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ABUNDANCE AND DIVERSITY OF DIATOM COMMUNITIES IN GADANI (BALUCHISTAN COAST) AND SANDSPIT (SINDH COAST)

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Abstract

The present research aims to study the species diversity, abundance and spatial distribution of diatom from the coastal waters of Sindh coast (Sandspit) and Baluchistan coast (Gadani ship breaking area). The Seawater samples were collected monthly from Gadani ship breaking area and Sandspit for analysis of phytoplankton (Diatom) on board using Niskin bottles. A total of 109 phytoplankton species are identified from two sites. Eight dominant species of Bacillariophyceae observed in all stations on both sites such as *Bacillaria paxillifer, Coscinodiscus* spp., *Cymatosira lorenziana, Guinardia delicatula, Melosira arctica, Nitzschia longissima, Rhizosolenia Setigera and Rhizosolenia imbricata.* Diverse species of phytoplankton in Gadani compared to Sandspit were observed. In the Gadani area, 85 species of diatoms and from Sandspit 74 species of diatom were recorded. Thirty-four genera were observed in Gadani, whereas 27 genera were observed in Sandspit. The results showed quite variation in the species composition of phytoplankton in two coastal sites and along with the difference of nearshore and offshore zones. Diatom communities are susceptible to change in their environment; the pollution due to anthropogenic substances in the coastal waters and changing climatic conditions trigger HAB forming species, which is perilous for marine fauna particularly, fishes.

Key words: Phytoplankton, Microorganisms, Diversity, *Rhizosolenia*, *Nitzschia*.

Introduction

Diatoms are the most dominant group of photosynthetic microorganisms in aquatic ecosystem. They form major group of phytoplankton community in various parts of the world (Tomas, 1997; Raghavan *et al*., 2008). Diatoms have great species diversity 10,000 to 100,000 taxa and are found in diverse range of habitats (Norton *et al*., 1996; Muruganantham *et al*., 2012). They are placed in class Bacillariophyceae having two orders pennales and centrales. They are primary producers of marine ecosystem and are present in the upper part (pelagic zone) of the ocean, where sunlight penetrates the water. Diatom requires inorganic nutrients such as nitrates, nitrite and phosphates etc. which they convert into proteins, fats, and carbohydrates. Their role as bioindicator of ecological health is well recognized (Laskar & Gupta, 2009). Physico-chemical conditions, such as hydrographic environments, nutrient levels, and biological processes (e.g. grazing, growth) control the distribution and abundance of diatom species (Guo *et al*., 2020). Studies have shown that environmental factors such as temperature, light, pH, salinity and availability of nutrients induce the productivity, composition and growth of diatoms (Parida & Das, 2005). In the presence of maximum availability of nutrient, salinity, wind velocity and the Seawater inflow diatoms proliferate (Dwivedi & Pandey, 2002). Presence of Silicate is a limiting nutrient and the profusion of diatoms depends upon it. Growth of diatoms communities is related to physical condition like turbidity, depth and light (Dortch *et al*., 1997). Diatoms are a source of food for marine organisms in coastal waters (Cebrian *et al*., 2009). They are considered indicator organisms for change in water quality due to their short life span, nutrient and generation times, they can modify their diversity and abundance in response to water quality (Cloern *et al*., 1999). The accretion of nutrients in coastal areas may enhance the growth of phytoplankton species resulting in formation of blooms which cause negative effects on environment and human health implications (Masmoudi *et al*., 2015). Bloom of some diatom species may cause high damage to health and is reported to bioaccumulate in marine organisms (Landsberg, 2002). They are reported to alter the water discolouration, taste, odour and form mats that result in interference with boating, fishing activity and swimming.

Several diatom species have been known to tolerate pronounced degrees of salinity (Pal *et al*., 2011). Under stress environment they have a genetical ability to regulate nutrient consumption, biosynthetic process and biomass (Radakovits *et al*., 2012). However, phytoplankton are primary producers, they produce extracellular substances, store polysaccahrides and accumulate bioactive metabolites for example polyunsaturated fatty acids that contribute as a food for zooplankton and injurious biotoxins (Pulz, 2004). Some phytoplankton species are toxic and release toxins in the water column (Whitton & Patts, 2000). Some phytoplankton species produce toxins domoic acid that affects human and animal health. Domoic acid, a secondary metabolite is the cause of Amnesic Shellfish Poisoning (ASP). In human beings the Amnesic Shellfish Poisoning causes headache, abdominal cramps, vomiting, and diarrhea, loss of memory, coma and death. In marine mammals, fish, sea birds and sea lions Amnesic Shellfish Poisoning has been reported (Landsberg, 2002, Trainer*et al*., 2008). Domoic acid bioaccumulates in shellfish after consumption of toxic phytoplankton. Genus of Diatom *Pseudonitzchia* and *Amphora* species are toxic and produce domoic acid (Bates, 2000).

