Intern. J. Environ. Studies, 2002, Vol. 59(1), pp. 59–71

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CAUSES OF FISH MORTALITY ALONG THE QATARI WATERS (ARABIAN GULF)

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(Received in final form 24 January 2001)

Excessive fish mortality were observed along the Qatari coastline and offshore during the summer of 1996 and 1998. Massive amounts (about 40 tons) of dead fish were recorded off the eastern coast. Siganidae, Lethrinidae and Carangidae, coral reef inhabiting fish, were the main species observed dead along the beaches. Hydrographic parameters (temperature, salinity and dissolved oxygen) and main pollutants (ex: NH_4^+, TPH, BOD_5, metals, PCB's and PAHs), as well as chlorophyll *a* were monitored. Pollutants levels during summer were around background concentrations. Thermal plumes from industrial facilities don't extend more than 2 kms offshore. Fish kills did not follow the appearance of patchy algal blooms during spring and autumn seasons. Temperatures along the Qatari coast rising to 37.0°C during summer 1996 and 38.6°C during summer 1998, seem to be the main reason for fish-kills. The 35°C are regarded as the threshold beyond which fish-kill phenomena exist. Beside the control and monitoring of landbased and marine derived pollution sources, the development of a Temperature and Red tide Watch Program in the Gulf is a must.

Keywords: Fish kill; Temperature; Red tide; Qatar; Arabian gulf

INTRODUCTION

Qatar is a peninsula located along the western coast of the Arabian Gulf between latitudes 24° 30′ and 26° 34′ N and longitudes 50° 40′ and 52° 45′ E. The total land area is 11,437 km^2 surrounded by 35,000 km^2 of Gulf water with an average depth of 30 m. Because of its

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Print ISSN: 0020-7233. Online ISSN: 1029-0400. © 2002 Taylor & Francis Ltd
DOI: 10.1080/00207230290011526

geography, fish and fisheries are not only a main food source for the country but also of prime importance to the nation's economy. The total fish landing during 1995 was 3883 tons increased to 4309 and 4575 tons during 1996 and 1997, respectively, rising to 5306 tons in 1998.

Over 150 fish species belonging to 50 families are currently recorded from the Qatari waters. According to the annual fish landings statistics the most important fishes belong to family Lethrinidae (17.2%), Serranidae (16.0%), Carangidae (12.6%), Pomadasyldae (9.1%) and Scombridae (8%). Each of the families Siganidae, Chirocentridae, Sparidae and Gerreidae constitutes about 5% of the catch.

Mass mortalities of marine animals attract the attention of the public and media. Public warnings about eating fish and shellfish result in economic losses to fish industry, while the media immediately start to highlight main landbased pollution sources pointing out leaks in measures and surveillance taken by environmental and fisheries authorities. Major potential causes of marine mortalities are: Temperature, red tide, pollution (oil spills, sewage, industrial discharge), fishing methods and parasite infection.

Although dolphins and sea turtles mortalities were recorded during the last decade, previous records of fish mortalities along Qatar are not available.

The main objective of the present study is to throw some light on the excessive fish mortality phenomena taking place in the Arabian Gulf and determine the significant causes and contributing factors underlying the fish kill events along the Qatari waters of the Gulf. It extends to discuss the measures to be taken to avoid this phenomenon and development of a regional plan for monitoring, assessment and combating the mass mortality of Arabian Gulf fishes.

FISH KILL HISTORY IN THE GULF

Fish mortality incidents appeared in the Gulf since late summer of 1985 where a regionwide mortality of fish, turtles and mammals was confined to shallow areas of Bahrain, Qatar, Saudi Arabia, UAE and Iran. No single cause appeared for the mass mortality event but fish disease, temperature and red tide were suspected.

Along the ***Iranian*** coast, many incidents of fish and marine mammals mortalities have been reported throughout the period 1993–1996 [1]. Small pelagic fish (Indian oil-sardine) as well as demersal fishes (flathead and silver seabream as well as yellow fin seabream) were reported dead in 1993 following an offshore ship wreck (containing chemicals) southwest to Lavan Island. Cd and NH_4^+ contents of water and sediments were high. During 1996, large numbers of dead and dying demersal fish (silver seabream, yellow fin seabream and flathead seabream) were observed coinciding with abnormally high temperatures ($>36°C$), heavy metals content in seawater (Cd, Zn, Fe, Ni and Pb) and 50 times increase in phytoplankton densities than normal conditions. Recently, during September 1999, major fish mortality (>10 tons) of blue spot mullet, silver sillago, sobaiti seabream and haemulidae was recorded by the Department of the Environment along 1500 km^2 area within the Khozestan province.

