Existence of potentially harmful microalgae in coastal waters around Zanzibar: A need for a monitoring programme?

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ABSTRACT

A nine-month survey of potentially harmful microalgae was carried out in the coastal waters around Unguja Island, Zanzibar, from September 1998 to June 1999. Using a light microscope, more than 20 species were identified. These were distributed among three major microalgal groups: the cyanobacteria, mostly dominated by *Trichodesmium* spp; the dinoflagellates, dominated by *Prorocentrum* spp. and *Gambierdiscus toxicus*; and the diatoms, mostly *Pseudo-nitzschia* spp. This and other preliminary studies indicate the presence of harmful microalgae in Zanzibar waters. Further studies to assess both spatial and temporal distribution, as well as potential ecologic and economic effects, are recommended.

INTRODUCTION

Phytoplankters, which are predominantly autotrophic, are the primary producers of organic matter in aquatic habitats. Like plants on land, these are the basic food in the sea for consumers such as zooplankton and fish. The phytoplankton thus stand on the baseline of many food webs in aquatic environment (Boney, 1975). Some planktonic genera, especially those belonging to the cyanobacteria, e.g. *Trichodesmium*, *Richelia* and *Nostoc* spp., are able to fix nitrogen, hence contributing to the rise of nitrogenous nutrients in the marine environments (e.g. Bryceson, 1977; Carpenter, 1983).

The population of Tanzanian islands such as Mafia, Unguja and Pemba as well as the dwellers along the entire coastline of Tanzania is heavily dependent on fish obtained from a variety of local habitats as the primary source of animal protein. Hence, it is vulnerable to microalgal-borne toxins, which could be present in reef, open sea, sea-grass beds and mangrove areas.

Sometimes blooms of toxic phytoplankton occur, especially in coastal waters of tropical seas (Quod and Turquet, 1996; Orellana-Cepeda, 1996; Wyatt, 1998). This may cause massive fish kills and contamination of shellfish with the consequent death

of other marine life as well as terrestrial animals (Boney, 1975; Habermehl et al., 1994; Ochoa et al., 1996). Biotoxins produced by some dinoflagellates are accumulated via the food chain by herbivorous and carnivorous fish (Qoud and Turquet, 1996). For example, ciguatera fish poisoning is the term introduced to a well-documented disease from the Pacific, the Indian Ocean and Caribbean Sea (e.g. Ruff and Lewis, 1994). The commonly bloom-forming cyanobacteria *Trichodesmium thiebautii* has also been reported to be toxic to calanoid and cyclopoid copepods (Hawser et al., 1992).

Potentially harmful microalgae are normally found occurring in low numbers, but under certain conditions may form extensive blooms that can have devastating effects on the environment (Moestrup and Larsen, 1992). Some species however, such as *Dinophysis* spp. can cause serious problems even at moderate biomass (Hallegraef, 1995). Several potentially harmful microalgae have so far been found to exist in Tanzanian coastal waters (Bryceson, 1977; Lugomela, 1996) though their relative abundance and spatio-temporal variability is not well assessed. Probably the first report of potentially harmful microalgae in Zanzibar waters is that of Ballantine (1961) who recorded several dinoflagellates, including *Gymnodinium chukwanii* named after Chukwani village just south of Zanzibar town. Lugomela (1996) reported about eight species of potentially harmful microalgae. These include the cyanobacteria *Trichodesmium*, *Schizothrix* and *Anabaena* spp.; the dinoflagellates *Prorocentrum lima*, *Dinophysis caudata* and *Osteriopsis lenticularis*; and the diatom *Pseudonitzschia* sp. as well as the haptophyceae *Prymnesium parvum*.

The present study aims at surveying and documenting the occurrence of harmful microalgae in different habitats (mangrove, coral reef, Zanzibar Port and open ocean areas) in waters around Unguja Island in Zanzibar.