Substantial studies have been carried out to record phytoplankton community from coastal waters of Pakistan. Seasonal variations in abundance, diversity, and biovolume and growth rate of phytoplankton community including diatoms have been investigated from coastal waters of Karachi, Pakistan (Naz *et al*., 2013, 2014; Khokhar *et al*., 2016). Many taxonomical and distributional studies of diatoms have been conducted in the coastal waters of Pakistan (Chaghtai & Saifullah, 1992; Shameel & Tanaka, 1992; Saifullah, 1994; Tabassum & Saifullah, 2010, 2011, 2012; Latif *et al*., 2013; Naz *et al*., 2013).

It is important to analyze the phytoplankton diversity and composition as it determines the productivity of the sea (Qasim & Kureishy, 1986). Bell *et al*., (1996) indicated that water quality characteristics influenced phytoplankton abundance, diversity, species richness, distribution and densities, as well as changes in species composition of aquatic communities and high mortality of sensitive life stages of macroinvertebrates (Welch, 1980). Change in phytoplankton community (diatoms) structure may have important implications in food web dynamics and nutrient cycling (Graham *et al*., 2009). In the present study biodiversity and richness of phytoplankton (Diatom) in relation to physicochemical parameters from the coastal and near–shore waters in the Ship breaking industry and Sandspit was carried out.

Material and Methods

The Seawater samples were collected monthly from Gadani ship breaking area and Sandspit for analysis of phytoplankton (Diatom). The extent of biodiversity and richness of diatom were studied. Physical and chemical parameters were determined from Seawater samples collected on board using Niskin bottles (1.7 litre). Seawater temperature was determined with the help of mercury thermometer, pH meter (Hanna. Inc). Salinity was recorded using Atago refractometer. Dissolved Oxygen was detected by Winkler method (Strickland & Parsons, 1972). Nutrients (nitrate, nitrite, ammonia and phosphate) and chlorophyll *a* were assessed according to Strickland & Parsons, 1972.

Seawater sample were fixed with Lugols solution in amber bottle (200ml) on board. Diatom was observed by using inverted microscope (Olympus, BX-51, Japan). For Dissolve Oxygen samples of seawater were collected in BOD glass bottles (150 ml) and fixed with 1 ml of alkaline potassium iodide and 1 ml of manganese sulphate. Precipitates were dissolved by adding 1 ml of sulphuric acid in BOD bottles. The fixed water samples were then titrated with sodium thiosulphate. For the analysis of Chlorophyll-*a,* 1L of water samples were filtered by using filtration assembly through glass fiber filter papers (0.7 µm; Whatman). The filter papers along with residue were transferred to 90% acetone and were placed in dark at 4°C for 24 hrs. Chlorophyll *a* was determined by using Shimadzo UV-visible spectrophotometer (Strickland & Parsons, 1972).

Results

The environment parameters at two different sites are depicted in Tables 3 and 4. No significant difference in mean values of temperature, salinity, pH and Nitrate was found between two site. However, Dissolve Oxygen, Phosphate and Chlorophyll *a* was greater in Gadani compared to Sandspit.

Eight dominant species (1001-50,000<) of Bacillariophyceae (Tables 1 and 2) were observed in all stations from both sites such as *Bacillaria paxillifer, Coscinodiscus* spp., *Cymatosira lorenziana, Guinardia delicatula, Melosira arctica, Nitzschia longissima, Rhizosolenia setigera* and *Rhizosolenia imbricate.* Fourteen common species (250-1000) while 29 rare (1-249) species of Bacillariophyceae were identified from both sites.

In Sandspit dominant species of Bacillariophyceae were observed in all stations such as, *Coscinodiscus* spp.*, Cymatosira lorenziana, Guinardia delicatula, Melosira arctica, Nitzschia longissima,* while *Cosinodiscus gigas, Cosinodiscus granii, Thalassionema nitzschioides,* dominant only in ST I. *Cylindrotheca closterium, Melosira nummuloides, Navicula septentrionalis, Nitzschia multiseries, Pseudonitzchia lineola,* are dominant in ST II (Table 1).

In Gadani dominant species were observed from all stations named as *Bacillaria paxillifer, Coscinodiscus* spp., *Cymatosira lorenziana, Nitzschia longissima, Rhizosolenia Setigera, Rhizosolenia imbricata* while *Guinardia flaccida, Nitzschia acicularis* are dominant only in ST I. *Melosira arctica, Pseudonitzchia Pseudodelicatissima, Pseudonitzchia delicatissima,* abundant only in ST II &III. *Cylindrotheca closterium, Hemiaulus sinensis, Odentella sinensis, Pseudonitzchia lineola,* dominant in ST III whereas *Nitzschia spp* found dominant in ST I & III (Table 2).

Variations in the abundance and diversity of diatoms were observed in Sandspit and Gadani. The abundance of diatoms was highest in Gadani in month of February as compared to Sandspit (Fig. 1).

Total phytoplankton were compared to diatom in Sandspit. The phytoplankton were most abundant in the month of August (Fig. 2). The peak abundance of phytoplankton was recorded in the month of February in Gadani when total phytoplankton were compared to diatom (Fig. 3). The results showed abundance of diatom in all three stations in Gadani. While the abundance of diatoms was highest in station II compared to other stations (Fig. 4). The abundance of diatom in two stations of Sandspit in January was at peak compared to other months in Sandspit (Fig. 5).

