Pakistan J. Zool., vol. 50(6), pp 2099-2106, 2018. DOI: http://dx.doi.org/10.17582/journal.pjz/2018.50.6.2099.2106

Huge Fish Killing after Rain at Jeddah Coast, The Red Sea, Saudi Arabia

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ABSTRACT

A study was conducted to find out the possible reasons of fish killing at the Jeddah Coast, the Red Sea, Saudi Arabia. There are many factors for a sudden fish die-off in a water body such as toxic discharges, low dissolved oxygen (DO), temperature, salinity, pH, ammonia, turbidity, pesticides, toxins, and diseases. The study was carried out to find out the reasons of sudden fish killing. Therefore, physico-chemical and biological parameters, and postmortem, especially the gills and gut content of dead fishes were studied. The dead *Tilapia tilapia* (Tilapia), *Chanos chano* (Milkfish) and *Parapriacanthus ransonneti* (Glassfish) were found with wide mouth opened, skin with huge mucous and a bent back head, flared gills lesion and reddish sanguinary. The water temperature (°C), DO, salinity and pH varied from 24.8 to 26.2 (°C), 0.10 to 0.35 mg/L, 7.41 to 18.77 ppt and 7.31 to 7.64, respectively. Water column microalgal cell abundance varied from 78×10^3 to 147×10^3cells/L, with an average of 97.2×10^3 cells/L. The abundance of microalgae in gut was 137.30×10^3, 105.30×10^3 and 204.14×10^3 cells/g of gut of Tilapia, milkfish and glassfish, respectively. In gut, microalgae of Bacillariophyceae were 60, 81 and 61% among total microalgae in gut content of Tilapia, Milkfish and Glassfish, respectively. There was no microalga on gills. The salinity was 50 to 79% lower than that of the normal salinity of the Red Sea due to rain on previous day of fish killing. Sudden decrease of salinity and nearly zero DO concentration might be the reasons of killing fish by creating osmotically imbalance and suffocation of fishes. Additionally, due to low pH, huge mucous covered the gills filaments which might have created difficulties for respiration. Thus, the fish killing incident might have occurred by synergetic effects of different physico-chemical factors.

Article Information
Received 16 October 2017
Revised 27 February 2018
Accepted 04 May 2018
Available online 05 September 2018

Authors' Contribution
AA, AS and AJK designed the research. AA prepared the research article. AA, AS and and MSBH did field investigation and sampling.

Key words
Fish killing, Heavy rain, Jeddah coast, Saudi Arabia, The Red Sea.

INTRODUCTION

A mass mortality of fish occurred at the coastal area of Balad of the Red Sea, Jeddah, Saudi Arabia. The fish mortality is generally defined as the sudden and unexpected destruction or mass mortality of cultured or wild fish. Mass mortalities can occur due to persistent ecosystem changes (Hughes, 1994). The expansion of the changes may be determined in part by the intensity of mortality and by the ecological roles and characteristic of affected species (Mangel, 2005; Paine, 1998). The reasons of fish die offs may be predictable or unpredictable. There are many causes of fish mortality, and generally large proportions are due to natural events like low level of dissolved oxygen (DO), high fluctuation of temperature and pH, acid rain, storm, huge freshwater surface run off due to heavy rain, chemical pollution, disease epidemics and toxic algal blooms (Woodley et al., 1981; Harvell et al., 1999, 2002; Harley, 2008; Hallegraeff, 2010). Some fish kills perhaps went unnoticed or is under-reported. Some events of fish killing may be reported but with lack of sufficient data of their degree of intensity and severity. These challenges may apply strongly in the ocean where baseline data of species occurrences and population sizes are mostly scarce (Tegner et al., 1987; Dayton et al., 1990). Additionally, in several cases, mass mortality remain still poorly described or documented due to rapid responding to unforeseen events in remote or marine systems. The geographic pattern and intensity of mass mortalities are especially critical in the face of global changes predicted to alter regional disturbance regimes (Jurgens, 2005). It has been reported that over 100 species of fish, including finfish, molluscs and crustaceans died off in New South Wales, Australia where the most frequently affected species were mullet, European carp, shrimp, anchovy,

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0030-9923/2018/0006-2099 $ 9.00/0

worms and oysters (www.dpi.nsw.gov.au/fisheries/habitat/threats/fish-kills). Suh *et al*. (1998) reported that a large number of useful macroscopic marine animals like abalone, oysters, sea turtles, sea cucumbers and sea urchins were killed in large quantities on the west coast of Jeju Island in the summer of 1996 (Suh *et al*., 1998). Animals of both freshwater and estuarine areas are equally died off (each contributing approximately 45% of all kills, respectively) while fewer kills reported from oceanic waters (approximately 10%). However, fish killing can be very large and spectacular when fish killing occur in ocean (Whittington, 1990).

