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NOCTILUCA SCINTILLANS (MACARTNEY) KOFOID & SWEZY BLOOM OFF GADANI SHIP BREAKING AREA OF NORTHERN ARABIAN SEA, BALUCHISTAN

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Abstract

The *Noctiluca scintillans* (Macartney) Kofoid & Swezy a dinoflagellate of marine environment can form bloom and generates substances that are noxious to aquatic organisms. An intense bloom of the *N. scintillans* in Gadani, Baluchistan coast along Northern Arabian Sea is reported in the present study. Sea water was collected using Niskin water sampler from three locations for water quality and nutrient analysis. Maximum number (6780 cells/l) of phytoplankton cells were observed in Station-I than that of Station-II (4180 cells/l) and in Station III (3580 cells/l). Maximum number (2740 cells/l) of *Noctiluca* was observed in station I than station II (1020 cells/l) and minimum (620 cells/l) in Station III. Among toxic species of dinoflagellates, *Alexandrium tamaresence, Ceratium fusus, Dinophysis caudata, Gyrodinium spirale, Prorocentrum micans, Prorocentrum arcuratum* and *Scrippsiella trochoidea* were observed. The *Noctiluca scintillans* can transfer toxins to higher trophic levels by grazing these toxic dinoflagellates. The increase in intensity of algal blooms occurring in marine waters cause detrimental effects including bio toxins, physical damage and the anoxia which caused massive fish mortality, affect fishery resources, biodiversity and vulnerable to the aquatic ecosystem.

Introduction

Harmful algal blooms (HABS) are caused by the dinoflagellate, the *Noctiluca scintillans* which is an oblong, luminescent heterotrophic dinoflagellate, size up to 1200 μm. The plankton lives in freshwater, estuarine, and marine environment and can aggregate to form bloom and generates substances that are noxious to aquatic organisms (Elbrachter and QI 1998). The green type of *N. scintillans* inhabits *Pedinomonas noctilucae* (R. Subrahmanyan) Sweeney (Family: Pedinomonadaceae) as an endosymbiont (Sriwoon *et al.* 2008). While red *N. scintillans* (non-chlorophyll) is completely heterotrophic and observed globally in subtropical and temperate seas, whereas, the green *N. scintillans* blooms are usually limited to western Pacific and Indian ocean (Saito and Furuya 2006). Both feeds on microalgae by phagotrophy, zooplankton, copepods, and fish eggs thus shaping the size distribution and species composition of plankton (Saito and Furuya 2006).

N. scintillans is itself nontoxic but sometimes causes mortality of marine organism associated with anoxia. However, *N. scintillans* feeds on toxigenic microalgae and may serve as a vector of phycotoxins to higher trophic levels (Escalera *et al.* 2007). The increase in HABs formation can be related to the global warming and human activity. Microalgae cause negative effects including bio-toxins, physical damage and the anoxia. The bloom end when one of the nutrients required runs short so the cell masses of *N. scintillans* becomes unable to multiply (Van den Bergh *et al.* 2002). Harmful algal bloom incidents caused by dinoflagellates are increasing around the world causing ecological damage during the decades (Al Kindi *et al.* 2007).

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N. scintillans does not have swimming capability, however it uses buoyancy to remain floating in water and grab prey by interception without differentiation (Kiørboe and Titelman 1998). Nakamura (1998a) showed preference for its feeding to certain types of prey. *N. scintillans* accumulates toxic ammonia, which is excreted into the ambient waters, probably killing other agents in the bloom (Fukuyo *et al.* 1990). Most algal blooms are harmless, but under certain conditions, they become intensely concentrated and deplete oxygen causing anoxia, clogging of fish gills or generate poisonous substances which are lethal to fish. Toxic blooms of *Noctiluca* have been reported in history but recently it is increasing due to human activities and climate change. Harmful algal blooms cause damage to environment, biodiversity, and human health. Bloom forming algae are threats to fisheries, fish culture industries, and hazardous to community health (ICES 1992).

