Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 12, No. 5, p. 107-118, 2018
http://www.innspub.net

INNSPUB
RESEARCH PAPER

OPEN ACCESS

Species composition, abundance and distribution of phytoplankton in the coastal waters off Zanzibar Island, Tanzania

Edward Moto[1*], Margareth Kywelyanga[2], Thomas Lyimo[3], Mariam Hamisi

[1]*School of Biological Sciences, University of Dodoma, Dodoma, Tanzania*

[2]*Institute of Marine Sciences, Zanzibar, Tanzania*

[3]*Department of Molecular Biology and Biotechnology, University of Dar es Salaam, Tanzania*

Article published on May 13, 2018

Key words: Phytoplankton, Species composition, Abundance, Distribution.

Abstract

Species composition, abundance and distribution of phytoplankton were studied in Zanzibar coastal waters for one year (May 2012 - May 2013) at two sites, Bawe and Chwaka Bay. The objective of this study was to quantify the health ecosystem of Zanzibar coastal waters as phytoplankton are good indicator in studying an ecosystem. A total of 260 species belonging to 94 genera and 6 classes were recorded at both sites. The phytoplankton assemblage was dominated by Bacillariophyceae (diatoms) which accounted for 70% of the total phytoplankton. Dinoflagellates ranked second in terms of abundance (24%). Cyanophyceae accounted for 5% of the total phytoplankton and less than 1% of the total standing crop was attributed to chlorophyceae, dictyochophyceae and crysophyceae. Abundant concentrations of diatoms composed mostly of several species which were observed throughout the sampling time which included Chaetoceros *sp, Rhizosolenia sp, Thalassiothrix sp, Nitzschia sp, Guinardia sp, Bacteriastrum sp, Pleurosigma sp* and *Coscinodiscus sp*. Diatoms were abundant due to their resilient ability to withstand the varied environmental factors. Some dinoflagellates in low densities were observed at both sites. The highest phytoplankton density was 9189 cells/l, while the lowest density was 2227 cells/l recorded at Bawe and Chwaka Bay, respectively. Southeast monsoon (SEM) season phytoplankton (15244 counts/l) were higher than the Northeast monsoon (NEM) season (13982 counts/ml). Also species diversity was higher during the SEM than the NEM ($t = 3.155$, $p = 0.0058$). Higher abundance and diversity during SEM might be attributed by low sea surface temperature, higher salinity, sulphate and nitrate levels.

***Corresponding Author:** Edward Moto ✉ eddymotto@yahoo.co.uk

Introduction

Phytoplankton constitutes the basic components of the aquatic food chain. They act as primary producers and represent themselves as a direct food source for other aquatic organisms. The community composition of phytoplankton is largely influenced by the interaction of a number of physico-chemical factors. They are largely governed by light, nutrients, temperature, community structure life-cycle history, stratification or vertical mixing and tides (Alvarez-Góngora and Herrera-Silveira, 2006).

The interactive effects of these factors play important but different roles in structuring the phytoplankton community. Marine phytoplankton biodiversity and associated physico-chemical factors has been studied in Western India Ocean by Bryceson (1977), Lyimo (1995), Lugomela (1996) and Kyewalyanga (2002), just to mention few.

These types of studies give relevant information about the productive nature of the water bodies under consideration. Various dynamic features of sea water depend to a large extent on phytoplankton composition. Phytoplankton fluctuation and diversity are widely used as biological determinants of water quality, healthy status of an ecosystem, detection of pollution and productivity of the area. From phytoplankton density and species composition in aquatic tropical waters, the annual cycle and biological distinctiveness can be established (Palmer, 1977; Shubert, 1984). Variation in phytoplankton community composition is influenced by several factors such as availability of nutrients, temperature, light intensity and other physico-chemical factors. Normally phytoplankton follows a fairly recognizable annual cycle of growth, but sometimes the synchrony in their normal annual cycle is interrupted by explosive growth of some species (Vaulot, 2001).

Diversity, distribution, and variation in the biotic parameters provide a good indication of energy turnover in aquatic environments (Forsberg, 1982). In aquatic environments phytoplankton are located at the base level and are represented as a major source of organic carbon (Gaikwad *et al.,* 2004).

Their sensitivity and fluctuation in species composition are usually a suitable explanation to demonstrate the alteration within an ecosystem (Devassy and Goes, 1988). Species diversity responds to changes in environmental gradients and may characterize many interactions that can establish the intricate pattern of community structure. Normally, it is found that any slight alteration in environmental status can change diversity until there is no adaptation or gene flow from non-adaptive sources.

A high diversity count suggests a healthy ecosystem; the reverse of this indicates a degraded environment. In the latter situation only a few organisms can thrive and flourish (Smith, 2006).

The present study focuses on study of phytoplankton diversity, species composition and community characterization in Zanzibar coastal waters.

In Zanzibar coastal waters, however, some studies on phytoplankton diversity and Chl-*a* concentration have been done (Bryceson, 1977; Lyimo, 1995; Lugomela, 1996; Kyewalyanga, and Lugomela, 2001; Kyewalyanga, 2002).

The main objective of the present study has been to gain quantitative information on the composition, abundance, and distribution of the phytoplankton sampled between May 2012 and May 2013.

Methods and materials

Study site and sampling design

The study was conducted at two sites in Bawe and Chwaka Bay located in the western and eastern sides of Unguja Island (Zanzibar), respectively (Fig. 1).