An investigation was done on sudden fish killing at Jeddah coast, the Red Sea, Saudi Arabia. On the Jeddah coast, there are two lagoons which are directly connected with the Red Sea. The coastal area is beautifully arranged and constructed to attract the tourists. People generally enjoy on sitting at the coastal bank with family, and sometimes family gathering parties also have also been held there. Unfortunately huge fish of different species were found death and moribund on coastal water. The moribund fishes were found to gulp and swim at the surface of water sluggishly. Coastal water fish mortality can generate considerable public, media interest and concern because they are often perceived to be the result of water pollution. There was no more report on fish killing incidents at Jeddah coast. Huge fish mortality was observed at this coast on 3rd December, 2016. Before fish mortality incidents, there was a heavy rainfall at Jeddah on previous day at late night around 5.00 AM. The street and city washed water entered the Red Sea through the lagoons. However, a study was conducted immediately on fish killing area to find out the possible reasons of fish mortality. The objectives were to examine physical appearance of gills and gut, and naked with eyes as well as to assess the water quality parameter, phytoplankton abundance and community composition of water.

MATERIALS AND METHODS

Study area

Jeddah is the second biggest city of Saudi Arabia, located on the Coast off the Red Sea and is extending rapidly. It receives huge waste water from fish farms, industry and domestic use. It has two lagoons which receive rain waters and discharge to the sea. The fish killing was more severe in those lagoons. The samples were collected from 5 different stations of the lagoons which were St-1(N 21 29 18.4, E 39. 10 51.7) St -2 (N 21 29 24.9, E 39 10 51.7), St -3 (N 21 29 23.3, E 39 10 57), St -4 (N 21 29 16.9, E 39 10 50.3) and St-5 (N 21 29 10.1, E 39 10 31.9) at Jeddah coast, the Red Sea, Saudi Arabia (Fig. 1).

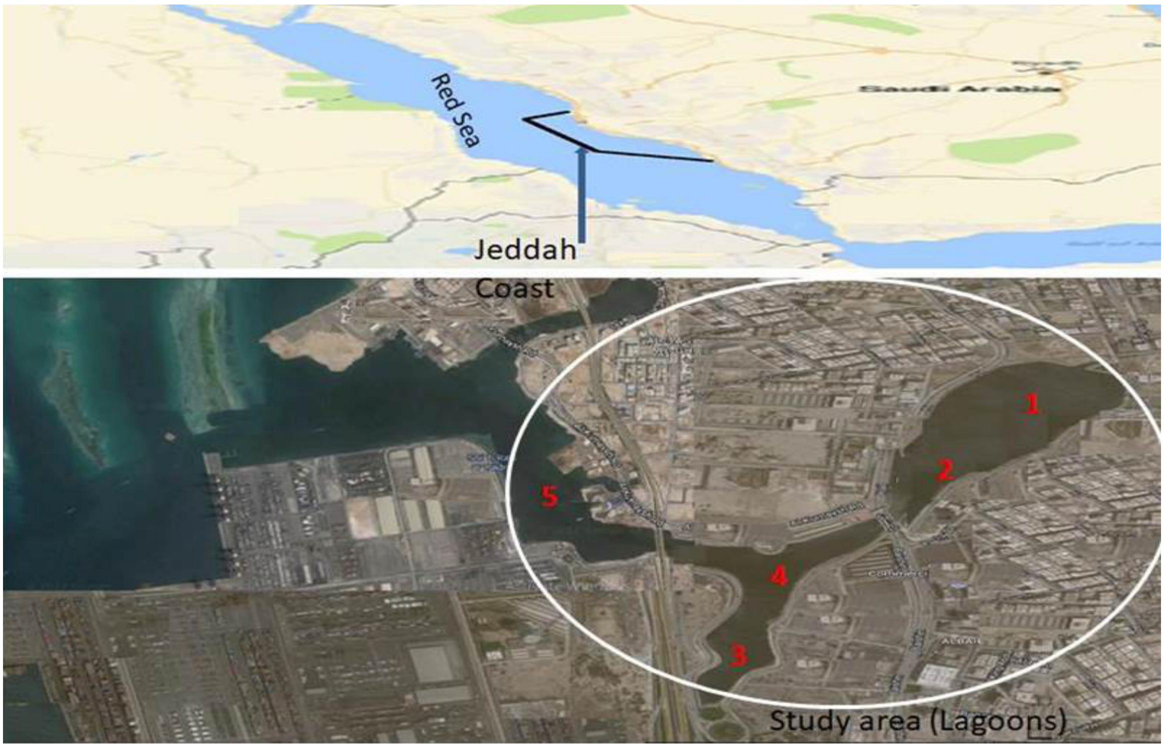

Fig. 1. Map showing the study area at Jeddah coast, the Red Sea, Saudi Arabia.