MATERIALS AND METHODS

Study area

Four stations were established to represent a range of ecosystems (Figure 1). The first two stations were at Chwaka Bay, i.e. about 34km to the East Coast of Unguja Island. The Bay is a shallow water body and has an average depth of 2m at mean sea level. It covers an area of approximately 35km^2 and is fringed to the south by a limestone reef platform covered by a dense mangrove forest of approximately 3000ha. A series of tidal creeks drain the forest, and these include Mapopwe Creek, where station I was located. On the seaward side, immediately adjacent to the forest, the Bay opens up to larger inter-tidal flats, which are covered by mixed assemblages of seagrasses and algae. Seaweed farming is also practised in this area, and station II was located there. Stations III and IV were located to the West Coast of Unguja Island off Zanzibar Town. Station III was just off Zanzibar Town, near Zanzibar ferry port, where there are several sewage outlets. Station IV was about 6km from the shoreline, on the coral reef area near Bawi Island.

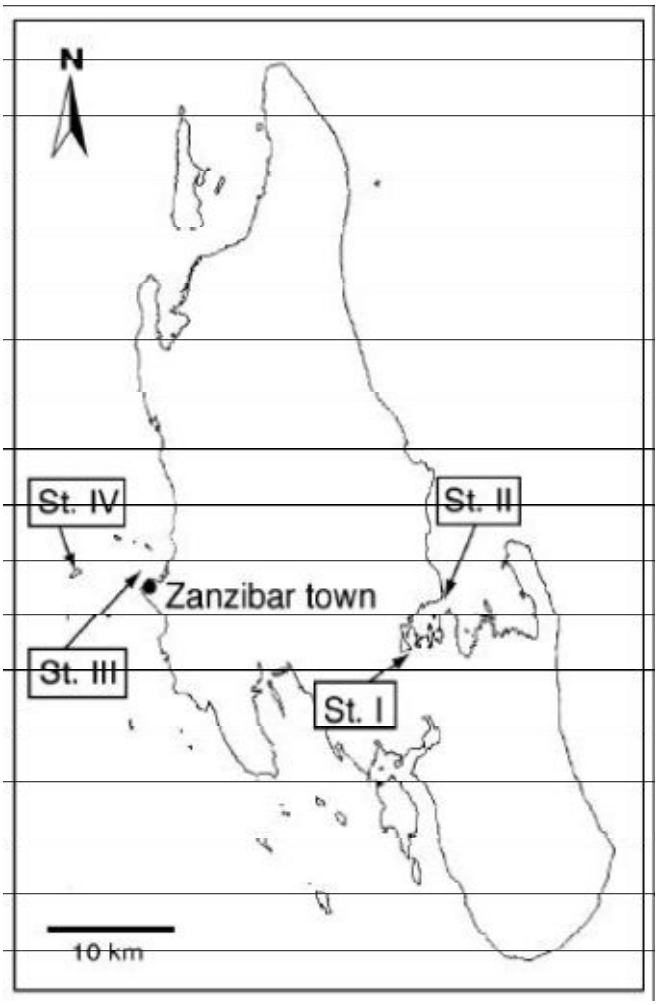


Figure 1. Map of Unguja Island (Zanzibar) showing location of sampling stations

Sampling procedures and laboratory analysis

Duplicate samples for qualitative analysis were collected regularly, once a month (first week of the month), from each station for a period of nine months. A plankton net of mesh size 20µm was used during sample collection. At the deeper stations (Sta. III and IV), the net was lowered to a depth of about 15m and vertically hauled. At stations I and II, with an average depth of 2m, samples were collected by surface towing of the net. Out of the duplicate samples, one was immediately fixed with Lugol's solution while the other was brought to the laboratory for analysis of live material. Both samples were examined under a light microscope.