Chwaka Bay:Chwaka Bay is situated 22 km East of Zanzibar town in Unguja Island (Fig.1). The bay is characterized by shallow water body with an average of 3.2 m depth and an area of approximately 35 km^2

(Arthurton, 2003) and is fringed by a limestone reef, which is covered by a dense mangrove forest. Three sampling stations were set in this site, the first station (CW1) being within the creek with shallow water at approximately 06°10.490'S and 039°26.000'E, second station (CW2) being at the mouth of the creek at 06°10.257'S and 039°26.354'E and the third station (CW3) being in the open bay with oceanic characteristics located at 06°09.685'S and 039°26.884'E (Fig. 1).

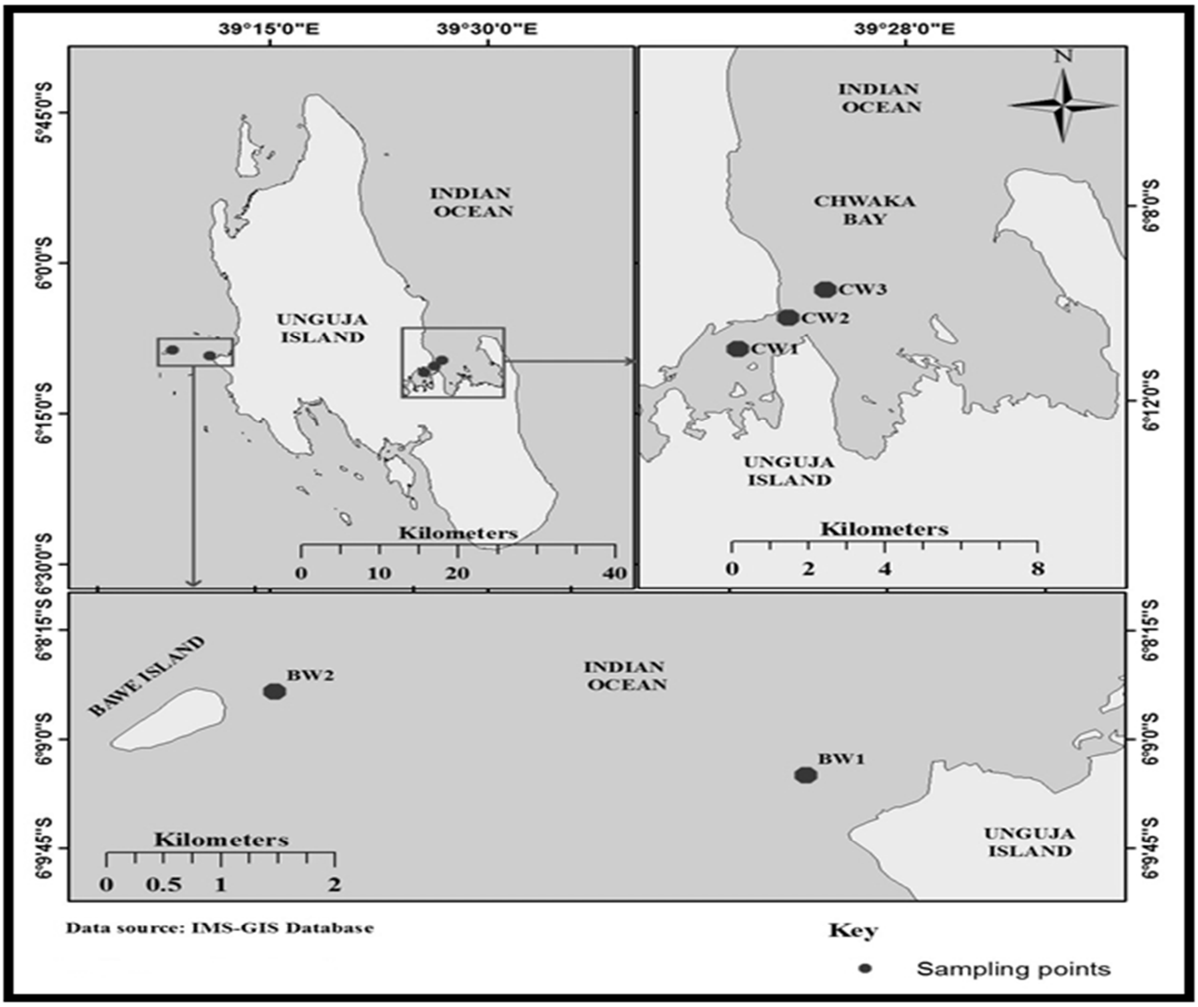

Fig. 1. Map showing the sampling points in Zanzibar coastal waters.

Bawe Site:Bawe Island is a small island in Zanzibar archipelago located about 10 km from the shore of Stone Town. Two sampling stations were set at this study site; the first station (BW1) was located at approximately 06°09.443'S and 039°11.451'E near Zanzibar harbour and the Institute of Marine Sciences. This station was chosen as a representative of polluted area because it is close to the harbour and there is a waste pipe outlet from the city located very close to the station.

The second sampling station (BW2) was near Bawe Island located at 06°09.654'S and 039°11.022'E (Fig. 1). This station is characterized by a relatively deep-water body of more than 10 m depth and is rich in coral reefs. Therefore, this area was taken as a representative of open sea, which has oceanic characteristics.