Sampling and laboratory analysis

Dead fishes were collected on the spot and their head, mouth and gills were observed weather head was bent or straight, mouth was widely opened or closed and the gills were flared or not, as those symptoms are the keys to find out the possible reasons of natural fish killing which is described by Lugg (2000) in New South Wales (NSW) Government, Department Primary Industries. On the spot, Tilapia, milkfish and glassfish dead fishes were found to float on the surface of the water. Fifteen pieces of dead fish of each species were collected and observed with naked eyes, the fishes were taken to the laboratory for gills and gut content phytoplankton study. The gills of dead fishes were dissected, collected, and each of the gill samples was squashed with a known volume (50 ml) of water. The qualitative and quantitative analysis of phytoplankton in the squashed water was done under microscope. Gut content of fish was analysed following the methods of Hynes (1950). For water content phytoplankton study, the water samples were collected directly in a 500 ml plastic bottle and preserved with 2% of Lugol's solution. The sample content bottles were covered with aluminium foil to keep dark condition. The preserved sample was kept for 72 h to settle down the phytoplankton, then 450 ml of supernatant was removed and the concentrated sample was taken for qualitative (taxonomical) and quantitative study. For taxonomical study, the fixed sample was observed under the phase-contrast microscope (Zeiss Axioplan, Germany) at 400x magnification. Taxonomic identifications were made with reference to Prescott (1973), Tomas (1993, 1997), Shim (1994) and Kobayasi *et al*. (2006). The phytoplankton on gills and in gut was identified and counted following the same methods as mentioned above. Finally, the gills and gut content phytoplankton abundance were expressed as cells/g/of gills and cells/gram of gut, respectively.

The temperature, pH, salinity, DO were also estimated on the spot with portable DO-meter and HACH multimode pH-Salinometer (Model HQ14d). For nutrients analysis, each water sample was filtered through a glass fiber filter (Whatman GF/C 47 mm, UK) and the filtered water was used for nutrients analysis. The concentrations of NO_3-N, NO_2-N, NH_4-N, and PO_4-P were determined using a spectrophotometer (Shimadzu UV-1201, Japan) according to the methods of Parsons *et al*. (1984).

Fig. 2. Sewage water carrying sprinkler truck (S_1), Freshwater discharge narrow channel (S_2, S_3 and S_4) at Lagoons of Jeddah coast, the Red Sea, Saudi Arabia.

Table I.- Sampling stations (St-1), coordinates (N, E), temperature (°C), dissolved oxygen (DO (mg/L)), salinity (ppt), pH and nutrients (NH_3-N, NO_2-N, NO_3-N, PO_4-P and SO_4-S) mg/L during fish killing incident at lagoons of Jeddah coast, Saudi Arabia, the Red Sea.

Stations	Temp.(°C)	DO (mg/L)	ppt	pH	NH_3-N	NO_2-N	NO_3-N	PO_4-P	SO_4-S
St -1	24.8	0.14	14.13	7.64	1.20	0.024	0.040	0.940	1100
St -2	24.8	0.10	18.52	7.28	1.24	0.026	0.040	0.640	1300
St -3	24.9	0.35	18.77	7.37	0.48	0.018	0.030	0.880	1800
St -4	25.0	0.32	16.61	7.28	0.52	0.021	0.031	0.620	1880
St -5	26.2	0.31	7.41	7.31	0.78	0.019	0.040	0.730	1700

Table II.- Phytoplankton cell abundance (Cells/L) and their percent (%) contribution during fish killing incident of Al-Arbain and Al-Shams lagoons at Jeddah coast, Saudi Arabia, the Red Sea.