Pearson correlation coefficient (Table 8) was used to observe the association between phytoplankton with hydrographical parameters and nutrients. Phytoplankton abundance was positively correlated with salinity, temperature, Nitrate, Nitrite, Phosphate and Ammonia and negatively correlated with pH, Dissolve Oxygen and Chlorophyll *a*, at Gadani. However, in Sandspit (Table 7) phytoplankton abundance was positively correlated with Nitrate, salinity, Ammonia and Phosphate whereas negative correlation was found with pH, temperature, Dissolve Oxygen, Nitrite and Chlorophyll *a*.

Pearson correlation coefficient (Table 6) was used to observe the association among diatom communities with hydrographical parameters and nutrients. Diatom abundance was positively correlated with Ammonia and salinity and negatively correlated with temperature, pH, Dissolve Oxygen, Phosphate, Nitrite, Nitrate and Chlorophyll-*a* at Gadani. Whereas in Sandspit (Table 5) Diatom abundance was positively correlated with salinity, pH, Nitrite, Phosphate and Ammonia and a negative correlation was found with temperature, Dissolve Oxygen, Nitrate, and Chlorophyll *a*.

Table 1. Identified species of Bacillariophyceae (Cells/L) from the sandspit.

S. No.	Genra	S. No.	Class Bacillariophyceae	ST I	ST II
1.	*Amphora*	1	*Amphora* spp.	**	**
2.	*Bacteriastrum*	1	*Bacteriastrum delicatulum*	A	*
		2	*Bacteriastrum elongatum cleve*	*	*
3.	*Coscinodiscus*	1	*Coscinodiscus* spp.	***	***
		2	*Coscinodiscus gigas*	***	**
		3	*Coscinodiscus radiatus*	*	*
		4	*Coscinodiscus granii*	***	**
		5	*Coscinodiscus Astesomphalus ehrenberg*	**	*
4.	*Chaetoceros*	1	*Chaetoceros affinis*	A	*
		2	*Cheatoceros criopillus*	A	*
		3	*Chaetoceros costatus*	*	A
		4	*Chaetoceros danicus*	*	*
		5	*Chaetoceros neglectus*	A	*
		6	*Cheatoceros* spp.	**	**
5.	*Cylindrotheca*	1	*Cylindrotheca closterium*	**	***
6.	*Cymatosira*	1	*Cymatosira lorenziana*	***	***
7.	*Ditylum*	1	*Ditylum brightwellii*	A	*
8.	*Eucampia*	1	*Eucampia zodiacus*	**	**
		2	*Eucampia cylindricornis*	A	*
9.	*Guinardia*	1	*Guinardia delicatula*	***	***
		2	*Guinardia flaccida*	**	*
		3	*Guinardia striata*	*	A
10.	*Hemiaulus*	1	*Hemiaulus sinensis*	*	*
11.	*Leptocylindrus*	1	*Leptocylindrus danicens*	*	A
12.	*Licmophora*	1	*Licmophora flabellate*	A	*
13.	*Melosira*	1	*Melosira arctica*	***	***
		2	*Melosira nummuloides*	*	***
14.	*Navicula*	1	*Navicula directa*	**	**
		2	*Navicula distans*	**	**
		3	*Navicula directum*	*	*
		4	*Navicula transitrans* var *derasa*	*	*
		5	*Navicula septentrionalis*	**	***
		6	*Navicula vanhoeffenii*	A	*
15.	*Nitzschia*	1	*Nitzschia longissima*	***	***
		2	*Nitzschia acicularis*	**	*
		3	*Nitzchia subpacifica*	*	A
		4	*Nitzchia turgidula*	*	**

Table 1. (Cont'd.).

S. No.	Genra	S. No.	Class Bacillariophyceae	ST I	ST II
		5	*Nitzschia multiseries*	**	***
		6	*Nitzschia lorenziana*	*	A
		7	*Nitzschiz sigmoidea*	*	A
		8	*Nitzschia dissipata*	**	A
		9	*Nitzschia* spp.	**	**
16.	*Odontella*	1	*Odontella sinensis*	**	**
		2	*Odontella aurita*	**	**
		3	*Odontella mobiliensis*	**	*
17.	*Pinnularia*	1	*Pinnularia*	*	A
18.	*Planktoneilla*	1	*Planktoneilla sol* (Wallich) Schutt.	A	*
19.	*Pleurosigma*	1	*Pleurosigma directa*	*	A
		2	*Pleurosigma normanii*	*	*
		3	*Pleurosigma directum*	*	*
		4	*Pleurosigma elongatum*	*	*
20.	*Proboscia*	1	*Proboscia alata*	*	*
21.	*Porosira*	1	*Porosira glacialis*	A	*
22.	*Pseudoguinardia*	1	*Pseudoguinardia recta*	A	*
23.	*Pseudonitzschia*	1	*Pseudonitzschia* spp.	A	*
		2	*Pseudo nitzschia australis*	A	*
		3	*Pseudonitzschia heimii manguin*	**	*
		4	*Pseudonitzchia fraudulenta*	**	**
		5	*Pseudonitzchia pseudodelicatissima*	**	**
		6	*Pseudonitzchia delicatissima*	**	*
		7	*Pseudonitzschia lineola*	**	***
		8	*Pseudonitzchia turgidula*	**	*
		9	*Pseudonitzschia granii* var. *granii*	*	A
		10	*Pseudonitzchia subpacifica*	*	*
		11	*P. prolongatoides*	**	*
24.	*Rhizosolenia*	1	*Rhizosolenia setigera*	**	**
		2	*Rhizosolenia imbricate*	*	**
		3	*Rhizosolenia hyalina*	**	*
		4	*Rhizosolenia robusta*	*	*
		5	*Rhizosolenia styliformis*	*	*
25.	*Striatella*	1	*Striatella unipunctata*	**	*
26.	*Thalasiosira*	1	*Thalasiosira* spp.	*	*
27.	*Thalassionema*	1	*Thalassionema nitzschioides*	***	**
		2	*Thalassionema freuenfledii*	*	**