Benthic species were collected by scuba diving. However, this was carried out only at station IV, during the months of February, April, May and June 1999. Dead

corals with algal tufts were hand-picked and placed into plastic bags. In the laboratory, the corals were brushed with a stiff household brush to remove the organisms from the substrate. Next, the water was filtered through an 850µm sieve to remove rubble and other coarse particles. Larger seaweeds were also collected in plastic bags. In the laboratory the samples were shaken vigorously and then filtered through an 850 µm sieve to remove the larger particles. The collected seawater was then examined under the light microscope.

RESULTS AND DISCUSSION

Several phytoplanktonic and benthic species were identified during the 9-month sampling period. Some of the species are potentially harmful, while others are harmless. The results are summarised in Tables 1, 2 and 3.

Many of the phytoplankton species identified during this study were diatoms (Table 1). Fortunately, most of the diatoms are not known to be harmful. Of the 40 species of diatoms observed during the study period, only one potentially harmful diatom, *Pseudonitzschia* spp., was identified (Table 1). This genus has several members known to be toxic (Hasle and Fryxell, 1995). The toxic *Pseudonitzschia* species cause amnesiac shellfish poisoning, the symptoms of which include gastrointestinal and neurological problems as well as persistent loss of short-term memory.

Dinoflagellate is the group with the largest number of harmful species (Taylor et al., 1995). In this study, a total of 26 dinoflagellate species (Table 2) were identified, out of which 19 species are known to be potentially harmful. These include 10 species of the genus *Prorocentrum*, which were mostly found at station IV in the benthic fraction. Others include *Amphidinium* spp.; *Ostreopsis* spp., *Gambierdiscus toxicus*, *Coolia* (cf. *Monotis*) and *Gonyaulax* spp. *Prorocentrum* species are known to produce okadoic acid which is a diarrhoetic shellfish poison (Rhodes et al., 1995). *Prorocentrum lima* has also been associated with ciguatera syndrome (Faust, 1991).

Gambierdiscus toxicus is the major contributor to ciguatera syndrome. This species produce lipid-soluble ciguatoxins (Legrand et al., 1992). A new ciguatoxin-producing benthic dinoflagellate named *Gambierdiscus yasumotoi* has recently been isolated from macroalgae in the fringing reef surrounding the Singapore Island (Holmes, 1998). In the Indian Ocean, ciguatera was first described in Mauritius (Halstead and Cox, 1973, cited in Quod and Turquet, 1996). In Reunion, for example, 81% of the poisoning cases are due to ciguatoxins. A severe poisoning occurred in the West Coast of Madagascar in 1994 where ciguatera had not been reported before (Habermehl et al., 1994). *Gambierdiscus toxicus* was also observed in the benthic microalgae at station IV. A study by M. Silver (unpublished preliminary report) and that by J.P. Quod (unpublished data) also indicated the presence of *G. toxicus* at a location close to Zanzibar port and Bawi Island respectively. Other dinoflagellate species observed in this study which are possible contributors to ciguatera fish poisoning include *Amphidinium* spp., *Ostreopsis* spp. and *Coolia* spp.

Table 1. List of diatoms observed between September 1998 and June 1999 for Stations I, II, III and IV

