GENERAL INTRODUCTION

The oceans are home to thousands of microscopic algae, which constitute the base of the marine food web. These phytoplankton are essential for the production of biomass at all levels of the food web and thus play an important role in ocean’s ecology. Beneficial phytoplankton blooms defined by Smayda (1997) as ‘a significant population increase during which the bloom and the subordinate species within the community have equivalent ecological and physiological valence’, are thus intrinsically beneficial to food web processes as they channel carbon or energy into the marine food web. There are however a few dozen of algal species whose blooms are associated with some adverse impacts. According to International Council For the Exploration of Seas (1984), exceptional blooms have been defined as ‘those which are noticeable, particularly to the general public, directly or indirectly through their effects such as visible discolouration of the water, foam production, fish or invertebrate mortality or toxicity to humans’. These species make their presence known in many ways ranging from massive ‘red tides’ or blooms of cells that discolour the water to dilute inconspicuous concentration of cells noticed only because of the harm caused by their highly potent toxins. These toxins accumulate in shellfish feeding on these algae, resulting in poisonous syndromes like paralytic (PSP), diarrhetic (DSP), amnesic (ASP) and neurotoxic (NSP) shellfish poisoning in human consumers. Fish may be contaminated as well, causing ciguatera fish poisoning (CFP), which results in human illness or death followed by consumption of such whole fish.

Though algal blooms are natural phenomenon and have occurred throughout the recorded history, recent studies from around the world indicate that they have increased in frequency and geographic distribution over the past few decades. Ho and Hodgkiss (1991) in a review on the red tides in subtropical coastal waters from 1928 to 1989 showed that the number of blooms increased from 1 or 2 every 10 year at the beginning of the period to over 220 between 1980 and 1989. Maclean (1989) has noted a spread of the bloom of the toxic dinoflagellate Pyrodinium bahamense var. compressa to new locations in the coastal waters of Philippines, with increased occurrence of human deaths by PSP caused by this species. Increase in frequency of algal blooms have been reported along South African coasts (Horstman, 1981), Dutch coastal waters (Cadee, 1986), Seto inland sea, Japan (Imai and Itoh, 1987), Hong Kong harbour (Lam and Ho, 1989), Black sea (Turkoglu and Koray, 2002), in Chinese coastal waters (Qi et al., 1995) and in the coastal waters of North America (Horner et al., 1997). All these point to a ‘global epidemic of algal blooms’ as referred to by Smayda (1990). According to Hallegraeff (1995)
there has been increased reports of harmful algal bloom (HAB) occurrences world wide, due to increased scientific awareness, improved analytical techniques and also because increased coastal mariculture activities have resulted in regular monitoring of these waters. He also commented that HAB events have been on a rise and has spread to previously pristine waters as a result of eutrophication, unusual climatological conditions, and transport of dinoflagellate cysts in ships ballast water and with shellfish imports.

Exceptional bloom forming species form a very low percentage of the total marine phytoplankton. According to a recent survey conducted by Sournia (1995), only about 200 species (184-207) of the total 4000 known (3365-4024) marine phytoplankton species produce exceptional blooms which constitute only about 5.5- 6.7% of the total. Of these, only 1.8 to 1.9% has been so far identified to be toxic. 73-75% of these toxic species are dinoflagellates followed by diatoms. Rapidophyceae, Cyanophyceae, Prymnesio phyceae, Cryptophyceae, Prasinophyceae, Chlorophyceae and Euglenophyceae, all have members which produce exceptional blooms but their percentage is very low compared to that of the first two. Of the dinoflagellates, four genera, *Alexandrium*, *Dinophysis*, *Gymnodinium* and *Prorocentrum* are responsible for majority of the toxic events. New species of toxic algae are being continually added to the list.