Samplings were conducted on monthly basis from May 2012 to May 2013, and samples were collected from the 20th to the end of each month.

Methods for composition and abundance determination

To gather information on the species composition, about 50-60 ml of the plankton net concentrated seawater samples were preserved by using one to four drops of acidic Lugol`s solution.

The treated (preserved) phytoplankton samples were allowed to settle in the laboratory for at least 24 hours. One drop, approx. 1 ml of a sample was collected using a dropper and smeared on the slide then covered with slide cover, for investigation on microscope at different magnifications of 10X, 20X, 40X and 100X. To identify phytoplankton to species level, the aid was obtained from some previous work in the area, in particular the theses of Bryceson (1977), Lyimo (1995), Lugomela (1996), A book of marine phytoplankton atlas of Kuwait waters (al-Yamin *et al.,* 2009) and Monograph on Marine Plankton of East Coast of India (Sahu *et al.,* 2013).

For species abundance, prior to analysis, the volume of the stored seawater samples (preserved in Lugol`s solution) were measured and shaken thoroughly. 1 ml aliquot was poured into a counting chamber (Sedgwick rafter cell) and about 10 transects were counted, in which, the unicellular, colonial and filamentous algae were counted as single cell (individual).

The total volume of the whole samples was later used in calculating the number of cells per litre.

Results

Identification and species composition

The phytoplankton species composition varied considerably between sites and season during the study period. Six major groups were encountered namely; Bacillariophyceae (Diatoms), Dinophyceae (Dinoflagellates), Cyanophyceae (Cyanobacteria), Dictyochophyceae, Crysophyceae and Chlorophyceae (Fig.2). A total of 94 genera with 260 species were identified from the samples collected in the surface layer during the study.

Table 1. Showing summary of phytoplankton numbers, per month per site and station.

	2012								2013					
Station/Month	M	J	J	A	S	O	N	D	J	F	M	A	M	
Bawe														Total
BW1	724	56	782	580	1112	588	165	303	529	180	1820	2192	158	9189
BW2	909	213	490	486	1118	308	329	504	323	610	1331	1698	167	8486
Chwaka Bay														
CW1	329	147	109	393	207	163	133	83	92	69	190	133	179	2227
CW2	372	111	142	561	653	309	125	72	170	148	388	1706	247	5004
CW3	875	309	203	833	576	323	214	125	67	175	757	844	213	5514

The identified phytoplankton consisted of 11 genera with 15 species of cyanobacteria, 66 genera with 171 species of diatoms, 20 genera with 71 species of dinoflagellates and 1 genus with 1 species of silicoflagellate (Appendix 1).

At Bawe 148 species were diatoms, 61 species were dinoflagellates, and 9 species were cyanobacteria, while dictyochophyceae, chlorophyceae and crysophyceae were represented by 1 species each. At Chwaka Bay, 125 species were diatoms, 36 species dinoflagellates, 13 species cyanobacteria and 1 species each for dictyochophyceae, chlorophyceae and crysophyceae. Some of the species were observed at all sampling stations while others were missing in some sampling stations. Among phytoplankton, Bacillariophyceae was the dominant group followed by Dinophyceae, Cyanophyceae, Dictyochophyceae, Crysophyceae and Chlorophyceae. Over 70% of the taxa were diatoms, 24% taxa were dinoflagellates, 5%

were Cyanobacteria, and 1% was composed of Chlorophyceae, Crysophyceae and Dictyochophyceae. A taxonomic list and occurrence of phytoplankton were recorded in Appendix 1.

Phytoplankton abundance

Phytoplankton abundance showed variations among stations due to season's fluctuations. Phytoplankton abundance in Zanzibar coastal waters ranged from 56 cells/l in June 2012 to 2192 cells/l in August 2012 both recorded at BW1 station in Bawe (Table 1).

At BW2, phytoplankton abundance was observed to range from the lowest value of 167 cells/l in May 2013 to the highest value of 1698 cells/l recorded in April 2013. Generally, station BW1 recorded high value of phytoplankton compare to station BW2 except in the months of May, June, November, December, 2012 and February 2013 where BW2 recorded higher value than BW1. However, statistically there were no significant difference between BW1 and BW2 (t = 1.00, p = 0.500).

Table 2. Comparison of phytoplankton abundance among stations Tukey-Kramer multiple comparisons test.

Comparison	Mean Difference	q	Significance	P value
BW1 vs BW2	0.1354	1.604	ns	P>0.05
BW1 vs CW1	0.6742	7.869	***	P<0.001
BW1 vs CW2	0.4255	5.086	**	P<0.01
BW1 vs CW3	0.3404	3.976	ns	P>0.05
BW2 vs CW1	0.5802	6.260	***	P<0.001
BW2 vs CW2	0.2996	3.477	ns	P>0.05
BW2 vs CW3	0.1972	2.367	ns	P>0.05
CW1 vs CW2	-0.2325	2.783	ns	P>0.05
CW1 vs CW3	-0.3238	3.893	ns	P>0.05
CW2 vs CW3	-0.09231	1.110	ns	P>0.05

ns: not significant; P> 0.05; *significant; P< 0.05; **very significant; ***extremely significant.

