toxic dinoflagellates as *Gymnodinium* (Fraga & Bakun 1993).

Phytoplankton species can be moved from one part of the world to another with cargo vessel ballast water. The problem of ballast water transport of plankton species has gained considerable interest. Evidence has been brought forward that toxic species have been introduced into new waters with disastrous consequences (Rigby & Hallegraeff 1996). Another vector for the dispersal of algae, and especially their resting cysts, is transfer of shellfish stocks from one area to another. The faeces and digestive tracts of bivalves can contain viable cells and resting cysts (Scarratt *et al.* 1993).

REVIEW

Harmful phytoplankton blooms

There are three types of harmful phytoplankton blooms. The first type of algal bloom causes oxygen depletion which kills fish and invertebrates. Under exceptional conditions as in sheltered bays, many harmless phytoplankton species can grow so dense that they generate anoxic conditions. Oxygen depletion can result from high respiration by the algae while still suspended in the water column, but is more commonly caused by bacterial respiration during decay of the dead phytoplankton after sinking to the sea floor.

Another type of harmful bloom can kill fish and invertebrates by damaging or clogging gills and inhibiting respiration. The algae species causing this bloom are non-toxic to humans, but can become harmful to fish and invertebrates when they occur in high numbers. This type of harmful bloom has become apparent only as a result of man's increased interest in aquaculture systems for finfish. These algae can seriously damage fish gills either mechanically or through production of haemolytic substances. Wild fish stocks have the freedom to swim away from problem areas, but caged fish and molluscs are extremely vulnerable to such algal blooms.

The third type of harmful phytoplankton bloom is the one causing shellfish-poisoning in humans. This type is essentially different from the two others because the species produce potent toxins that find their way through fish or shellfish to humans and cause so-called shellfish poisoning. In this case even low densities of the toxic phytoplankton can cause illness or death in humans. The shellfish have in such cases been feeding on toxic phytoplankton. The toxin has no effect on the shellfish but cause illness in people and other mammals eating the shellfish.

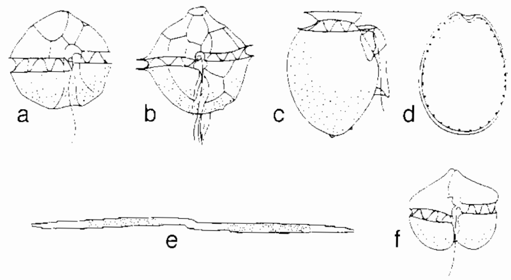

Fig. 1. Representative selection of toxic phytoplankton species: a. *Alexandrium tamarense*; b. *Pyrodinium bahamense*; c. *Dinophysis acuminata*; d. *Prorocentrum lima*; e. *Pseudonitzschia pseudodelicatissima*; f. *Gymnodinium breve.*

Four types of shellfish poisoning

There are four different types of shellfish poisoning caused by the 40 phytoplankton species known to be able to produce toxins. These are; paralytic shellfish poisoning (PPS), diarrhoetic shellfish poisoning (DSP), amnesiac shellfish poisoning (ASP), and neurotoxic shellfish poisoning (NSP).

Paralytic shellfish poisoning. The best known type of shellfish poisoning is paralytic shellfish poisoning (PSP). The first fatal case of human poisoning after eating shellfish was recorded 200 hundred years ago in Canada (Dale & Yentsch 1978). Mild symptoms of this poison are headache, tingling sensation or numbness around lips, and diarrhoea occurring within 30 minutes after digestion. In extreme cases the patients die because of respiratory paralysis which can occur within 2-24 hours after ingestion (Hallegraeff 1991). Most of the species causing PSP belong to *Alexandrium* species (Fig. 1a) which are very wide spread and every year cause many thousands cases of PSP poisoning all over the world. Another PSP producing species is *Pyrodinium bahamense* (Fig. 1b) which is confined to tropical, mangrove-fringed coastal waters of the Atlantic and Indo-West Pacific. *P. bahamense* is the most important toxic species in the Indo-Pacific region. Until 1970, PSP poisoning was only recorded from Europe, North-America, Japan, and South Africa (LoCicero 1974), but in 1990 also from Indonesia

(Adnan 1993), South America, Australia, India, Malaysia, and Thailand (Yasumoto *et al.* 1996).