At the commencement of *N. scintillans* bloom, diatoms are abundant in phytoplankton community signifying that diatom are favorite prey, even though *N. scintillans* also feeds on prokaryotic and eukaryotic plankton (Umani *et al.* 2004). On feeding noxious phytoplankton, *N. scintillans* can transfer toxins to food chain (Escalera *et al.* 2007). Although, zooplankton feed on *N. scintillans* (Erkan *et al.* 2000), the end of its blooms are frequently the consequence of food reduction. After grazing phytoplankton, *Noctiluca scintillans* excretes ammonia and following cell demise release ammonia which is lethal to fish and other organisms (Okaichi and Nishio 1976). The rapid breakdown of blooms generates hypoxic environment in marine waters (Naqvi *et al.* 1998). The present research was undertaken to study the occurrence of *N. scintillans* bloom which are causing intense impacts on coastal fisheries, economy and public health in off Gadani ship breaking area (Baluchistan).

Materials and Methods

Seawater samples were collected from three stations of Gadani where the green-water occurrence was observed. In method I, Seawater samples were taken from onboard a fishing vessel. Water samples collected in triplicate at 0, 1, and 2 hrs intervals by using a Niskin bottle (1.7l capacity) from 1m depth and was fixed immediately in amber bottle by adding 2 ml of Lugol's solution (Utermöhl 1958). For second method, triplicate samples of sea water were collected annually from Gadani ship breaking area by using water sampler (Niskin 1.7 l) from 1m depth. The samples were preserved in amber bottles having 2ml of acid Lugol's (1%), water quality and abundance diversity were recorded employing standard methods.

Parallel to the collection of plankton sample, *in situ* measurement of water temperature, salinity, and pH were also carried out by using a thermometer, a refractometer and a field pH-meter, respectively. Dissolved oxygen (DO), chlorophyll *a* and nutrients were measured according to Strickland and Parsons (1972). After 24hrs, 50 ml of sample was settled in settling chamber (Hydrobios, Germany). Inverted microscope (Olympus, IX-51 Japan) was used for observation and counting of cells. The identification of cells was based on Tomas (1997).

The data were analyzed using PRIMER 7.0. Variations in phytoplankton species were examined via Shannon Weiner diversity (H'), Richness (Margalef) and evenness (Pielou's index).

Results and Discussion

Variation in the phytoplankton abundance was observed in all the three stations (Fig. 1). The dinoflagellates were abundant as compared to diatoms at the time of *Noctiluca* bloom. Twenty four species of Dinoflagellates and thirteen species of diatoms were recorded at the time of *Noctiluca* bloom. Total number of species in station I, II and III was 21, 27 and 17, respectively. Maximum number of phytoplankton cells were observed in station I (6780 cells/l) than that of station II (4180 cells/l) and in station III (3580 cells/l). Shannon diversity index in station I, II and III was 2.048, 2.365 and 2.197, respectively. Simpson index in station I, II and III was 2.267, 3.118 and 1.955, respectively. Pielou's evenness index in station I, II and III was 0.67, 0.71 and 0.77, respectively. Maximum number and diversity of species was recorded in station II as compared to station I and III. Maximum number of *Noctiluca* was observed in station I (2740 cells/l) cells than station II (1020 cells/l) and minimum in station III (620 cells/l).

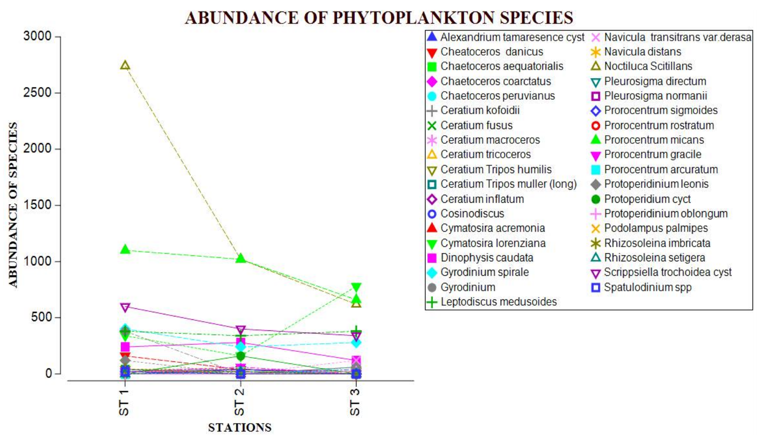

Fig. 1. Abundance of phytoplankton species in Gadani with respect to stations.