	Month observed									
Species identified	S	O	N	D	J	F	A	M	J	Station
Amphora spp.								x	x	I, II
Asterionella spp.	x		x	x		x			x	III, IV
Bacillaria spp.					x				x	I
Bacteriastrum spp.		x	x			x	x	x		III, IV
Chaetoceros spp.		x	x		x	x	x	x		III, IV
Cosnodiscus spp.	x		x					x		III, IV
Cylindrotheca spp.						x		x		III, IV
Dictyota spp.			x							III,
Diploneis bombus								x	x	III, IV
Ditylum brightwerii					x					III
Eucampia spp.								x		III
Guinardia flaccida							x			III
Guinardia spp.								x		IV
Gyrosigma spp.	x						x	x	x	I, III, IV
Hantzschia spp.							x			IV
Hemiaulus spp.	x	x	x			x	x	x		III, IV
Isthmia spp.							x			IV
Lauderia annulata								x		IV
Leptocylindrus spp.					x		x	x		III, IV
Licmophora spp.		x						x	x	II, III, IV
Mastogloia spp.								x		I
Navicula spp.								x	x	I, II, IV
Nitzschia longissima		x					x	x	x	I, II, III, IV
Nitzschia sigma								x	x	IV
Nitzschia spp.			x	x		x	x	x	x	II, III, IV
Odontella sinensis								x	x	IV
Rhabdonema spp.	x					x				III, IV
Pleurosigma spp.		x	x		x			x	x	I, II, IV
Pseudo nitzschia spp.+	x	x	x			x	x	x		III, IV
Rhizosolenia alata	x	x				x	x			III, IV
Rhizosolenia crassipisna		x								III
Rhizosolenia cylindrus							x			III
Rhizosolenia delicatura								x		IV
Rhizosolenia hebatata	x									III
Rhizosolenia stolterforthii		x					x			III, IV
Rhizosolenia spp.		x	x		x	x		x	x	III, IV
Schroederella spp.		x								III
Synedra spp.								x	x	III, IV
Thallassiothrix frauenfeltii								x		III
Thallassiothrix spp.						x	x	x		III, IV

+Potentially harmful species.

Table 2. List of dinoflagellates observed between September 1998 and June 1999 for Stations I, II, III and IV

Species identified	Month observed									Station
	S	O	N	D	J	F	A	M	J	
Amphidinium carterae+						x	x	x	x	IV
Amphidinium klebsii+						x	x			IV
Amphidinium opeculatum+						x		x	x	IV
Ceratium furca	x		x	x	x	x		x		III, IV
Ceratium fusus		x	x	x	x					I, III, IV
Ceratium pentagonum								x		III
Ceratium spp.						x				III
Coolia (cf. *Monotis*)+						x				IV
Gambierdiscus toxicus+						x		x	x	IV
Gonyaulax spinifera								x		IV
Gonyaulax spp.+	x							x		II, IV
Gymnodinium spp.								x		IV
Ostreopsis heptagona +						x				IV
Ostreopsis ovata +						x	x			III, IV
Ostreopsis spp.+								x	x	IV
Prorocentrum belizeanum+						x				IV
Prorocentrum borbonicum+						x				IV
Prorocentrum concavum +						x		x	x	II, IV
Prorocentrum elegans+						x				IV
Prorocentrum emarginatum+						x				IV
Prorocentrum lima+						x		x		II, IV
Prorocentrum maculosum+						x				IV
Prorocentrum mexicunum+						x				IV
Prorocentrum micans+								x		II
Prorocentrum spp.+		x						x	x	II, IV
Protoperidinium spp.		x	x		x			x		II, III, IV

+Potentially harmful species.

For ciguatera toxins, there are about 150 symptoms and all are difficult to diagnose (Turquet, pers. commun.). The general symptoms caused by ciguatoxins include digestive problems, neurological problems, respiratory difficulties and skin irritation. However, the most important symptoms are strong itching, tiredness, tingling sensations, diarrhoea, inverse sensation, respiratory difficulties and dental pain. At low doses, only the digestive symptoms occur.

In the cyanobacteria group, a total of 10 species were identified (Table 3), out of which 4 species are potentially harmful. *Trichodesmium* spp. were commonly observed and have been reported to form blooms in Tanzania waters (e.g. Bryceson, 1977; Lyimo, 1995; Lugomela, 1996). When abundant and decaying, *Trichodesmium* produces an unpleasant smell and pinkish colour and has been shown to be toxic to some shrimps (Taylor, pers. commun.). *Trichodesmium thiebautiis* has been shown to possess a neurotoxin

Table 3. List of cyanobacteria observed between September 1998 and June 1999 for Stations I, II, III and IV