Microalgae name	St-1		St-2		St-3		St-4		St-5	
	Cells/L	%	Cells/L	%	Cells/L	%	Cells/L	%	Cells/L	%
Bacillariophyceae (Diatoms)										
Amphora decussate Grunow					12,000	8			8,471	9
Chaetoceros convolutes Castracane							9,000	14	8,471	9
Cylidrotheca closterium Ehrenberg	9,000	9	9,000	12						
Navicula incerta Grunow					3,000	2	3,000	5	2,824	3
Pleurosigma angulatum Quekett			6,000	8						
Pleurosigma sp.	9,000	9	3,000	4	6,000	4			5,647	6
Percent contribution		18		23		14		19		26
Dinophyceae										
Crypthecodinium sp.	18,000	18	27,000	35	63,000	43	9,000	14	16,941	18
Gymnodiniumbreve Davis	9,000	9								
Gymnodinium sp.					6,000	4			8,471	9
Noctilucascintilis Macartney					3,000	2			2,824	3
Prorocentrum micans Ehrenberg	6,000	6			3,000	2			2,824	3
Protoperidiniumbrochii Balech			6,000	8			3,000	5	2,824	3
Protoperidiniumpentagonum Balech					6,000	4	3,000	5	5,647	6
Percent contribution		32		42		55		24		41
Chlorophyceae										
Nannochloropsis sp.	21,000	21	9,000	12	21,000	14	12,000	19	14,118	15
Rhodomonas sp.			6,000	8						
Tetraselmissuecica Butcher	15,000	15					6,000	10	5,647	6
Percent contribution		35		19		14		29		21
Cyanophyceae										
Trichodesmium sp.	15,000	15	12,000	15	9,000	6	9,000	14	5,647	6
Microcystis sp.					15,000	10	9,000	14	5,647	6
Percent contribution		15		15		16		29		12
Total cells/L	102,000		78,000		147,000		63,000		96,000	

RESULTS

On spot of study area, we found dead fish of Tilapia, milkfish and glassfish to float on the surface of water. Dead fish were found with wide opening of mouth. Skin of fishes was found with huge mucous. Gills were flared with lesion and the filaments were observed with reddish sanguinary under microscope. The head of dead fish was bent back (Fig. 3).

During sampling, the water temperature varied from 24.8 to 26.2 °C with an average of 24.88°C. The concentration of DO varied from 0.10 to 0.35 mg/L, with an average of 0.24 mg/L. Salinity was found to be varied from 7.41 to 18.77 ppt with an average of 15.01 ppt. pH fluctuated from 7.31 to 7.64 with an average of 7.38. The concentration of NH_3-N varied from 0.48 ti- 1.24 mg/L with an average of 0.97 mg/L. NO_2-N concentration varied from 0.018 to 0.026 mg/L with an average of 0.020 mg/L. Similarly, NO_3-N concentration varied from 0.04 to 0.03 mg/L with an average of 0.04 mg/L. The concentration of PO_4-P fluctuated from 0.64 to 0.97 mg/L and the average was 0.82 mg/L. Concentration of SO_4-S was found to be very high and its' concentration varied from 1100 to 1800 mg/L with an average of 1400 mg/L (Table I).

Phytoplankton cell abundance varied from 78×10^3 to 147×10^3cells/L, with an average of 97.2×10^3 cells/L, and the highest cell abundance was at St.-3, followed by St.-1 and St.-5 which were 102×10^3 and 96×10^3 cells/L, respectively. The percent composition of Dinophyceae was 32, 42, 55, 24 41% among the phytoplankton. The contribution of Dinophyceae was higher among all stations except St.-4 among phytoplankton. At St.-2 and St.-5, diatoms showed highest percent contribution which was 24 and 26%, respectively among phytoplankton. Chlorophyceae was 35, 29 and 21% among phytoplankton at St.-1, St.-4 and St.-5, respectively. The highest percent abundance of Cyanophyceae was 29% among phytoplankton at St.-4 (Table II).

Gut content analysis was done according the steps mentioned in Figure 3. Gut was mostly occupied with Zooplankton. However, the abundance of Phytoplankton in gut of Tilapia, milkfish and glassfish was 137×10^3, 105×10^3 and 204×10^3 cells/g of gut, respectively (Table III).

Fig. 3. The bent head of milkfish (A) and glassfish (B) collected at Lagoons, Jeddah coast, Saudi Arabia.

Table III.- Gut content phytoplankton cell abundance (cells/g) and percent (%) composition of Tilapia, milkfish and glassfish during fish killing incident of Al-Arbain and Al-Shams lagoons at Jeddah coast, Saudi Arabia, the Red Sea.