Figure 2 represent abundance of species with respect to time. Maximum number of phytoplankton cells were observed in station II i.e., 5540 cells/l than that of station I (3980 cells/l) and in station III (5020 cells/l). Maximum number of *Noctiluca* was observed in station II (1900 cells/l) than that of station I (1720 cells/l) and minimum (760 cells/l) in station III. With respect to time total number of species in stations I, II and III was 21, 26 and 19, respectively. Shannon diversity index in stations I, II and III was 2.031, 2.239 and 2.299, respectively. Simpson index was in station 1, 2 and 3 was 2.412, 2.900 and 2.112, respectively. Pielou's evenness index in station I, II and III was 0.66, 0.68 and 0.78, respectively.

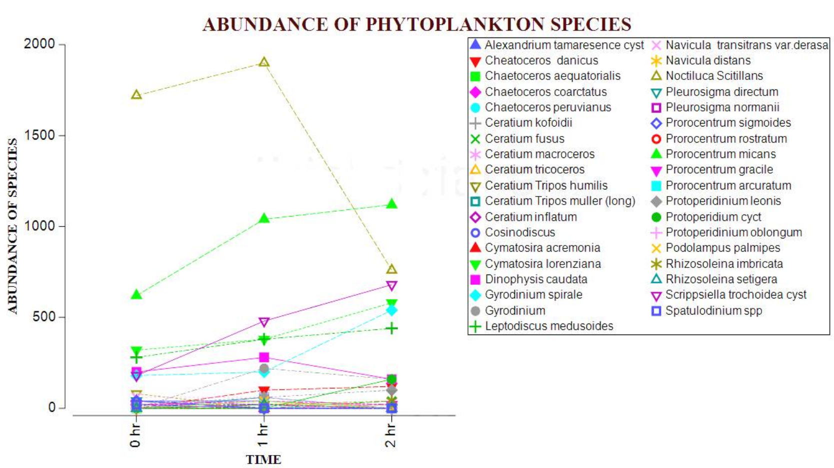

Fig. 2. Abundance of phytoplankton species in Gadani with respect to time.

Toxic species of dinoflagellates observed in the present study were *Alexandrium tamaresence, Ceratium fusus, Dinophysis caudata, Gyrodinium spirale, Prorocentrum micans, Prorocentrum arcuratum* and *Scrippsiella trochoidea.* In microscopic examination food vacuole of *Noctiluca* having dinoflagellate (*Ceratium tripos*) and diatoms (*Rhizosolenia, Cheatoceros, Cosinodiscus* sp. and eggs of zooplankton) were observed (Figs 9 and 10).

Figure 3 represent the variation in dissolve oxygen (ppm) at three stations in Gadani. Variations in Principal Component Analysis (ppm) at three Stations in Gadani were observed (Fig. 4). Figure 5 represent pH, salinity (ppt), sea temperature (°C), air temperature (°C) at three Stations in Gadani at the time of bloom. The observed mean value of Chlorophyll ***a*** was 0.427 µg/l at three stations at the time of bloom while the mean annual Chlorophyll ***a*** value was 0.94 µg/l.

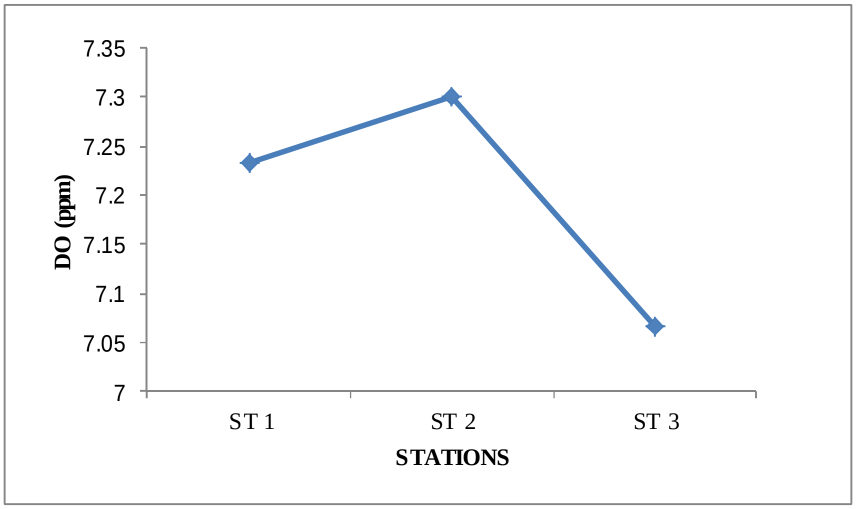

Fig. 3. Dissolve oxygen (ppm) at three stations in Gadani at the time of bloom.