Rare= 1-249 *, Common= 250-1000**, Abundant = 1001-50,000<***

Table 2. Identified species of bacillariophyceae (Cells/L) from the gadani ship breaking area.

S. No.	Genra	S. No	Class Bacillariophyceae species	ST I (cell/L)	ST II (cell/L)	ST III (cell/L)
1.	*Amphora*	1	*Amphora* spp.	A	*	*
2.	*Adoneis*	1	*Adoneis pacifica*	*	*	A
3.	*Asterionella*	1	*Asterionella formosa*	*	A	A
4.	*Asterionellopsis*	2	*Asterionellopsis glacialis*	A	A	*
5.	*Aulacoseria*	5	*Aulacoseria granulate*	A	*	A
6.	*Achnanthes*	6	*Achnanthes taeniata*	A	*	*
7.	*Bacillaria*	7	*Bacillaria paxillifer*	***	***	***
8.	*Bleakeleya*	8	*Bleakeleya notate*	A	*	A
9.	*Cyclotella*	9	*Cyclotella* spp.	A	*	*
10.	*Coscinodiscus*	10	*Coscinodiscus* spp.	***	***	***
11.	*Cymatosira*	11	*Cymatosira lorenziana*	***	***	***
		12	*Cymatosira acremonia*	**	A	*
12.	*Chaetoceros*	1	*Chaetoceros decipiens*	*	*	*
		2	*Cheatoceros peruvianus*	*	*	*
		3	*Cheatoceros criopillus*	*	*	*
		4	*Chaetoceros atlanticus*	*	*	*
		5	*Cheatoceros lorenziana*	*	*	*
		6	*Chaetoceros aequatorialis*	*	*	*
		7	*Chaetoceros laciniosus*	A	*	A
		8	*Chaeoceros lauderi*	A	A	*
		10	*Chaetoceros danicus*	*	*	*
		11	*Chaetoceros affinis*	A	A	*
		12	*Cheatoceros* spp.	*	*	*
13.	*Cylindrotheca*	1	*Cylindrotheca closterium*	**	**	***
14.	*Eucamphia*	1	*Eucamphia* spp.	*	A	A
15.	*Guinardia*	1	*Guinardia delicatula*	**	**	**
		2	*Guinardia flaccida*	***	**	**
		3	*Guinardia striata*	A	*	*
16.	*Haslea*	1	*Haslea wawrikae*	*	*	*
17.	*Hemiaulus*	1	*Hemiaulus sinensis*	*	**	***
18.	*Hantzschia*	1	*Hantzschia amphioxys*	*	A	A
19.	*Leptocylindrus*	1	*Leptocylindrus danicens*	A	A	*
20.	*Melosira*	1	*Melosira arctica*	*	***	***
21.	*Merdion*	1	*Merdion circular*	A	*	A
22.	*Navicula*	1	*Navicula directa*	**	**	**
		2	*Navicula distans*	*	*	*
		3	*Navicula transitrans* var. *derasa*	A	A	*
		4	*Navicula septentrionalis*	**	**	**
23.	*Nitzschia*	1	*Nitzschia longissima*	***	***	***
		2	*Nitzschia acicularis*	***	*	A
		3	*Nitzchia subpacifica*	*	A	A
		4	*Nitzschia* spp.	***	**	***

Table 2. (Cont'd.).