In Chwaka Bay, at CW1, phytoplankton abundance ranged from a minimum value of 69 cells/l recorded in February 2013 to a maximum value of 393 cells/l recorded in August 2012 (Table 1). At CW2, the lowest phytoplankton abundance was 72 cell/l in December 2012 while the highest value was 1706 cells/l recorded in April 2013 (Table 1). At CW3, phytoplankton abundance ranged from the lowest value of 67 cells/l recorded in January 2013 to the highest value of 875 cells/l recorded in May 2013. Generally, station CW3 recorded higher values of phytoplankton in term of abundance than stations CW1 and CW2, but CW2 recorded higher values than CW1. Thus, the abundance at Chwaka Bay stations was in this order CW3>CW2>CW1.

However, comparing abundance among stations at Bawe and Chwaka Bay, it was observed that, Bawe stations (BW1 and BW2) recorded higher values of phytoplankton abundance than the stations at Chwaka Bay (CW1, CW2 and CW3) (Table 1). Tukey-Kramer Multiple Comparisons Test showed that there was significant difference among some of the stations like between BW1 and CW1 (p < 0.001) and between BW2 and CW1 (p< 0.001), BW1 and CW2 (P<0.01), while other stations didn't show any significant difference (Table 2). There was also a significant difference between NEM and SEM (U = 6475.0; p = 0.030) with higher phytoplankton abundance during the SEM period.

Between seasons, phytoplankton showed a relative variation between NEM and SEM. SEM recorded higher number of phytoplankton than the NEM. Statistically, there was no significant difference in phytoplankton abundance between seasons (t = 0.98,

$p < 0.056$). Comparing the means of individual genera during the major monsoon seasons (NEM and SEM) it was found that the differences were explained by only a few genera, most notably is the cyanobacteria genus Trichodesmium, which was one of the most abundant genus during the wet season (NEM) (836cells/l), and became rare or absent during the dry season (134cell/l). Additionally, Trichodesmium was more dominant at Bawe site, generally during November/December and lasted for about 2 months. In Chwaka Bay, Trichodesmium were rarely encountered, and were observed only during the dry season (May to August). Also other species like *Rhizosolenia, Chaetoceros* and *Nitzschia species* were more abundant at Bawe site. *Rhizosolenia spp* were more abundant and common at all stations at Bawe from March to May, while *Chaetoceros* were abundant from July to September. *Nitzschia species* were common and abundant at all sites.

Table 3. Temporal variations in phytoplankton classes at Bawe and Chwaka Bay during the study period (number of cell/l).

	2012								2013					
Month/Classes	M	J	J	A	S	O	N	D	J	F	M	A	M	
Bawe														Total
Bacillariophyceae	1543	187	1183	831	1974	608	256	612	663	212	2766	3464	196	14495
Dinophyceae	72	67	77	205	219	233	132	116	130	319	235	239	125	1930
Cyanophyceae	17	15	10	29	36	51	105	79	59	259	147	187	12	1006
Dictyochophyceae	1	0	1	0	0	3	1	0	0	0	0	0	2	8
Chlorophyceae	0	0	1	1	0	0	0	0	0	0	0	0	0	2
Crysophyceae	0	0	0	1	1	1	0	0	0	0	3	0	0	6
Chwaka Bay														
Bacillariophyceae	726	405	372	872	626	271	226	68	195	139	564	433	269	5166
Dinophyceae	218	39	24	675	599	339	174	161	108	192	700	1970	217	5416
Cyanophyceae	632	123	58	240	211	185	72	51	26	61	71	280	153	2163
Chlorophyceae	0	0	1	1	0	0	0	0	0		1	1	0	4

At Bawe, the individual composition were as follows; Bacillariophyceae were the dominant group with a minimum value of 187 cells/l recorded in June and maximum value of 3464 cells/l recorded in April 2013. Dinophyceae were ranked second dominant group with minimum abundance value of 67 cells/l recorded in June 2012 to the maximum value of 319 recorded in February 2013. Cyanophyceae were ranked third with lowest value of 10 cells/l recorded in July 2012 and highest value of 529 cell/l recorded in February 2013. Dictyochophyceae were ranked fourth with minimum abundance of 0 cells/lrecorded in several months to 3 cells/l recorded in October 2012 while Crysophyceae and Chlorophyceae ranked fifth and sixth presenting lowest abundance of total phytoplankton and they were recorded in very few months (Table 3).

At Chwaka Bay, phytoplankton community was represented by only four groups which were Bacillariophyceae, Dinophyceae, Cyanophyceae and Chlorophyceae. At station CW1, Bacillariophyceae was the most dominant group with the lowest number being 68 cell/l recorded in December 2012, and highest value being 726 cells/l recorded in May 2012 (Table 3). Dinophyceae was the second abundant group and recorded the lowest value being 24 cells/l in July 2012 and the highest value being 1970 cells/l recorded in April 2013 (Table 3). Cyanophyceae was the third abundant group with minimum number of 26 cells/l recorded in January 2013 and the maximum number was 632 cells/l recorded in May 2012 (Table 3). The presence of Chlorophyceae was occasionally and recorded in very low number as shown in Table 3.

At site level, diatoms were more prominent at Bawe compare to Chwaka Bay as indicated in Fig. 2. Dinoflagellates and cyanobacteria were occurring at high numbers in Chwaka Bay compare to Bawe, while other groups of phytoplankton were occurring at low number at all sites (Fig. 2).