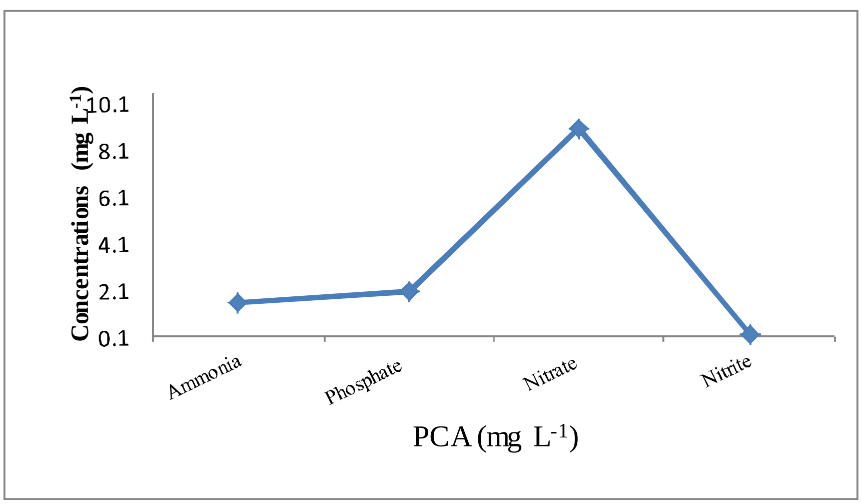

Fig. 4. PCA (ppm) at three stations in Gadani at the time of bloom.

Annual abundance of *Noctiluca scintillans* was highest in number (7300 cells/l) in station I, than station II (6840 cells/l) and station III (5000 cells/l) (Fig. 6). Station I is near ship breaking industry. Highest *Noctiluca* abundance was 4660 cells/l in December in station I and lowest (20 cells/l) in station II in August and Station III in February. Figure 7 depicts mean of annual variations in Dissolved Oxygen, PH, Salinity (ppt), sea and air temperature at three stations in Gadani. Figure 8 represent mean of annual variations in PCA (ppm) at three stations in Gadani.

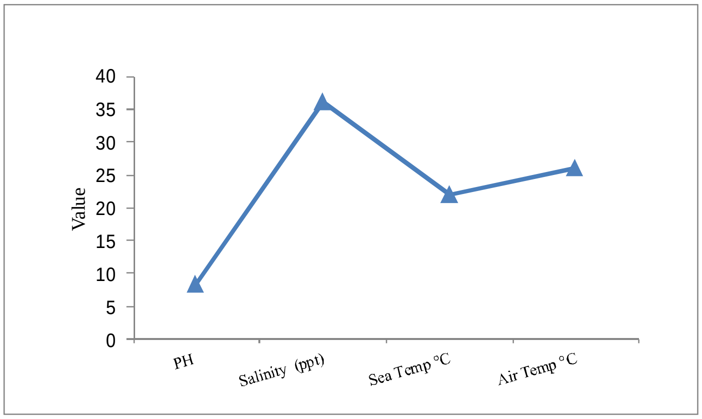

Fig. 5. pH, salinity (ppt), sea and air temperature (°C) at three stations in Gadani at the time of bloom.