Most of the fish mortality (mainly sardines, jutjanus and sparus spp.) along the ***United Arab Emirates*** coast, observed during 1997, was caused due to oil exploration and transport activities opposite to Umm Al-Quwain [2]. On the other hand, most of fish mortalities reported in ***Saudi Arabia*** were observed along the Red Sea coast. The only record in the Gulf was off Ras Tanura during May 1996. Despite having over 1700 km of coastline along the Arabian Sea and Gulf of Oman, no fish mortalities were recorded along the beaches of the ***Sultanate of Oman***. Moreover, Khamdan [3] suggested that oil pollution and temperature elevation could be the cause of not only fish mortalities but also crabs, turtles and seabirds off the ***Bahraini*** coast.

The two main events of fish kills reported in ***Kuwait*** during 1993 and 1996 were associated with a discharge from power generation plants. High doses of chlorine (2.5–5.0 ppm) in cooling water, as well as a warm discharge during winter at low tide, caused both incidents, respectively. More recently, a massive fish kill of Mullets (*Liza macrolepis*) and Sobaity seabream (*Sparidentex hasta*) was observed along the Kuwaiti coastline during September–October 1999 and September 2000. About 30 tons of dead fish were collected from the northern area of Kuwait bay in addition to about 100 tons of farmed imported European Sobaity seabream. Investigations emphasized the appearance of the red tide in the region dominated

by *Gymnodinum mikomotoi*/*Gyrodinium aureolum* and *Gymnodinium breve* causing an environmental disturbance in the water quality equilibrium, especially oxygen (during night time) on the surface layer. The density of the first two species reached 1.7×10^6 cells/l while the latter did not exceed 40 cells/l [4]. These species are toxic excreating haemolytic and ichthyotoxic compounds such as l-acyl-3-digalactosylglycerol and Octadecapentaenoic acid [5]. *Prorocentrum maxicannum* and *Dinophysis miles* also occurred frequently associated with fish mortality.

RED TIDE PHENOMENA

"Red tide" is a natural phenomenon appearing worldwide and in the Gulf due to the abnormal growth and accumulation of some microscopic micro-algal species. These species reproduce asexually where each cell grows to maturation stage then divides into two cells and consequently to four, and thus the number multiplies. If favourable conditions like temperature, salinity and nutrients prevail these cells reproduce rapidly and bloom. During unfavourable conditions and as a part of their sexual life cycle some species (more than 60 species) form resistant resting cysts which sink to the bottom, sometimes for years, but reinvade the water column when conditions get better [6]. During spring and autumn seasons, patchy blooms of dinoflagellates appears along the Qatari coast, mostly at the NE borders, when nutrients reach maximum concentrations and water temperatures are around the twenties.

Most of the dominant organisms observed around Qatar like Alexandrium spp., Dinophysis spp., Pseudo-nitzschia spp., *Gymmnodinum breve* leads to shellfish poisoning while Prorocentrum spp., and *Pfiesteria piscicida* cause fish poisoning [7]. Such algal blooms normally lead to fish suffocation due to the irritation of the gills. Their decay increases bacterial action which reduces the dissolved oxygen pool. Some of these species produce toxins which are lethal to fish and their effect could extend to humans. Bivalves and Gastropods, feeding by filtering plankton from water, are greater accumulators for such species and could be dangerous for human consumption. Algal blooms lead to environmental disturbances for water quality physical

characteristics, especially dissolved oxygen, where limits are greatly reduced during nighttime (<2 ppm) and sometimes during daylight. This also leads to an increase of water viscosity, which affects the capability of fish to extract dissolved oxygen from water through negatively impacting the respiration system and leading to fish mortality.

FISH KILL ALONG THE QATARI COAST

During 1996–1998, huge quantities of killed fish were observed during summer time along the eastern coast of Qatar (Fig. 1). Fish were mainly floating on sea surface or lying dead on the coast (along the inter-tidal zone). Most of the fish look like they have been boiled. Siganidae, Lethrinidae, Carangidae and coral reef inhabiting fish (*Pomacanthus maclosus*, *Scarus ghobban*, *Chaetodon melapterus* and *Acanthurus lineatus*) dominated the fish kill. The general features of fish showed neither visible signs of poisoning by oil or chemicals nor the presence of parasites or ulcerations. The gills were pale, indicating that the collection was sometime after death. Gill rackers showed no signs of dinoflagellates or other algae. Live fish were exhibiting difficulties in swimming and could be easily collected by hand. Such observations revealed no evidence of disease, exposure to pollution or poising by algae. The amount of dead fish was estimated to be between 30 and 40 tons during 1996 and 1998, respectively.