Discussion

Composition, abundance and distribution of phytoplankton in Zanzibar coastal waters

Abundance of phytoplankton in tropical waters were reported to vary outstandingly due to the seasonal environmental fluctuations, and these variations are well pronounced in the protected system of estuarine waters (Marinho and Huszar, 2002). In this study contribution of each group of phytoplankton in term of abundance and composition was in the following order:
Diatoms>Dinoflagellates>Cyanobacteria>Dictyochophyceae, Chlorophyceae and Crysophyceae.

The dominance of diatoms could be due to the fact that they can withstand broadly changing hydrographical conditions (Rajasegar *et al.,* 2000; Gowda *et al.,* 2001). The high value of phytoplankton abundance irrespective of the season at Bawe was due to the favourable conditions for phytoplankton growth that existed at Bawe. Bawe stations were having stable environmental conditions with clear and good water quality. Most of diatoms prefer clear and aerated water that are rich in dissolved oxygen.

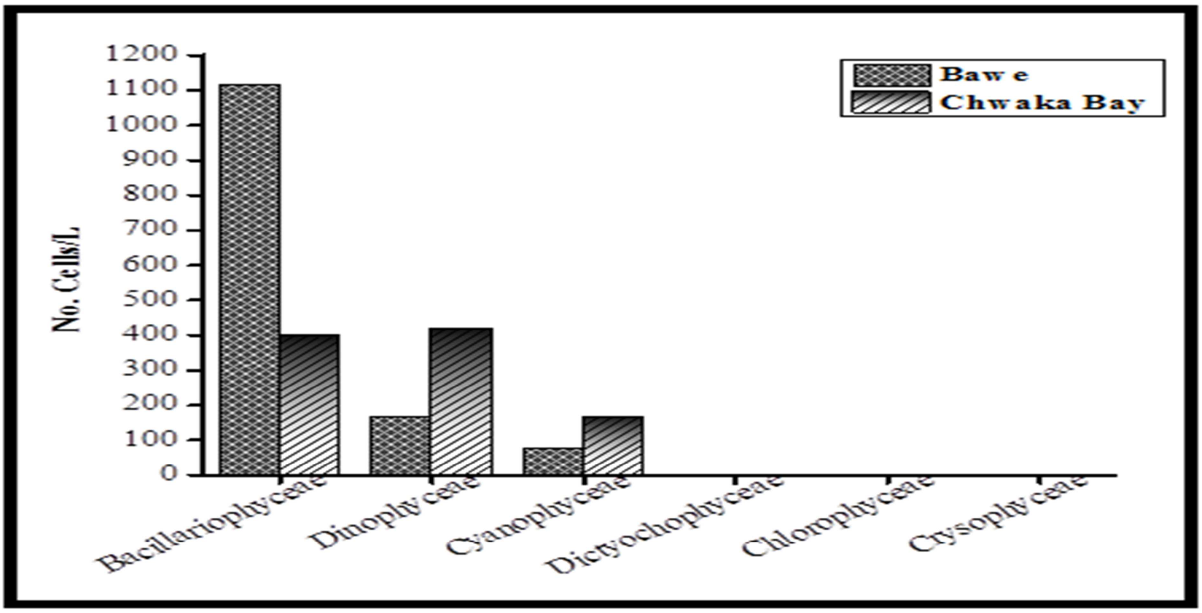

Fig. 2. Phytoplankton major groups and their abundance at Bawe and Chwaka Bay sites over the entire sampling period (May 2012 to May 2013).

The results observed at the Bawe site showed that dissolved oxygen was high throughout the study period, which supports growth of diatoms. Dissolved oxygen at Bawe stations ranged between 5.40 - 8.37 mg/l and 4.73 - 7.55 mg/l at BW1 and BW2, respectively. This finding corresponds with the observation of Venkateshwarlu (1970) who found that diatoms choose well aerated waters that are rich in dissolved oxygen. The genera *Chaetoceros* (18 species) and *Rhizosolenia* (19 species) were more dominant and abundant and were observed in good numbers at Bawe site during both seasons (SEM and

NEM). The significant presence of the *Rhizosolenia species* could be due to the fact that these species come to the surface for photosynthesis and in search of nitrate through vertical migration (Singler and Villareal, 2005).

On the other hand, members of the genus Chaetoceros prefer relatively higher nutrient regions with clear and aerated waters and were recorded mostly at Bawe stations implying nutrient enriched areas. *Guinardia flaccida, Nitzschia pugens, N. longissima* and *Thalassiothrix flauenfeldii* were also found mostly in Bawe waters, this could be due to their ability to tolerate wide temperature variations (Horner, 2002). Predominance of the genera Chaetoceros, Rhizosolenia and Nitzschiaover the study period confirmed their hardy nature and adaptation to the environmentalcondition of Zanzibar coastal waters. Genera Chaetoceros, Thalassiosira, Rhizosolenia and Nitzschia are often described in the literature as being dominant in coastal upwelling regions (Kobayashi and Takahashi, 2002). In addition, these diatoms are actually well customized to the turbulent, high-energy, nutrient-rich upwelling conditions and are found to be cosmopolitan genera frequently occurring in coastal waters (Van den Hoek *et al.,* 1995, Tomas, 1997). The diatoms abundance could also be attributed by the increase in salinity, pH, medium temperature and high intensity of light penetration during the SEM season (Rajkumar *et al.,* 2009). The occurrences of species from the genera: Bacteriastrum, Cerataulina, Chaetoceros, Coscinodiscus, Guinardia, Hemiaulus, Leptocylindrus, Nitzschia, Thalassiosira, Thalassiothrix, and Rhizosoleniaat Bawe were consistent with previous reports of the preference for high salinity waters and are referred to as open sea water species (Rajkumar *et al.,* 2009).