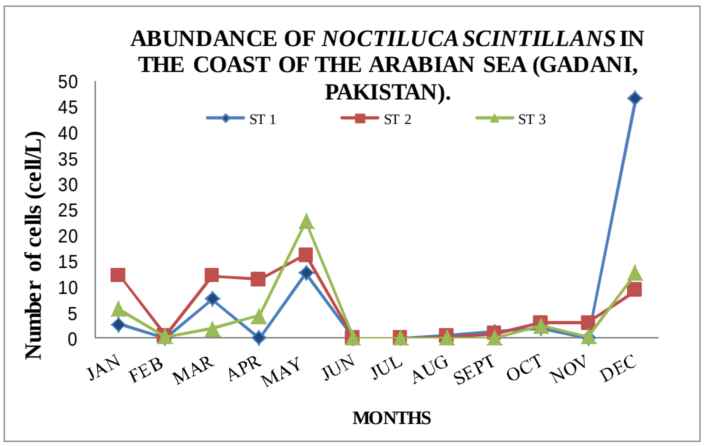

Fig. 6. Annual Abundance of *Noctiluca Scintillans* in Gadani

Maximum number of *Noctiluca* was observed in station I than that of station II and minimum in station III annually and at the time of *Noctiluca* bloom. The station I is Gadani (Balochistan coast) is considered as a polluted area for the reason that it has the world's one of the largest ship breaking yards. Sarraf *et al.*(2010) reported high level of contamination of heavy metals, namely cadmium, chromium, lead and mercury from Gadani ship breaking area and the residential town of Gadani is due to dumping their domestic waste through sewerage system into the sea. Similarly, Tabish (2019) reported high level of Cr, Pb, Co, Zn and Cu in Gadani ship breaking yard as compared to Keti Bunder. A relation between rising occurrences of *Noctiluca* and the various factors enhancing bloom formation include nutrients, eutrophication in the marine waters, environmental conditions and phase of bloom formation (Elbrachter and QI 1998). Worldwide there is an increase in occurrence of algal blooms related to the human activity in the coastal zone (Dharani *et al.* 2004). The occurrence of harmful algal bloom depends on various factors including temperature, salinity, light, currents, wind, rich nutrients supply and stable humid weather without heavy rain (Huang and QI 1997).

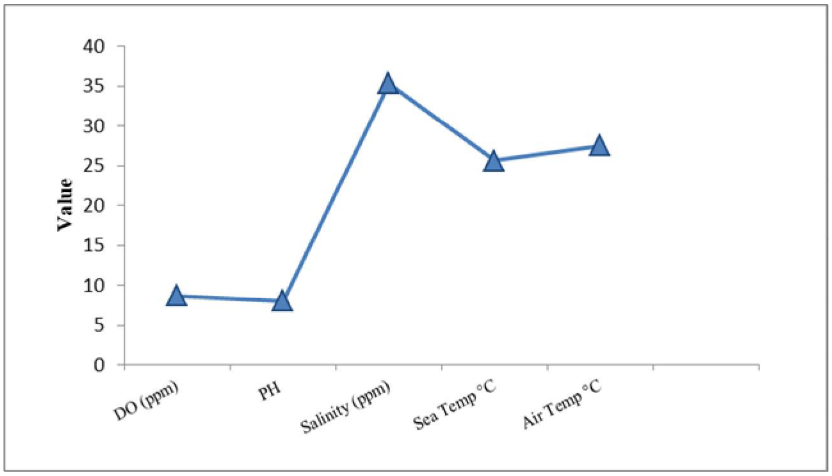

Fig. 7. Mean of annual variations in pH, salinity (ppt), sea and air temperature (°C) at three stations in Gadani.

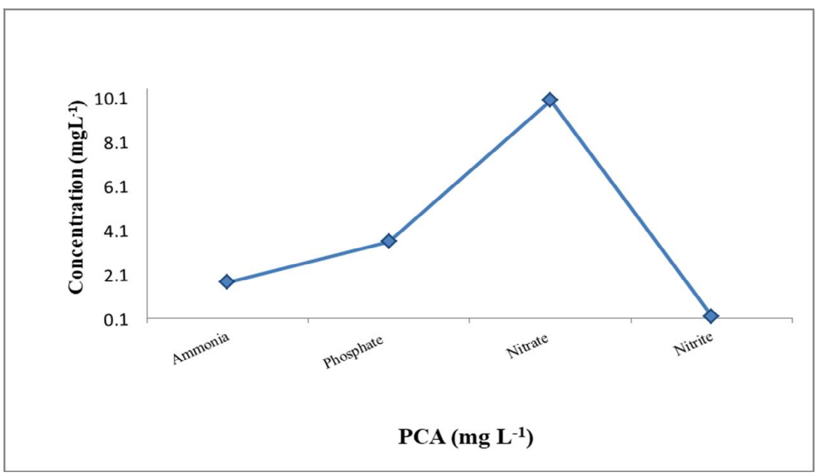

Fig. 8. Mean of annual variations in PCA (ppm) at three stations in Gadani.