S. No.	Genra	S. No	Class Bacillariophyceae species	ST I (cell/L)	ST II (cell/L)	ST III (cell/L)
24.	*Neodenticula*	1	*Neodenticula seminae*	*	A	A
25.	*Odentella*	1	*Odentella sinensis*	**	**	***
		2	*Odentella aurita*	*	*	*
		3	*Odentella mobiliensis*	A	A	*
		4	*Odentella longicruris*	*	*	*
26.	*Octactis*	1	*Octactis octonaria*	A	*	A
27.	*Planktoniella*	1	*Planktoniella sol* (Wallich) Schutt.	*	*	*
28.	*Pleurosigma*	1	*Pleurosigma directa*	*	*	*
		2	*Pleurosigma normanii*	**	**	**
		3	*Pleurosigma directum*	*	*	*
29.	*Proboscia*	1	*Proboscia alata*	*	*	**
30.	*Pseudonitzschia*	1	*Pseudonitzschia* spp.	**	**	*
		2	*Pseudonitzschia heimii manguin*	A	**	A
		3	*Pseudonitzschia pungens*	**	*	**
		4	*Pseudonitzchia fraudulenta*	*	**	A
		5	*Pseudonitzchia pseudodelicatissima*	A	***	***
		6	*Pseudonitzchia delicatissima*	**	***	***
		7	*Pseudonitzchia seriata*	A	*	A
		8	*Pseudonitzchia lineola*	**	**	***
		9	*Pseudonitzchia subcurvata*	A	A	*
		10	*Pseudonitzchia multiseries*	A	*	**
		11	*Pseudonitzchia turgidula*	A	*	A
		12	*Pseudonitzschia granii* var. *granii*	A	*	A
		13	*Pseudonitzchia subpacifica*	A	A	*
		14	*Pseudonitzschia longissima*	*	A	A
31.	*Rhizosolenia*	1	*Rhizosolenia setigera*	***	***	***
		2	*Rhizosolenia formosa*	*	**	**
		3	*Rhizosolenia imbricate*	***	***	***
		4	*Rhizosolenia hyaline*	*	*	A
		5	*Rhizosolenia borcalis*	A	*	*
		6	*Rhizosolenia robusta*	*	*	*
		7	*Rhizosolenia styliformis*	*	*	*
		8	*Rhizosolenia heimii*	*	A	A
		9	*Rhizosolenia curvata*	A	A	*
		10	*Rhizosolenia cressa*	*	*	*
		11	*Rhizosolenia pungens*	*	A	A
		12	*Rhizosolenia* spp.	*	*	*
		13	*Rhizosolenia alata*	A	A	*
32.	*Striatella*	1	*Striatella unipunctata*	A	*	A
33.	*Thalasiosira*	1	*Thalasiosira* spp.	A	*	A
34.	*Thalassionema*	1	*Thalassionema nitzschioides*	**	*	**
		2	*Thalassionema freuenfledii*	*	A	A
		3	*Thalassionema javanicum*	*	A	A

Rare= 1-249 *, Common= 250-1000**, Abundant = 1001-50,000<***

Table 3. Values showing environmental parameters at Gadani stations.

Parameters	Mean	St. Dev.	S.E	Range (Min-Max)
Temp°C	25.667	4.053	2.866	20-31
Saliniy (ppt)	35.333	2.498	1.767	31-38
PH	8.075	0.469	0.332	7-8.7
Oxygen (ppm)	9.275	1.076	0.761	7.7-10
Nitrate (ppm)	9.967	0.049	0.035	9.8-10
Nitrite (ppm)	0.200	0.001	0.001	0.19-.20
Phosphate (ppm)	3.583	1.564	1.106	1.4-5
Ammonia (ppm)	1.750	0.544	0.384	09-2.5
Chlorophyll (µ/l)	0.946	1.088	0.769	5-2.4

Table 4. Values showing environmental parameters at Sandspit stations.

Parameters	Mean	St. Dev.	S. E	Range (Min-Max)
Temp°C	25.333	3.916	2.769	19-30
Saliniy (ppt)	35.833	2.588	1.830	32-39
PH	8.108	0.355	0.251	7.7-8
Oxygen (ppm)	8.683	1.765	1.248	11-6.2
Nitrate (ppm)	9.983	0.039	0.028	9.9-10
Nitrite (ppm)	0.300	0.195	0.138	0.02-0.5
Phosphate (ppm)	2.667	1.614	1.142	0.42-4.9
Ammonia (ppm)	1.958	0.396	0.280	1.4-2.5
Chlorophyll (µ/l)	0.600	0.498	0.352	0.08-1.2

Table 5. Pearson correlation coefficient relationships between abundance of Diatom with hydrographical parameters and nutrients in Sandspit.

	Abundance	Temp.	Salinity	pH	Oxygen	Nitrate	Nitrite	Phosphate	Ammonia
Temp	-0.319								
Salinity	0.056	0.158							
pH	0.616	-0.081	-0.107						
Oxygen	-0.306	-0.105	-0.109	0.096					
Nitrate	-0.020	-0.020	0.421	-0.383	0.135				
Nitrite	0.454	-0.036	-0.054	0.380	0.089	0.478			
Phosphate	0.147	-0.168	-0.297	0.449	-0.171	-0.096	0.288		
Ammonia	0.224	0.244	0.436	-0.126	0.007	0.540	0.059	-0.450	
Chlorophyll a	-0.640	0.470	0.118	-0.611	0.238	0.441	-0.076	-0.336	0.301

Table 6. Pearson correlation coefficient relationships between abundance of Diatom with hydrographical parameters and nutrients in Gadani.