World wide approximately 2000 cases of human poisonings, with an overall mortality rate of 15% have been reported to be caused by consumption of fish/ shellfish contaminated with algal toxins (Hallegraeff, 1995). Paralytic shellfish poisoning (PSP) produced by dinoflagellates of the genera *Alexandrium*, *Gymnodinium* and *Pyrodinium* which was until 1970 known only from temperate waters of Europe, North America and Japan has at present been reported from throughout the southern hemisphere in South Africa, Australia, New Zealand, India, Thailand, Brunei, Sabah, Phillippines and Papua New Guinea (Hallegraeff, 1995). The dinoflagellate *Pyrodinium bahamense var. compressa* has been associated with severe PSP outbreaks in South East Asia (Maclean, 1987). In addition to PSP production, they have also been reported to be responsible for fish and shellfish mortalities (Shumway, 1990). Diarrhetic shellfish poisoning (DSP) reported for the first time in the late 1970's from the dinoflagellate *Dinophysis fortii* in Japan (Yasumoto *et al.*, 1978), has been at present reported from South America, New Zealand, Australia, Thailand, Europe, Chile, Canada and possibly Tasmania and New Zealand (Van Dolah, 2000). It may be more widespread in occurrence since the symptoms are very similar to that of the common bacterial gastroenteritis. Production of DSP toxins has been confirmed in
several species of *Dinophysis* like *D.acuminata, D.acuta, D.fortii, D.norvegica, D.rotunda, D.tripos* and suspected in *D.caudata, D.hasta and D.sacculus* (Lee et al., 1989).

ASP was reported for the first time in 1987 in Prince Edward Island Canada, where cultured blue mussel was implicated in 127 cases of poisoning and two deaths. *Pseudo-nitzschia multiseries* was identified as the harmful microalga (Bates et al., 1989). A recent study by Bates et al. (1998) points out that *Pseudo-nitzchia* spp is more cosmopolitan in occurrence than previously thought, with reported occurrence from Canada, North America, Holland, Denmark, Spain and New Zealand. CFP results from a consumption of reef fishes contaminated with algal toxins and humans consuming such fishes suffer from gastrointestinal and neurological illness and in extreme cases can die from respiratory failure. The benthic dinoflagellate *Gambierdiscus toxicus, Osteropsis siamensis, Coolia monotis and Prorocentrum lima* are thought to be the causative organisms. From being a rare occurrence two centuries ago, Ciguatera has now reached epidemic proportions in French Polynesia, with more than more than 24,000 patients of CFP reported from the area between 1966 and 1989 (Hallegraeff, 1995). Neurotoxic shellfish poisoning (NSP) caused by the dinoflagellate *Gymnodinium breve*, which was earlier thought to be endemic to the Gulf of Mexico region, has been now reported from other regions of the world like New Zealand (Richardson, 1997). All these point to a global spread of harmful algal bloom forming species.

Algal toxins can also alter the marine ecosystem, structure and function as they are passed through the food web affecting fecundity and survival at different trophic levels. Some of the microalgae kill wild and farmed fish populations. Fish mortalities are due primarily to *Gymnodinium nagasakiense* in the North Sea region, *Heterosigma akashiwo* in British Columbia, Chile and New Zealand and due to *Chattonella antiqua* in Japan. Besides direct fish kills caused by toxins produced by these algae, indirect kills can also occur as caused by the spine like process present on the setae of the diatoms *Chaetoceros convolutus* and *Chaetoceros concavicornis*. Some other harmful microalgae like *Gymnodinium breve* produce toxic and irritating aerosols. Other recent additions to the list are the silicoflagellate *Dictyocha speculum* and the prymnesiophyte *Chrysochromulina polylepis* which have been recorded as the causative species in many recent marine faunal kills (International Oceanographic Commission workshop, 1991).

Along the Indian coast, algal blooms and associated mortality have been recorded since the early half of the 20th century by many workers (Hornell, 1917; Aiyar, 1936; Jacob and
Menon, 1948; Bhimachar and George, 1950; Subrahmanyan, 1954). They have been reported to be more prevalent along the west coast than on the east coast. Algal blooms particularly HAB occurrences along the Indian coast have been reviewed by Karunasagar and Karunasagar (1990), including the major reasons for these blooms and the harmful effects they have caused. The harmful algae with regular bloom occurrence along the Indian coast are *Noctiluca scintillans* and *Trichodesmium* sp. *Chattonella marina* is a regular bloom forming species along the Calicut coast. Sporadic blooms of other harmful microalgae like dinoflagellate *Gonyaulax polygramma* along south west coast has been reported by Prakash and Sharma (1964) and along the coastal waters off Cochin by Gopinathan and Pillai (1976). Bloom of *Gymnodinium mikimotoi* along Kanara coast has been reported by (Karunasagar and Karunasagar, 1992; 1993). Planktonic and cyst forms of *Gymnodinium catenatum* have been reported along the coastal waters of Karnataka by Godhe *et al.* (1996).