Similarly, dinoflagellates of the following genera were dominant at Bawe: Amphisolenia, Ceratium, Prorocentrum, Dinophysis and Protoperidinium. These species were recorded from the near shore to open sea waters and may be regarded as oceanic species.Among the dinoflagellates, Ceratium was the dominant and abundant one, with 16 species, followed by Protoperidinium with 10 species. Ceratium and Protoperidinium have been reported to be dominant genera in tropical and subtropical waters (Balkis, 2003; Taylor *et al.,* 2008). Although it was observed that a total of 16 species under a single genus Ceratium, were present during the study period, but it was noted that only three species, *Ceratium furca, C. trichoceros* and *C. tripos* were found throughout the sampling period of the entire year. Usually in tropical and subtropical regions Ceratiumare the most dominant dinoflagellates (Taylor, 2004) and showed their greatest diversity in this study. Harmful dinoflagellates such as *Ceratium furca* and *C. gibberum* were also recorded during this study, though in low number. These species have been reported to chock the fish gills due to their epithecal and hypothecal horns. The same result has been reported by Taylor *et al.* (2008), that *Ceratium spp.* were the most abundant dinoflagellates species in tropical and subtropical coastal waters and tend to form blooms, but in this study no blooms was observed. Other toxin producing harmful phytoplankton like *Dinophysis caudata*, and *D. fortii*, were also observed but in relatively low numbers.

For Cyanophyceae the predominant species were *Schizothrix mexicana*, *Oscillatoria erythraea* and *Trichodesmium spp*. *Oscillatoria erythraea* is a common species found in both freshwater and marine environments in the Indian Ocean (Thajuddin and Subramanian, 2005), while *Trichodesmium spp* prefers areas with nutrients deficit (Lyimo, 1995; Lyimo, 2011). In dictyochophyceae, only one genus Dictyocha with one species *Dictyocha fibula* was reported. One species each from Chlorophyceae (*Chlamydomonas reinhardtii*) and Crysophyceae (*Distephanus speculum*) were observed.

Comparatively, at Chwaka Bay phytoplankton abundance was low compare to Bawe. The low abundance at Chwaka Bay particularly during the NEM could be due to early rainfalls which cause water turbidity and lower the pH as well as salinity. Also presence of fresh water during NEM shows a change in phytoplankton composition in accordance with changes in salinity due to dilution or mixing of fresh water which prohibit growth of some phytoplankton (Gao and Song, 2005). It was very rare to find phytoplankton of the genera of Chaetoceros and Rhizosolenia as they prefer clear and aerated water, while at Chwaka Bay the waters are turbid, thus inhibit growth and survival of these phytoplankton. Generally, during NEM the composition does change in accordance with the lowering of salinity and water turbidity due to rain water dilution. However, during this season, freshwater algal forms such as *Anabaena sp., Oscillatoria sp., Microcoleus lyngbyaceus, Nostoc sp., Spirulina sp., Schizothrix sp., and Microcystis sp.* were observed.

At the mouth of the creek (CW2) and in the open water (CW3): Diatoms were the most dominant groups followed by dinoflagellates and small number of cyanobacteria species and very few species of chlorophyceae. Diatoms such as; *Amphiprora gigantea, Asterionella notata, Bacillaria paxillifer, Cylindrotheca closterium, Diatoma hyalina, Navicula spp, Nitzschia longissima, N. sigma,* and *Pleurosigma naviculaceum,* were dominant during the sampling period. The abundance and dominance of diatoms was enhanced by moderately high pH (8.0) and dissolved oxygen during both monsoon seasons, which would have provided suitable condition for their survival (Round *et al.,* 1990). It has been reported that *Cylindrotheca closterium, Diatoma hyalina, Nitzschia longissima*and *N. sigma* are euryhaline species (Gopinathan *et al.,* 2001). Though the composition of dominant species varied with seasons and with increasing salinity, *Nitzschia longissima, N. pugens* and *N. sigma* were always prominent. In the present study, the increased abundance of these species occurred during the SEM season, when the salinity was relatively high (around 35 ppm). The abundance of phytoplankton during SEM season could be attributed to the increased salinity, pH, moderate temperature and high intensity of light penetration during the season (Rajkumar *et al.,* 2009). Most phytoplankton species occurred on a seasonal basis. Species from the genera, *Asterionella, Coscinodiscus, Hantzschia, Leptocylindrus* and *Oscillatoria,* were observed at moderately high numbers during NEM at the mouth of the Creek and open bay stations in Chwaka Bay, indicating their thermophilic nature. *Trichodesmium erythraeum* was very rare/almost absent in the creek. A few phytoplankton species of diatoms (*Navicula spp, Striatella unipunctata*, *Surirella amoricana* and *Thalassiothrix frauenfeldii*) were predominantly abundant during the SEM season, indicating that these species are adapted to relatively low temperature conditions. Thus, the seasonal occurrence of phytoplankton species may be closely associated with the species-specific environmental conditions required for encystment or excystment. The occurrences of species from *Pleurosigma* and *Nitzschia* genera in Chwaka Bay were conspicuous. The presence of *Navicula species* is an indication of polluted water, means that Zanzibar coastal waters are at risk of being polluted. Phytoplankton populations also respond to temperature and salinity variation (Mani, 1992). Generally, phytoplankton abundance was observed to be slightly higher in the open bay than in the creek at Chwaka Bay. Robertson and Blabber (1992) found that phytoplankton productivity is significantly lower in estuarine and mangrove areas than it is in lagoons or open embayment fringed by estuaries or mangroves. In contrast, Selvam *et al.* (1992) found phytoplankton productivity is higher in mangrove or estuarine waters than in adjacent marine waters in the South India. Thillai *et al.* (2005) observed that the number of phytoplankton species increased consistently towards the open sea in the Bay of Bengal, and this was due to increase in salinity. The same was observed in the present study, where there was an increase of phytoplankton species and abundance towards the open bay of Chwaka.