During this period, a water and sediment quality survey took place along the Qatari coast. Table I shows the results of water samples collected from areas where fish kills were recorded. Seawater and sediment sampling and analysis followed the protocols and methods described in references [8–10]. Compared to background levels recorded along the Qatari coast, water quality parameters showed no signs of severe pollution. Increased levels of NH_4^+ and Total Petroleum Hydrocarbon (TPH) off the Messaieed industrial area, located south of the capital Doha, were related to the discharge from fertilizer and petrochemical industries. Low phosphate and nitrate levels reflected remarkably low chlorophyll *a* concentrations. Such low mean chlorophyll *a* levels indicate that no algal blooms exist during

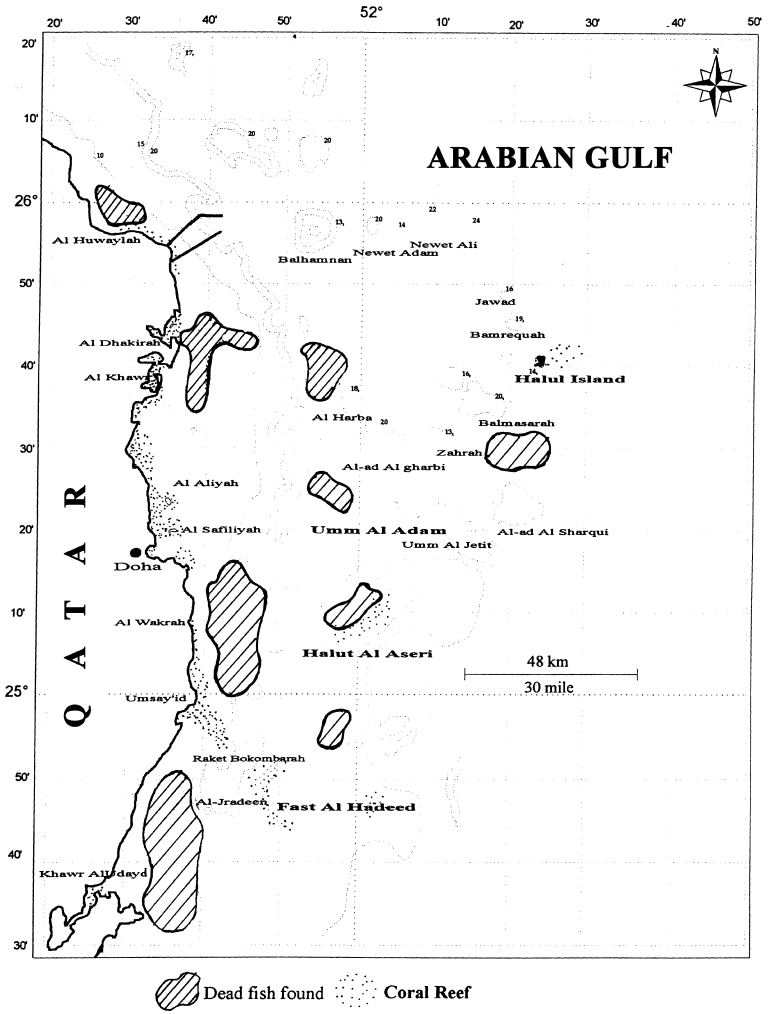

FIGURE 1 The coastal waters of Qatar showing the locations of dead fish.

this period of the year. Monitoring temperature and chlorine plumes opposite to industrial discharge points off Messaieed and Ras Laffan industrial complexes showed that the temperature within the first kilometer was 6°C different from the ambient temperature near the outfalls, decreasing to < 0.1°C difference by approaching a 2 km distance from the outfall. Residual chlorine levels lied between 0.2 and

TABLE I Range and mean of environmental conditions recorded around Qatar during summer 1996 and 1998