Diarrhoetic shellfish poisoning (DSP). The DSP is a less severe type of poisoning. Unlike PSP no human deaths have been reported by DSP and patients usually recover within 3 days. The symptoms of the poisoning are diarrhoea and abdominal pain appearing 30 minutes to a few hours after ingestion (Hallegraeff 1991). The clinical symptoms are very much alike bacterial food poisoning and therefore the DSP may be much more widespread and serious than previously thought as many cases may not be recorded as DSP. This type of poisoning is caused by various *Dinophysis* species (Fig. 1c) and by the benthic species *Prorocentrum lima* (Fig. 1d) which are found all over the world. DSP poisoning was first documented in 1976 from Japan (Yasumoto *et al.* 1978). Since then it has been reported in Europe, Chile, North America, New Zealand, Thailand, and Australia and lately in India (Yasumoto *et al* 1996).

Amnesiac shellfish poisoning. The third type of shellfish poisoning, called amnesiac shellfish poisoning (ASP) or DAP (domoic acid poisoning), was first recognised in 1987 in Canada. In this first case 105 people got sick and 3 died after eating mussels (Bates *et al.* 1989). The symptoms are abdominal pain, diarrhoea, dizziness, memory loss, and in some cases death (Hallegraeff 1991). The phytoplankton species producing this toxin belong to *Pseudonitzschia* (Fig. 1e) which is a diatom. However, most species producing toxins belong to the dinoflagellates. The record of a toxic diatom species was an unpleasant discovery since diatoms had always been considered harmless and species of *Pseudonitzschia* are wide spread around the world. But, the toxin is only produced by the diatom under very special circumstances (Bates *et al.* 1991). After 1987 domoic acid has been found in mussels from the east coast of the USA (Horner *et al.* 1996), Spain (Miguel *et al.* 1996), Japan (Kotaki *et al.* 1996), and New Zealand (Rhodes *et al.* 1996). It has also been reported that *Pseudonitzschia* showed domoic acid production in a culture from Canada (Bates *et al.* 1991), and in the Netherlands (Vrieling *et al.* 1996).

Neurotoxic shellfish poisoning. The fourth kind of shellfish poisoning is neurotoxic shellfish poisoning (NSP) caused by *Gymnodinium breve* (Fig. 1f). The symptoms are headache, diarrhoea, muscle weakness, and in extreme cases difficulty in breathing, talking, and swallowing. The symptoms come 3-6 hours after ingestion (Hallegraeff 1991). Cases of NSP have been reported caused by *Gymnodinium* in oysters in New Zealand (Mackenzie *et al.* 1996). Blooms of this species and fish kill have been reported from the Gulf of Mexico since 1946 (Greesey & Tester 1993). This species has also been recorded from West Indies, Europe, and Australian waters (Steidinger & Tangen 1996).

Shellfish poisoning caused by gastropods and crustaceans

Traditionally, only filter-feeding molluscs that concentrate toxic algae are considered causing shellfish poisoning, however, increasing attention is being paid to higher-order consumers such as carnivorous gastropods and crustaceans. Whelks and other species of carnivorous snails prey on filter-feeding bivalves such as scallops, mussels, and clams. Thus the snails accumulate toxins present in the prey organism. As in bivalves toxins in gastropods are usually concentrated in the digestive gland while muscular portions are usually toxin-free. But there are exceptions from this as some species of moon snails concentrate tetrodotoxin and paralytic shellfish toxins in the muscle tissue (White *et al.* 1993a).

At least four species of snails have caused human death and many others have been implicated in illnesses (Noguchi *et al.* 1981, Sang & Ming 1984; Shiomi *et al.* 1984; Chen & Gu 1993; White *et al.* 1993b). The gastropods tend to release toxins very slowly once acquired. PSP toxin has been measured in some species of grazing snails as well (Kotaki *et al.* 1983). It is presumed that these snails ingested either cysts (resting spores) of *A. tamarense* or cells that had settled down out of the water column after a bloom (Shumway 1995).

There are no records of diarrhoetic (DSP) or amnesiac (ASP) shellfish toxins in gastropods, however there is reason to believe that these toxins may be transferred to predatory snails as well. Like carnivore snails, lobsters (Desbiens & Cembella 1995), and some species of *Cancer* crabs (Foxall *et al.* 1979) also prey on toxic bivalves and store accumulated toxins in the hepatopancreas. Horseshoe crabs have been responsible for food poisonings in Thailand and toxicity has been reported from all tissues of the crab (Saitanu *et al.* 1987).

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