Microalgae name	Tilapia		Milkfish		Glassfish	
	Cells/L	%	Cells/L	%	Cells/L	%
Bacillariophyceae (Diatoms)						
Amphora decussata Grunow	17,001	12	18,000	17	11,000	17
Chaetoceros convolutus Castracane	12,000	9	10,210	10	13,000	20
Cylidrotheca closterium Ehrenberg	28,000	20	26,000	25		
Navicula incerta Grunow				0	8,000	13
*Pleurosigma angulatum*Quekett			17,000	16		
Pleurosigma elongatum Smith	25,000	18	14,000	13	7,000	11
Dinophyceae						
Crypthecodinium sp.	1,000	1	520		200	
Gymnodinium sp.					100	
*Gymnodinium*breve Davis	200					
Noctilucascintilis Macartney					98	
Prorocentrum micans Ehrenberg	90				94	
Protoperidiniumbrochii Balech			310			
Protoperidiniumpentagonum Balech					76	
Chlorophyceae						
Nannochloropsis sp.	26,000	19	9,213	9	9,000	14
Rhodomonas sp.			5,000	5		
Tetraselmissuecica Butcher	17,000	12				
Cyanophyceae						
Trichodesmium sp.	11,000	8	5,000	5		
Microcystis sp.					15,000	24
Total cells	137,291	100	105,253	100	63,568	100

DISCUSSION

Mouth of each fish was found to be opened when it was collected on the spot. Flared gills were found in Tilapia, glassfish and milkfish, and those gills filament had more slime and bloody lesion. Here, the milk fish was found to be more bent back head than other fish. This finding is similar with the findings of Lugg (2000) reported that a total kill of all species could be due to severe deoxygenation, but other causes are also possible, and fish killed by DO depletion often exhibit three symptoms- Open mouth, flared gills and a bent back head. DO is the most vital factor of aquatic living organisms. It is well known that the critical point start at DO value of 5 mg/L to less. At Jeddah coast, during sampling the DO value range was 0.10 to 0.35 mg/L. DO refers to the level of free, non-compound oxygen present in water or other liquids. It is an important parameter in assessing water quality because of its influence on the organisms living within a body of water (Wetzel, 2001). The DO level that is too high or too low can harm aquatic life and affect water quality. DO is necessary to many forms of life including fish, invertebrates, bacteria and plants. These organisms use oxygen in respiration, similar to organisms on land. Fish and crustaceans obtain oxygen for respiration through their gills, while plant life and phytoplankton require DO for respiration when there is no light for photosynthesis (Anonymous, 2013). The amount of DO needed varies from creature to creature. Bottom feeders, crabs, oysters and worms need minimal amounts of oxygen (1-6 mg/L), while shallow water fish need higher levels of DO (4-15 mg/L) described in Chesapeake Bay Program (Anonymous, 2017). A fish kill that effects only the more oxygen-sensitive species is likely to be due to partial deoxygenation of the water. The amount of DO depends greatly on the temperature of the water and oxygen demanding hydrocarbon (Malina, 1996). DO level decreases with increasing of temperature. DO level is also influenced by the amount of compounds the water is already holding. These compounds may be solids, chemicals, or even other gasses. The storm water and surface runoff may bring many more chemicals to compete for the same DO as the fish. Lee and Jones (2003) found that urban runoff due to several inches rainfall caused the DO levels dropped from 7 to 9 mg/L to about 3.5 mg/L of the San Joaquin River Deep Water Ship Canal where the fish kill coincident occurred in the same storm water associated with low DO levels. At fish killing area there was channel which was found to flash huge brownish turbid surface runoff water to the coast. Thus, this surface runoff water might have brought organic compounds. The biodegradable matter in the water encourages the growth of microorganisms which end up using most of the oxygen. Degradation of organic matter utilizes oxygen, often rapidly enough to reduce the DO concentration to an extent that it impairs aquatic life. DO depletion often occurs due to storm water in urban stream just after major storms because of the transport of oxygen demanding substances into streams (Erickson *et al*., 2013). Therefore, it can also be said that DO depletion occurred after entering of huge surface runoff from the surface run off of previous day, and that water might have brought huge oxygen demanding matter which reduce the DO level near to zero which was the reason of fish killing. Thus, it can be also said that the low and even near to zero value of DO might be related to the death of fish at Jeddah coast.