	Abundance	Temp.	Salinity	pH	Oxygen	Nitrate	Nitrite	Phosphate	Ammonia
Temp	-0.347								
Salinity	0.143	-0.170							
pH	-0.194	0.101	0.792						
Oxygen	-0.349	0.061	0.477	0.844					
Nitrate	-0.189	0.078	0.826	0.988	0.811				
Nitrite	-0.192	0.083	0.849	0.951	0.763	0.986			
Phosphate	-0.335	0.378	0.304	0.435	0.309	0.475	0.509		
Ammonia	0.013	0.272	0.709	0.876	0.689	0.875	0.854	0.300	
Chlorophyll a	-0.148	0.406	-0.206	0.021	0.359	0.027	0.070	0.149	0.157

Table 7. Pearson correlation coefficient relationships between abundance of Phytoplankton with hydrographical parameters and nutrients in Sandspit.

	Abundance	Temp.	Salinity	pH	Oxygen	Nitrate	Nitrite	Phosphate	Ammonia
Temp	-0.041								
Salinity	0.227	0.158							
pH	-0.108	-0.081	-0.107						
Oxygen	-0.626	-0.105	-0.109	0.096					
Nitrate	0.106	-0.020	0.421	-0.383	0.135				
Nitrite	-0.110	-0.036	-0.054	0.380	0.089	0.478			
Phosphate	0.115	-0.168	-0.297	0.449	-0.171	-0.096	0.288		
Ammonia	0.423	0.244	0.436	-0.126	0.007	0.540	0.059	-0.450	
Chlorophyll *a*	-0.278	0.470	0.118	-0.611	0.238	0.441	-0.076	-0.336	0.301

Table 8. Pearson correlation coefficient relationships between abundance of Phytoplankton with hydrographical parameters and nutrients in Gadani.

	Abundance	Temp.	Salinity	pH	Oxygen	Nitrate	Nitrite	Phosphate	Ammonia
Temp	0.150								
Salinity	0.301	-0.170							
pH	-0.029	0.101	0.792						
oxygen	-0.441	0.061	0.477	0.844					
Nitrate	0.005	0.078	0.826	0.988	0.811				
Nitrite	0.043	0.083	0.849	0.951	0.763	0.986			
Phosphate	0.190	0.378	0.304	0.435	0.309	0.475	0.509		
Ammonia	0.102	0.272	0.709	0.876	0.689	0.875	0.854	0.300	
Chlorophyll *a*	-0.567	0.406	-0.206	0.021	0.359	0.027	0.070	0.149	0.157

Table 9. Bacillariophyceae diversity index, richness, and evenness in the sandspit and Gadani.

Site	Stations	No. of species	Total no. of ind.	Margalef richness index	pielou's evenness index	Shannon diversity index
Sandspit	I	62	37800	5.7874	0.79038	3.262
Sandspit	II	63	33220	5.9553	0.78623	3.2574
Gadani	I	57	28180	5.4654	0.73199	2.9595
Gadani	II	63	36440	5.9028	0.76757	3.1801
Gadani	III	59	33700	5.5634	0.79384	3.2369

In Sandspit the Shannon diversity index was 3.26 in Station I compared to 3.25 in station II whereas in Gadani in station III highest diversity was recorded as 3.23 (Table 9). Margalef richness index and number of species was high in both sites in station II. Total number of individuals observed in Sandspit was higher in Station I compared to station II. Total number of individuals detected in Gadani was highest in station II as compared to two stations. Pielou's evenness was higher in station I in Sandspit compared to station II whereas in Gadani it was highest in station III.

Discussion

The present study reveals the diversity of diatom from the coastal waters of Sind (Sandspit) and Baluchistan coast (Gadani ship breaking area). Species diversity of diatom was more in Gadani compared to Sandspit. It may be related to the high values of Dissolve Oxygen, Phosphate and Chlorophyll *a* in Gadani compared to Sandspit. Increase in nutrient enhances diatom growth and results in high productivity of the Ocean (Hansen *et al*., 2000). In the Gadani area 85 species of diatom and 74 species from Sandspit were recorded. Thirty-four genera were observed in Gadani whereas, 27 genera were found in Sandspit. In Gadani, station I and III, a total of 23 genera was recorded whereas in station II 28 diatom genera were observed. Whereas, in Sandspit in station I 21 diatom genera and in station II 23 genera were recorded.

However, twenty-one genera were common in Gadani and Sandspit stations (*Amphora, Coscinodiscus, Chaetoceros, Cylindrotheca, Cymatosira, Eucampia, Guinardia, Hemiaulus, Leptocylindrus, Melosira, Navicula, Nitzschia, Odontella, Planktoniella, Pleurosigma, Proboscia, Pseudo-nitzschia, Rhizosolenia, Striatella, Thalassiosira, Thalassionema*). The most abundant genera in Gadani were *Pseudo-nitzschia* (14 spp.), *Nitzschia* (4 spp) *and Rhizosolenia* (13 spp) whereas, in Sandspit the most abundant genera were *Coscinodiscus* (5 spp), *Cymatosira* spp, *Guinardia* (3 spp), *Melosira* (2 spp) and *Nitzschia* (9 spp). Literature showed that the marine diatom *Pseudo-nitzschia* produce domoic acid, which is a neurotoxin responsible for illness and mortality in both humans and marine wildlife (Jester *et al*., 2009). In the present study fourteen species of *Pseudo-nitzschia* were observed at Gadani ship breaking area including *Pseudo-nitzschia* spp, *P. delicatissima, P. fraudulenta, P. Pseudonitzschia delicatissima, P. pungens, P. multiseries,* P. *heimii manguin, P. lineola, P. subcurvata, P. turgidula, P granii var granii, P. subpacifica, P. prolongatoides, P. longissima.* In Sandspit total number of *Pseudo-nitzschia* species were eleven. *Pseudo-nitzschia* spp, *P. australis,* P. *heimii manguin, P. fraudulenta, Pseudonitzchia Pseudodelicatissima, P. delicatissima, P. lineola, P. turgidula. P granii var granii, P. subpacifica, P. prolongatoides.* While Khokhar *et al*., (2016) reported 4 species of *Pseudo-nitzschia: Pseudo-nitzschia sp.1, P. fraudulenta, P. seriata, P. subcurvata* from coastal waters of Pakistan.