At the time of *Noctiluca* bloom, toxic species of dinoflagellates were also observed in microscopic examinations. *A. tamaresence* causes Paralytic shellfish poison, *Dinophysis caudata* and *Prorocentrum arcuratum* causes Diarrhetic Shellfish Poisoning, *G. spirale* and *C. fusus* causes Ichthyotoxins. *C. fusus* bloom depletes oxygen in surrounding waters thus causing fish kills. People may be ill from eating shellfish contaminated with Paralytic Shellfish Poison.

In the present study green *Noctiluca* bloom was observed during February, occurrence of green *Noctiluca* was also observed by Elbrächter and Qi (1998).On the other hand Saifullah and Chaghtai (1990) reported the occurrence of the red *Noctiluca* and its red tide on northwest Arabian Sea shelf of Pakistan during February and March. The red *Noctiluca* generally occurred in oligotrophic offshore waters whereas the green one in eutrophic and polluted coastal waters. Both red and green *Noctiluca* intersect in their distribution in the eastern, northern and western Arabian Sea with a periodic shift from green *Noctiluca* in the cooler, winter, high productive season, to red *Noctiluca* in the oligotrophic, warmer season (Harrison *et al.* 2011). This clearly indicates that *Noctiluca* bloom occurs generally at low temperatures in the tropical waters of South Asia.

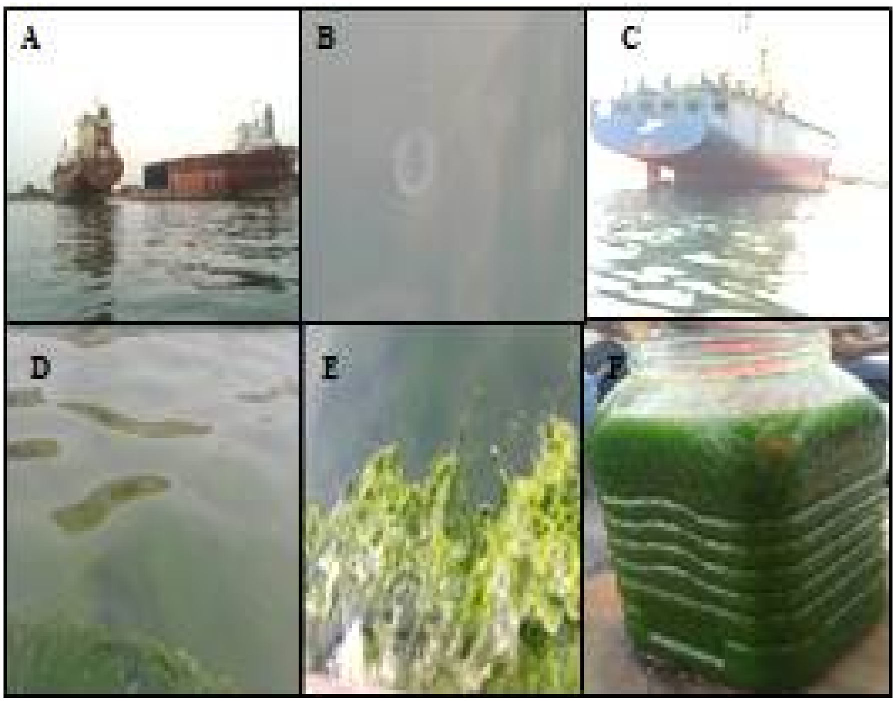

Fig. 9. (A, C) Ship breaking area of Gadani, (B) Jellyfish (D,E) Algal bloom, F) Green bloom of *N. Scintillans*.

Noctiluca exhibits phagotrophic nutrition and feeds on a variety of prey (Quevedo *et al.* 1999). The *N. scintillans* competes with grazers for example copepods that depend on similar food (Elbrächter and Qi 1998). According to Thangaraja *et al.*(2007), presence of *Noctiluca* is one of the factors involved in the decline of fish and shellfisheries in the coastal region of Indian Ocean. *N. scintillans* competes for food with other grazers indirectly (Umani *et al.* 2004) and directly by predating invertebrate eggs (Quevedo *et al.* 1999). *Noctiluca* multiplication rate is associated with the prey concentration when there is maximum food stock it multiply enormously (Kiorboe and Titelman 1998).