	Month observed									
Species identified	S	O	N	D	J	F	A	M	J	Station
Lyngbya spp.+	x					x	x	x	x	III, IV
Nostoc/Anabaena spp.+							x			IV
Oscillatoria spp. +		x	x		x	x	x	x	x	II, III, IV
Plectonema spp.		x								II
Richelia intracellularis	x				x	x				III, IV
Spirulina spp.								x	x	IV
Trichodesmium erythraeum					x	x				III, IV
Trichodesmium tenue+					x					IV
Trichodesimium thiebautii +					x	x				III, IV
Trichodesmium spp.				x	x	x		x		II, III, IV

+Potentially harmful species.

and has been reported to be toxic to some marine invertebrates such as calanoid and cyclopoid copepods (Hawser et al., 1992). Furthermore, there are reports of breathing difficulties to people who have been near red tide blooms of *Trichodesmium* (Carpenter and Carmichael, 1995). Another potential harmful cyanobacteria observed was the *Anabaena* spp., which is associated with neuromascular blocking alkaloid anatoxin and paralytic shellfish poisoning (Carpenter and Carmichael, 1995).

Some examples of cyanobacterial toxic blooms and scums such as those of *Microcystis, Anabaena, Oscillatoria* and *Aphanizomenon* species have been observed in several parts of the world (e.g. Sivonen et al., 1990; Scott, 1991; Yoo et al., 1995). Similarly, several saxitoxins have been found in mats and cultures of freshwater *Lyngbya wollei*, in Alabama, USA (Carmichael et al., 1997). In addition, new types of toxins, the microcystins, have been characterised from four strains of *Oscillatoria agardhii* and *Nostoc* strains [Sano and Kaya, 1995; Beattie et al., 1998 (both cited in Codd and Bell 1998)]. Health hazards related to cyanobacterial toxins could be seen in both animals and human beings, and may be attributed to drinking contaminated water or through recreational activities. Toxins like anatoxin-a and microcystins have been identified in affected animals, such as in dog stomach contents, sheep rumen contents and stomach contents of poisoned birds (Edwards et al., 1992; Lawton et al., 1995; Henriksen et al., 1997). In southeast China, microcystins have been linked to elevated rates of primary liver cancer in humans (Codd and Bell, 1998).

Large blooms and scums of cyanobacteria, like those of *Microcystis* and *Anabaena*, could be stimulated by land disturbances such as construction and filling of reservoirs, which increase eutrophication in catchment water body (Harper, 1992). An example is the event observed in Itoparica Dam, Bahia, Brazil in 1998, causing about 2000 gastroenteritis cases, with a death toll of 88 individuals (Codd and Bell, 1998). In another case that occurred in Caruaru, NE Brazil, 126 people were affected after using water from a lake with massive growth of cyanobacteria. The victims developed symptoms

of acute neurotoxicity and sub-acute hepatoxicity. Out of the 126 people affected, 60 died (Pouria et al., 1998; cited in Codd and Bell, 1998).

CONCLUDING REMARKS

Zanzibar coastal ecosystems are now experiencing great interference from human activities such as uncontrolled cutting of mangrove trees, the dumping of untreated sewage in coastal waters and destructive fishing activities in coral reef areas. All these could accelerate the rise of toxic microalgae such as *Gambierdiscus toxicus*. In addition, the fast-growing population of Zanzibar (currently at a rate of 5% per annum) and the increased influx of tourists also impart a significant pressure/stress on the coastal environment. This stress could again result in changes of water quality, and consequently the associated biota.

Therefore, it is not surprising that several species of potentially harmful microalgae have been observed in Zanzibar waters. Our results, and those of the previous studies, show without doubt that potentially harmful microalgae do exist in Zanzibar waters. To what extent do they affect the seafood, the consumers and the economy? What is the biomass, productivity and seasonality of these species? What causes them to occur? These are some of the questions that need to be answered. As such, this calls for a detailed study to assess their spatial and temporal distribution. Alternatively, a monitoring programme could be put in place. This would lead to a better understanding of factors that control the abundance and distribution of harmful microalgae, with the aim of controlling the possible impacts on the fishery and seafood consumers.

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