Additionally, killing aerobic organisms in this DO depletion can be the cause of producing more of toxins like ammonia and sulphides. Sulfate content was found to be very high (average was 1400 mg/L) in the water samples. Sources of sulfate include sewage treatment plants and industrial discharges such as tanneries, pulp mills, and textile mills. Runoff from fertilized agricultural lands also contributes sulfates to water bodies (http://ky.gov/nrepc/water/ramp/rmso4.htm). The source of sulfate at the study area might be related with surface runoff which occurred after rain. Sulfate is most often related to its ability to form strong acids which changes the pH, especially lowering the pH. During the study, the pH range was 7.28 to 7.64, which was lower than the pH reported by Harbi and Affan (2016). They found pH rage of 8.04 to 8.63, average of 8.39 at Jeddah coast of the Red Sea, Saudi Arabia. Hydrogen sulfide (H_2S) could be increased in water after receiving organic matter due to surface runoff. H_2S has a high to very high toxicity to fish; the lethal concentrations for different fish species range from 0.4 mg H_2S per liter (Salmonids) to 4 mg per liter (Crucian carp, Tench and Eel) (Svobodová *et al*., 1993). Similarly, Doudoroff and Katz (1950) reported that the concentration of H_2S below 10 mg/L (mostly 1-6 mg/L) was lethal to several species of aquatic organisms such as Lepomisgibborus, Salmogairdneri, Catostomuscommersoni, Carassiusauratus and Cyprinuscarpio. Therefore, it could be assumed that sulfate and H_2S might have also related to kill fish as the concentration of sulfate was high.

Similar to DO, the salinity was 50% lower in those lagoons than that of the normal salinity of the Red Sea. This occurred after entering of run off after heavy rain. A sudden decrease of salinity due to dilution with fresh water makes critical problems of marine fish especially the maintenance of osmotic balance and in closed area like lagoons where the exchange rate of water with sea is very much limited. The low salinity might have also created a critical circumstance of killing fish. Similarly, Suh *et al*. (1998) and Lee *et al*. (1999) found huge damage of fisheries such as Gastropods and fish farms due to fish death because of Changiang River Overflows which causes lowering salinity around western and southern coast of Jeju Island, Republic of Korea. Thus, it can be said that the fish death phenomenon occurred in these lagoons due to the complexity of maintaining of osmotic balance after decreasing of salinity. Therefore, because of sudden lower of salinity, those fishes faced highly physiological imbalanced to adapt the environment and death occurred.

The abundance of phytoplankton was too low that even cannot be considered the starting stage of bloom. The occurrence of less abundance of phytoplankton also associated with dilution, as huge surface runoff occurred after rain. The number of phytoplankton was similar as previous reported by Sommer (2000), Khomayis (2002) and Khomayis and Harbi (2003). However, the Red tide forming species of phytoplankton were more in percent contribution than that of other non-toxic phytoplankton. But, the density was too low that cannot make adverse situation for living organism, especially fish killing incident. Lisa *et al*. (2010) reported the bloom of Dinophyceae when the cell abundance was 300 $\times 10^3$ cells/L in U.S. In this study, the cell abundance is much lower than that report of U.S.

The gut content analysis revealed that Bacillariophyceae and other nontoxic phytoplankton abundance were higher than that of Dinophyceae or red tide forming phytoplankton. Tilapia, milkfish and glassfish take copepods and suction feed on benthic diatoms and epiphytic algae in their natural environment. Therefore, it can be said that phytoplankton were not responsible for fish killing at Jeddah coast, the Red Sea, Saudi Arabia.

CONCLUSION

From the study, it can be said that the fish killing was related with the physico-chemical factors especially low salinity, pH, low concentration of DO and high concentration of sulfate. Low salinity might have created osmotically imbalance, huge mucous covered the gills filaments due to low pH and fish failed to respiration, additionally low concentration of DO created suffocation circumstance to fishes. Thus, the fish killing incident might be occurred by synergetic effects of different physico-chemical conditions, such as low pH, low salinity and low DO. Phytoplankton abundance was too low in water samples that could not make gill cogged or algal toxic effect to kill fish. Gills were found to be not clogged by phytoplankton rather it's were covered with huge mucous. In gut, Bacillariophyceae phytoplankton abundance was highest in all fishes. Bacillariophyceae is generally non-toxic group of phytoplankton (except *Pseudo-nitzschiapungens*). Thus, it can be said that water column and gut content of phytoplankton were not responsible of killing fish due to their too less abundance. The lagoons were also not eutrophic since nitrogenous and phosphorous components concentrations were low and also the abundance of phytoplankton was very low.

Statement of conflict of interest

Authors have declared no conflict of interest.

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