In the present study microscopic analyses showed that the diatoms were mainly composed of four species of *Chaetoceros, namely C. danicus, C. aequatorialis, C. coarctatus, C. peruvianus,* two species of *Rhizosolenia,* namely *R. imbricate* and *R. setigera, Cosinodiscus,* two species of *Navicula* and *Cymatosira* (Figs 9 -10). Similarly, Turkoglu (2013) also reported diatoms species of *Chaetoceros* spp., *D. fragilissimus, C. closterium, P. alata, Rhizosolenia* spp., *Thalassiosira* spp. in the study area. In the cell of *N. scintillans* these diatoms were frequently detected therefore they are referred to as the main food of *N. scintillans.* Throughout the first phase of *N. scintillans* bloom, preferred food supply and favorable circumstances are the cause of increase growth rate.

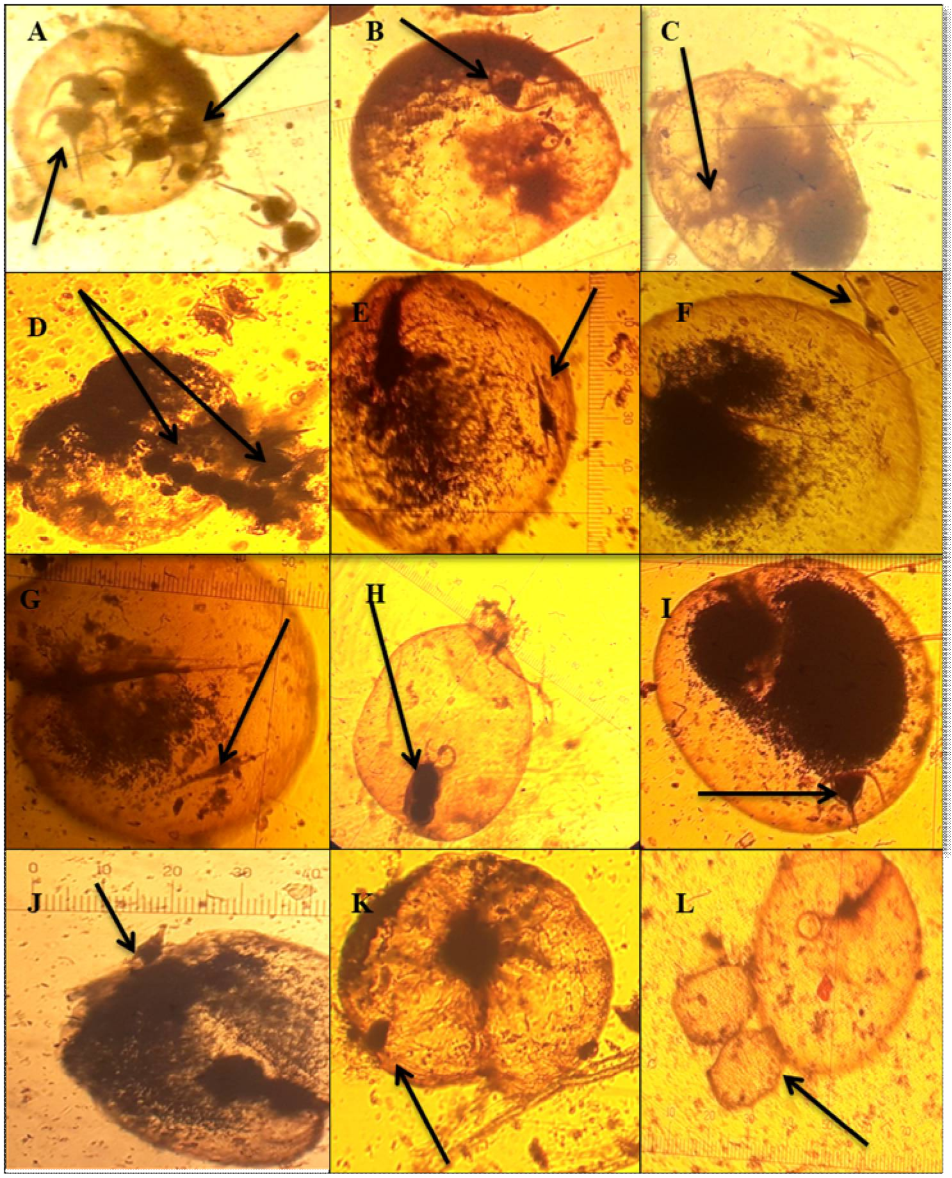

Fig. 10: Inverted Light microscopy (LM) of *N. Scintillans* gut content (A,B) *Ceratium tripos muller* (C) *Chaetoceros* (D) *Cochlodinium polykrikoides* and *Ceratium macroceros* (E) *Ceratium furca* (F) *Ceratium kofoidi* (G) *Ceratium inflatum* (H) Eggs (A and I) *Ceratiumtripos humilius,*(J) *Ceratium lineatum,* (K) *Evadne,* (L) *Odentella sinensis.*