The presence of organic pollution indicator species of *Navicula* and *Nitzschia* in coastal waters is a warning signal of environmental deterioration of the marine environment (Yusuf, 2020). However, the genus *Navicula* and *Nitzschia* were observed in both sites indicating organic pollution in marine environment. Blooms can develop in response to environment imposing with water quality parameters (e.g., nutrient loading), hydrologic transport, and species interactions all contributing by mixotrophic taxa. The occurrence of harmful algal blooms has increased due to climate change and eutrophication interactions (O'Neil *et al*., 2012). Changes in algal community composition and diversity may occur in short time periods in response to environmental variability (Paerl *et al*., 2010) and may affect ecological function (Duarte *et al*., 2006). It is anticipated that atmospheric nitrogen deposition would increase in the Arabian Sea by 2030 compared to what it was in 2000 (Duce *et al*., 2008). This shift of N:P ratio would certainly affect the creation of harmful algal blooms. In future, consistent system of monitoring plankton along with further investigation in the northern Arabian Sea is required.

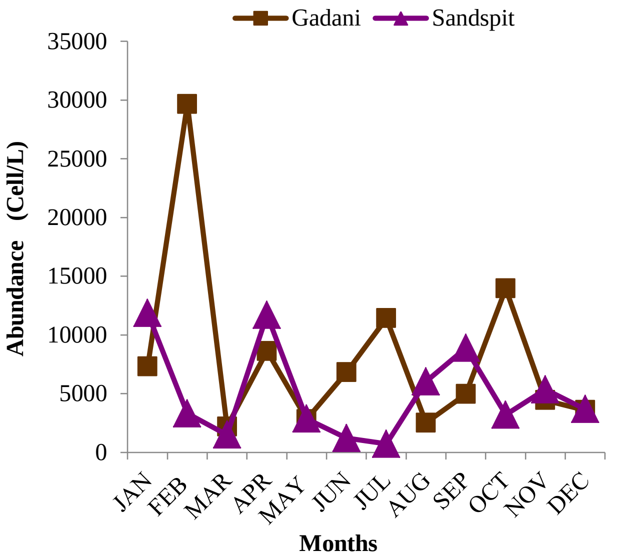

Fig. 1. Abundance of Diatom in Gadani and Sandspit.

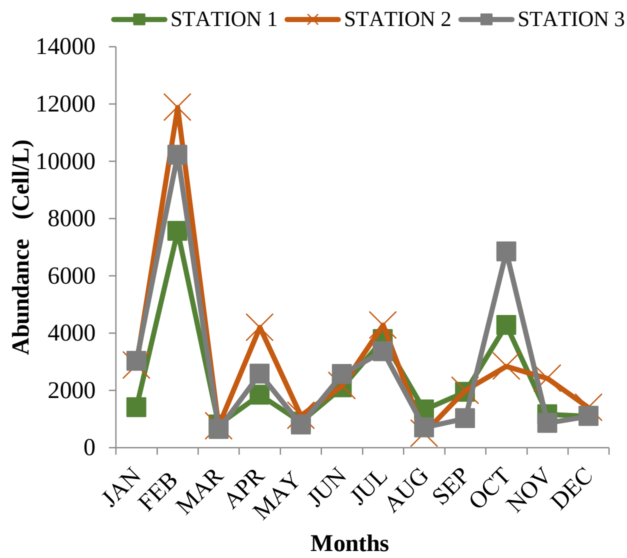

Fig. 4. Abundance of Diatom (Phytoplankton) in Gadani.

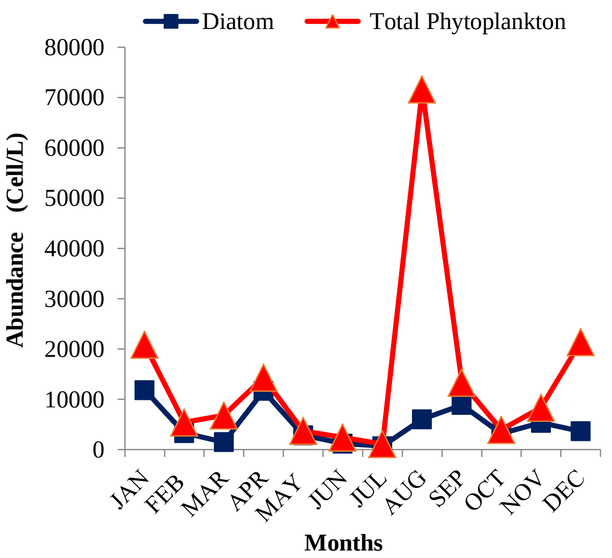

Fig. 2. Total Phytoplankton and Diatom diversity in Sandspit.