Furthermore, there were some species which were reported for the first time by this study which included; *Mastogloia aplondida, Thalassiothrix calcicola, Ceratium pentagonum, Dinophysis fortii, Gonyaulax polygramma, Gonyaulax spinifera, Peridinium quinquecorne* (observed at both sites, Bawe and Chwaka Bay), *Merismopedia spp* observed at Chwaka Bay (CW1 and CW2) and *Chlamydomonas reinhardtii* observed at Bawe (BW1). These new species could have been introduced in Zanzibar coastal waters with ballast waters of commercial ships navigating across Zanzibar coastal waters from different parts of the world. Alternatively, these species could have been present since a long time but they were not identified either due to their scarcity or chance of finding them during sampling time. Among the new observed species some are potential harmful bloom microalgae such as *Ceratium pentagonum, Dinophysis fortii, Gonyaulax polygramma, Gonyaulax spinifera* and *Peridinium quinquecorne*.

Conclusion and Recommendation

A total of two hundred and sixty (260) species of phytoplankton were identified from five sampling stations studied in Zanzibar coastal waters during this study. They belonged to 94 genera and six classes *viz.* Bacillariophyceae, Dinophyceae, Cyanophyceae, Chlorophyceae, Crysophyceae andDictyochophyceae. Class Bacillariophyceae was the most dominant and diverse group among the phytoplankton, followed by Dinophyceae, and Cyanobacteria, other groups such as Chlorophyceae, Crysophyceae and Dictyochophyceae their occurrence were rare. Distribution and abundance of phytoplankton varied remarkably with seasonal fluctuations. *Chaetoceros, Rhizosolenia, Coscinodiscus, Ceratium* and *Pleurosigma* were present during all seasons. Also fresh water phytoplankton viz. *Microcystis, Merismopedia, Spirullina, Anabaena, and Pediasterum* were found during the rainy season and become rare/disappeared during the dry season. Lastly, this study encountered potential harmful microalgae; hence, there is a need to carry out an intensive study to identify them and asses their spatial and temporal distribution. It would be highly desirable, if remote-sensing products allowing the detection/classification of HABs could be developed.

Acknowledgement

The authors would like to thank the assistance provided by Mtumwa Mwadini during data collection and some laboratory analysis. The assistance of Khayrat Ubwa Said in nutrient analysis is also appreciated. The grant for carrying out this research was provided by Western Indian Ocean Regional Initiative in Marine Sciences and Education (WIO-RISE).

References

Alvarez-Góngora C, Herrera-Silveira JA. 2005. Variations of phytoplankton community structure related to water quality trends in a tropical karstic coastal zone. Marine Pollution Bulletin. **52,** 48 – 60.

Al-Yamani FY, Bishop J, Ramadhan E, Al-Husaini M, Al-Ghadban AN. 2004. Oceanographic Atlas of Kuwait's Waters. Kuwait Institute for Scientific Research, Kuwait. 203 p.

Arthurton RS. 2003. The fringing reef coasts of eastern Africa - present processes in their long term context. Western Indian Ocean Journal of Marine. Sciences.**2,** 1-13.

Balkis N. 2003. Seasonal variations in the phytoplankton and nutrient dynamics in the neritic water of Buyukcekmece Bay, Sea of Marmara. Journal of Plankton Research, **25,** 703 – 717.

Bryceson I. 1977. An ecological study of the phytoplankton of the coastal waters of Dar es Salaam. Ph.D. Thesis, University of Dar es Salaam.560 p.

Bryceson I. 1982. Seasonality of oceanographic conditions and phytoplankton in Dar es Salaam waters, University Science Journal, **8**(1), 66–76.

Devassy VP, Goss JI. 1988. Phytoplankton community structure and succession in tropical estuarine complex (Central West Cost of India), Estuarine, Costal Shelf Science**27,** 671–685.

Gaikwad SR, Tarot SR, Chavan TP. 2004. Diversity of Phytoplankton and zooplankton with respect to pollution status of river Tapi in North Maharastra region, Journal of Current Science, **5,** 749–754.

Gao X, Song, J. 2005. Phytoplankton distributions and their relationship with the environment in the Changjiang Estuary, China. Marine Pollution Bulletin, **50**: 327–355.

Gopinathan CP, Gireesh R, Smitha KS. 2001. Distribution of chlorophyll 'a' and 'b' in the eastern Arabian sea (west coast of India) in relation to nutrients during post monsoon. Journal of Marine Biological Association of India, **43,** 21-30.

Gowda G, Gupta TRC, Rajesh KM, Gowda H, Lingadhaland C, Ramesh AM. 2001. Seasonal distribution of phytoplankton in Nethravathi estuary, Mangalore. Journal of Marine Biological Association of India, **43,** 31– 40.