Miyaguchi *et al.* (2006) and Al-Azri *et al.* (2007) also indicated a connection in the prey-predator association among *N. scintillans* and diatoms. Kopuz *et al*.(2014) demonstrated that diatom bloom of *Melosira* spp. coexists with *N. scintillans*, the dinoflagellates had large number of *Melosira* in their food vacuoles. Phytoplankton aggregation, frequently are rich in diatoms at the beginning of *N. scintillans* multiplication and elevated numbers of *N. scintillans* have been observed concomitantly with a high biomass of diatoms (Turkoglu 2013, Kopuz *et al.*2014). Similarly Sheng-Fang *et al.*(2018) observed diatoms (*Thalassiosira* spp.) in the cells of *N. scintillans* and high concentrations of diatoms related with lower abundance of *N. scintillans. Noctiluca* is an insatiable predator, with a varied diet including phytoplankton, copepods, nauplii, zooplankton eggs, organic debris, and microbes and fish eggs (Elbrächter and Qi 1998, Quevedo *et al.* 1999). Quevedo *et al.* (1999) reported adverse features of *Noctiluca* grazing on *Acartia clausi* spawns and offspring. In the Cantabrian coast of Spain, *N. scintillans* consumed 73% of the entire stock of *A. clausi* eggs, causing a negative effect on the recruitment of nauplii.

The most prominent consumers of *Noctiluca* are jellyfish and salps. Gelatinous zooplankton mainly jellyfishes are characterized with broad diets, high reproduction as well as growth rates and face less predation pressure (Richardson *et al.* 2009). Upsurge in jellyfish abundance is an indication of degraded oceans (Condon *et al.* 2013) who also reported increased blooms of medusa, for example, Sea of Japan, North Atlantic shelf regions, Barents Sea, Limfjorden (Denmark), and parts of the Mediterranean Sea. Similarly presence of jellyfish in *Noctiluca* bloom was observed in the present study site (Fig. 9). Jellyfish and salps feed on *N. scintillans* and it may change trophic interactions via carbon transfer to salps and jellyfish, both constitute less favored food for fish (Gomes 2014).

From the past fifty years deoxygenation of marine waters in tropical oceans are reported (Diaz and Rosenberg 2008). Ocean models 42 predict 1-7% decrease in the world ocean oxygen inventory over the coming era because of climate change, rising atmospheric CO_2, stratification of water masses, and increase nutrients inputs due to the fertilizer usage and continuous progression of coastal inhabitants. Substantial influences on marine fauna and flora affected marine fisheries in coastal areas due to severely oxygen depleted waters.

With respect to time maximum number of phytoplankton species (Diatom, Dinoflagellates and *Noctiluca*) was observed in station II as compared to Stations I and III. This shows that at the time of *Noctiluca* bloom in station II maximum diversity of species were observed with respect to time and stations. Dinoflagellates are frequently avoided by *Noctiluca* on diatoms and therefore become dominant. Bloom sequence usually follows the sequence of diatoms than *Noctiluca* and has been observed in many marine waters (Harrison *et al.* 2011). Similar results were observed in the present study at the time of *Noctiluca* bloom in Gadani. Dinoflagellates were more abundant than diatoms in Gadani. Twenty four species of Dinoflagellates and 13 species of diatoms were recorded at the time of *Noctiluca* bloom.

The present study provides data related to phytoplankton communities (dinoflagellate and diatoms) in Gadani (Balochistan coast) at the time of *Noctiluca* bloom. Presence of toxic species of dinoflagellates are threat to marine organisms, causing massive fish kill and accumulating in fish and shellfish, causing poisoning in higher food web. In view of the foregoing, the pollution due to anthropogenic substances in the coastal waters coming from the various sources particularly ship breaking industry along the coast induced HAB forming species which is perilous for fish and Shell fish.

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