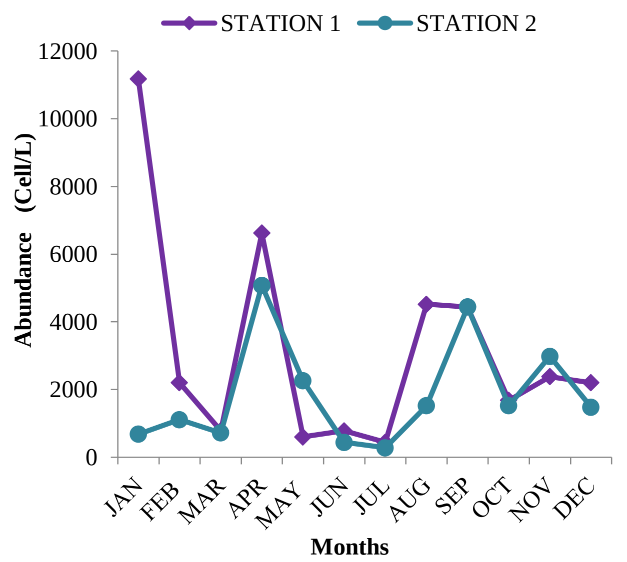

Fig. 5. Abundance of Diatom (Phytoplankton) in Sandspit.

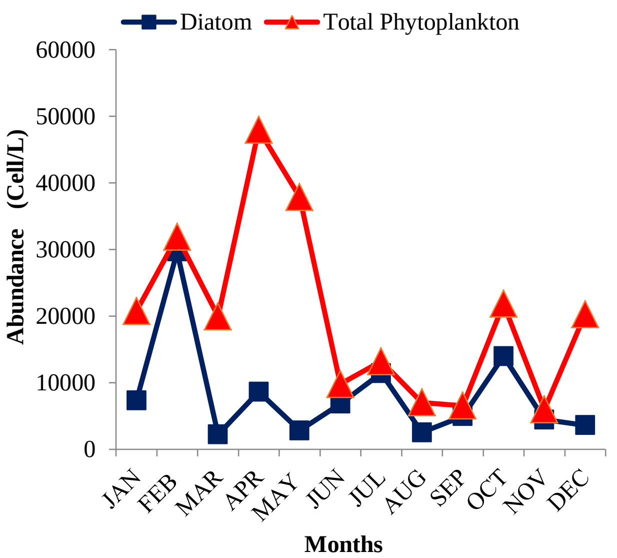

Fig. 3. Total Phytoplankton and Diatom diversity in Gadani.

The diatom communities are sensitive to change in the environmental conditions, the effect of pollution caused by the ship breaking activities is reflected through its diversity and abundance. In the present study mostly pollution indicator species of diatom near ship breaking industry were observed. Pollution from crude oil, persistent organic pollutants, and heavy metal from ship breaking industry affects phytoplankton which is augmented by solar UV radiation. The blooms of phytoplankton are often due to nutrient enrichment of the waters through upwelling. Global warming has caused intensification of stronger upwelling in the northern Indian Ocean leading to high primary productivity (Rixen *et al.*, 2019). Increase in water temperatures on a global scale due to anthropogenic substances caused climate change by about 1°C over the last years (Fischetti, 2013). Increasing in water temperatures is the cause of deoxygenation in coastal marine ecosystems which turn into dead zones for most marine organisms (Carstensen *et al*., 2014). These natural or ecological factors lead to major changes in species composition and productivity of phytoplankton and the whole food web (Coupel *et al*., 2012).

The present study provides data related to diatom communities present in the ship breaking area of Gadani and Sandspit. Phytoplankton communities are responsible for the change in the marine environment (Li *et al*., 2019). Therefore, total biomass of phytoplankton and their species were also analyzed as indicator of water quality. Phytoplankton are susceptible to alteration in the environment, their biomass and species diversity is used to measure quality of water (Reynolds *et al*., 2002). Studies reported that Biotic and abiotic factors were responsible to regulate distribution and abundance of diatom species (Baek *et al*., 2020). The current study recorded 85 species and 74 species of diatom from Gadani and Sandspit respectively. Thirty-four genera were observed in Gadani, whereas 27 genera were recorded from Sandspit. The results showed considerable variation in the species composition of phytoplankton in two coastal sites and along with the difference of nearshore and offshore zones. Diatom diversity was positively correlated with Ammonia and Salinity and negative correlation was detected with temperature, pH, Dissolve Oxygen, Phosphate, Nitrite, Nitrate and Chlorophyll a at Gadani. Whereas in Sandspit it was positively correlated with salinity, pH, Nitrite, Phosphate and Ammonia and negative correlation with temperature, Dissolve Oxygen, Nitrate, and Chlorophyll a.

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