Horner RA. 2002.A taxonomic guide to some common marine phytoplankton. Biopress, Bristol, England, Pages: 195.

Kobayashi F, Takahashi K. 2002. Distribution of diatoms along equatorial transect in the western and central Pacific during the 1999 La Nin˜ a conditions. Deep-Sea Research II **49,** 2801–2821.

Kyewalyanga M, Lugomela C. 2001. Existence of potentially harmful microalgae in coastal waters around Zanzibar: A need of monitoring programme? In Richmond D.M and J. Francis, (Eds). Marine Science Development in Tanzania and East Africa.Proceedings of the 20th Anniversary Conference on Advances in Marine Sciences in Tanzania. 28th June-1st July 1999, Zanzibar, Tanzania. IMS/WIOMSA.pp 319 – 327.

Kyewalyanga MNS. 2002. Spatial-temporal changes in phytoplankton biomass and primary production in Chwaka Bay, Zanzibar. Tanzania Journal of Science **28(2),**11-26.

Lugomela C. 1996. Studies on phytoplankton in the near shore waters of Zanzibar. M.Sc. Thesis, University of Dar es salaam.174 p.

Lyimo TJ. 2011. Distribution and abundance of the cyanobacterium Richelia Intracellularis in the coastal waters of Tanzania. Journal of Ecology and the Natural Environment. **3(3),**85 – 94.

Lyimo TJ. 1995. Role played by phytoplanktonic cyanobacteria with an emphasis on Trichodesmium spp. in increasing the nitrogen level in the nearshore waters of Tanzania. M.Sc. Thesis. University of Dar es Salaam. 156 p.

Mani P. 1992. Natural phytoplankton communities in Pichavaram mangroves, Indian Journal of Marine. Science, **12,** 278 – 280.

Marinho MM, Huszar VLM. 2002. Nutrient availability and physical conditions as controlling factors of phytoplankton composition and biomass in a tropical reservoir (southeastern Brazil). Arch Hydrobiology Journal, vol. **153(3),**443–468.

Palmer CM, Walter HJ, Adams S. 1977. Algae and water pollution: an illustrated manual on the identification significance and control of algae in water supplies and in polluted water. Office of Research and Development, Ohio, p. 124.

Rajkumar M, Perumal P, Ashok P, Prabhu V. 2009. Diversity of phytoplankton in Pichavaram mangrove waters, southeast coast of India. Journal of Environmental Biology, **30,** 489 – 498.

Rajsegar M, Srinivasan M, Rajaram R. 2000. Phytoplankton diversity associated with shrimp farm development in Vellar estuary, South India. Seaweed Research and Utilization Journal, **22,** 125–131.

Robertson AI, Blabber SJM. 1992. Plankton, epibenthos and fish communities. In: Robertson A. I, Alongi D. M, eds. Tropical Mangrove Ecosystems. Coastal Estuarine Studies, **41,** 173–224**.**

Round FE, Crawford RM, Mann DG. 1990. The Diatoms, Biology and Morphology of the Genera. Cambridge University Press, Cambridge, 747 p.

Sahu KC, Baliarsingh SK, Srichandan S, Lotliker AA, Kumar TS. 2013. Monograph on Marine Plankton of East Coast of India-A Cruise Report. Indian National Centre for Ocean Information Services, Hyderabad, 146 p.

Selvam VJ, Azariah J, Azariah H. 1992. Diurnal variation in physico-chemical properties and primary production in the interconnected marine, mangrove and freshwater biotopes of Kakinda coast, Andhra Pradesh, India. Hydrobiology, **247,** 181–186.

Shubert LE. 1984. Algae as ecological indicators. Department of Biology, University of North Dakota, Grand Forks, USA.

Singler HR, Villareal TA. 2005. Nitrogen inputs into the euphotic zone by vertically migrating. Rhizosolenia mats. Journal of Plankton Research, **27(6),**545–556.

Taylor FJR. 2004. Harmful dinoflagellate species in space and time and the value of morphospecies. In: Steidinger KA, Landsberg JH, Tomas CR et al (eds) Harmful algae, IOC UNESCO, St. Petersburg, pp 555–559.

Taylor FJR, Hoppenrath M, Saldarriaga JF. 2008. Dinoflagellate diversity and distribution. Journal of Biodiversity and Conservation, **17,** 407–418.

Thajuddin N, Subramanian G. 2005. Cyanobacterial biodiversity and potential applications in biotechnology. Current Science, **89,** 47–57.

Thillai RK, Perumal P, Santhanam P. 2005. Phytoplankton diversity in the Coleroon estuary, Southeast coast of India. Journal of Marine Biological Association of India, **47,** 127–132.

Tomas CR. 1997. Identifying Marine Phytoplankton. Academic Press, California, pp.858.

Van den Hoek C, Mann DG, Jans HM. 1995. Algae. An Introduction to phycology, Cambridge University Press, Cambridge, 623 p.

Vaulot D. 2001. Phytoplankton. CentreNationale de la Recherche Scientifique et Université Pierre et Marie Curie, Roscoff, France. 56 – 60 p.

Venkateshwarlu V. 1970. An ecological study of the algae of the River Moosi Hyderabad (India) with special reference to water pollution IV. Periodicity of some common species of algae. Hydrobiologia, **35,** 45 – 64 p.