Shellfish poisoning from algal toxins have also caused human fatalities and related discomforts along the Indian coast. In 1981, an incident of paralytic shellfish poisoning resulted in the hospitalization of 85 people and death of 3 persons due to consumption of the bloom affected clam *Meretrix casta* in Tamil Nadu. A similar incidence took place in Mulki estuary, Mangalore, in 1983 (Karunasagar, 1984; Bhat, 1981; Devassy and Bhat, 1991). In both the cases the toxic species could not be identified. Similarly at Poovar, near Vizhinjam in Kerala, 5 children died and more than 300 people were hospitalized in October 1998, due to shellfish poisoning from *Gonyaulax polygramma* (Karunasagar *et al.*, 1997). Recently, on 17th September 2004, a massive fish kill was noticed along the Trivandrum coast, along with foul smell coming from the sea. Many people, especially children, residing in the coastal districts of Trivandrum and Kollam, who got exposed to the stench, were hospitalized due to vomiting and nausea (The New Indian Express, 17th September, 2004). It was later identified to be caused by a bloom of the toxic dinoflagellates *Gonyaulax diegensis* and *Cochlodinium* spp (CMFRI Newsletter, 2004).

Due to its global distribution, the problem of HAB can be addressed comprehensively and effectively only through international, interdisciplinary and comparative research. Global monitoring programmes are designed and implemented to manage this problem more effectively. The first attempt for this was the creation of a ‘Harmful Algal Programme’ by IOC (International Oceanographic Commission) and UNESCO in 1989 followed by the formulation of ECOHAB (Ecology and Oceanography of Harmful Algal Blooms) programme by USA. The second international initiative was the GEOHAB programme (Global Ecology and Oceanography of Harmful Algal Bloom), by IOC and SCOR (Scientific committee on Ocean Research). The
European union also sponsors an European initiative on HAB’s known as EuroHAB. Other international organisations like PICES (North Pacific Marine Organisation), APEC (Asian Pacific Economic Cooperation) have all set up programmes and workshops on HAB’s. Besides, many of the coastal nations have local monitoring programmes, which have resulted in increased sampling intensity and frequency for identifying the presence of harmful microalgae. Workshops and conferences are being held every year to identify the most pressing research issues in the field.

Along the Indian coast, exceptional algal blooms can lead to serious constraints for the sustainable development of coastal areas, which calls for a coordinated scientific and management approach. Marine resource utilisation through fishing and mariculture activities has witnessed a phenomenal increase along the coast during the past few decades. The coastal mariculture programmes of the marine mussel *Perna viridis* (Linnaeus, 1758) and the edible oyster *Crassostrea madrasensis* (Preston), involving more than 8000 coastal rural families in Kerala, producing more than 4500 tonnes of farmed bivalve per annum is a direct indication in the phenomenal increase in coastal resource utilisation. Under these circumstances, the potential danger lurking behind the bivalve farmers and the consumers, through unpredicted harmful algal blooms has to be prioritized and precautionary steps taken to avoid human causalities and large scale economic losses.

Early warnings when harmful species or toxins reach critical concentration is the most widely used management strategy, which helps in implementing specific plans to avoid health problems and to minimise the economic losses. At a long time scale, it is essential to assess the risk of harmful events while planning the utilisation of coastal areas and for this, basic knowledge and a firm database about the species distribution, species succession and population dynamics of the bloom forming species is required. Hydrodynamic and ecologic conditions that lead to their blooming has to be studied which would help to build predictive models. Keeping this in view, the present research study entitled ‘Studies on the prevalence of algal blooms along Kerala coast, India’ has been undertaken.