Parameter	1996		1998	*Background levels*	1999
Region	*Messaieed*	*Doha*	*Ras Laffan*	*Qatari water*	*Kuwait Bay**
Salinity (psu)	43.5	41.7	40.6	40	37.9 – 40.3
D.O. (mg/L)	5.6	5.1	5.9	6.5	6.46 – 9.34
pH	8.41	8.23	8.2	8.1	8.01 – 8.67
BOD_5 (mg/L)	2.00	0.28	0.4	nd	ND
NH_4^+ (μM/L)	24.1	0.96	3.27	0.5	nd – 287
TPH (μg/L)	157	110	75	10 – 30	0.16 – 58.2
Pb (μg/L)	10	9	3	3 – 5	2.25
Cd (μg/L)	4.3	6.9	1.8	1 – 2	< 0.4
Cu (μg/L)	58	35	< 5	30	7.19
Chlorophyll a (μg/L)	0.23	0.09	0.18	0.05	0.002 – 38.4
Polychlorinated biphenyls PCB's (ng/l)					
Arochlor 1254	23	nd	nd	nd	ND
Arochlor 1260	nd	nd	nd	nd	ND
PO_4 (μg/L)	nd – 1.4	nd – 4.34	nd – 3.6	nd	7 – 183
NO_3 (μg/L)	1 – 18.0	0.7 – 32.1	nd – 58.4	nd – 3	3 – 4957
Chlorine (ppm)	nd – 0.2	nd – 0.1	0.39	0.0	0.05 – 0.4

nd = not detected.
ND = Not Determined.
* KEPA (1999).

0.4 ppm opposite to the discharge points diluting to < 0.02 ppm at 1 km distance.

Similarly, sediment analysis (Tab. II) also shows no irregularities from background levels. This supports the idea that neither water nor sediment contamination is responsible for the phenomena.

Figure 2a shows daily average subsurface (−30 cm below surface) seawater temperature records along the Qatari coast (marine stations) during the years 1995 – 1998. Data shows that during August 1996 and 1998, as well as in early September of both years, seawater temperatures exceeded the 35°C value. However, the seawater during August 1995 and 1997 was much cooler. The maximum registered water temperature was 37.0°C during summer 1996, while it approached 38.6°C during summer 1998, both recorded in early August. Due to the shallowness of the coastal zone (maximum depth 24 m), bottom water temperatures were slightly lower or in most cases similar to surface temperatures. During this period, air temperatures during daylight exceeded 50°C, the highest record during the last 40 years. A closer look on summer temperatures (Fig. 2b) shows that during

TABLE II Analysis of sediments collected along the Qatari coast

Parameter	*Qatar*		*Kuwait**
Region	*Messaieed*	*Ras Laffan*	*Kuwait Bay*
V (μg/g)	28.5	3.7 – 10.7	50.26
Cd (μg/g)	2.9	2.1 – 5.99	0.12
Cu (μg/g)	27.3	13.1 – 18.5	23.25
Pb (μg/g)	28.5	0.84 – 37.6	46.14
Ni (μg/g)	36.8	0.64 – 20.1	90.75
Fe (μg/g)	133.9	ND	21.62
Hg (μg/g)	ND	0.026 – 0.34	0.046
Cr (μg/g)	45.3	0.6 – 1.8	79.12
PAHs (μg/g)	ND	< 1.0	2.1 – 11.4
TPH (μg/g)	375	46 – 850	ND

ND = Not Determined.
* KEPA (1999).

1996 and 1998 elevated water temperatures were observed between late July to the first week of September, matching the appearance of dead fish. This indicates that the 35°C temperature limit is considered as the threshold beyond which fish-kill phenomena occurs. During this period, the water column suffers temporary stagnation which accelerated fish-kills mostly affecting demersal fishes. Changing depth is an important defensive mechanism in elevated temperatures in deeper waters where thermal gradients or stratification may occur.

In absence of information on upper lethal temperatures of fishes in the literature, especially for environmental temperatures more than 30°C, confirmatory experiments (simple temperature tolerance experiments) were achieved by exposing 10 dominant adult fish species that are affected by a temperature rise to increasing controlled temperature (rising 5°C increments from 20 – 30°C and 0.5°C every 12 hrs between 30 and 40°C) in 80 liters clean glass aquaria. None of the tested species (*Siganus canaliculatus*, *Lethrinus nebulosus* and *Alepes mate*) withstand or tolerated the increase of water temperature over 35°C for 24 hrs. Controls were kept at < 35°C for 1 week. An increasing temperature lead to difficulty in breathing, no feeding, uncontrolled swimming and reduced activity of fish followed by death. These results increased the likelihood that temperature was the cause of mortality for these species.

Reviewing the fish-kill phenomena that took place along the Kuwaiti coastline during September 1999, symptoms and causes are quite different from those appearing around Qatar. Toxic algae

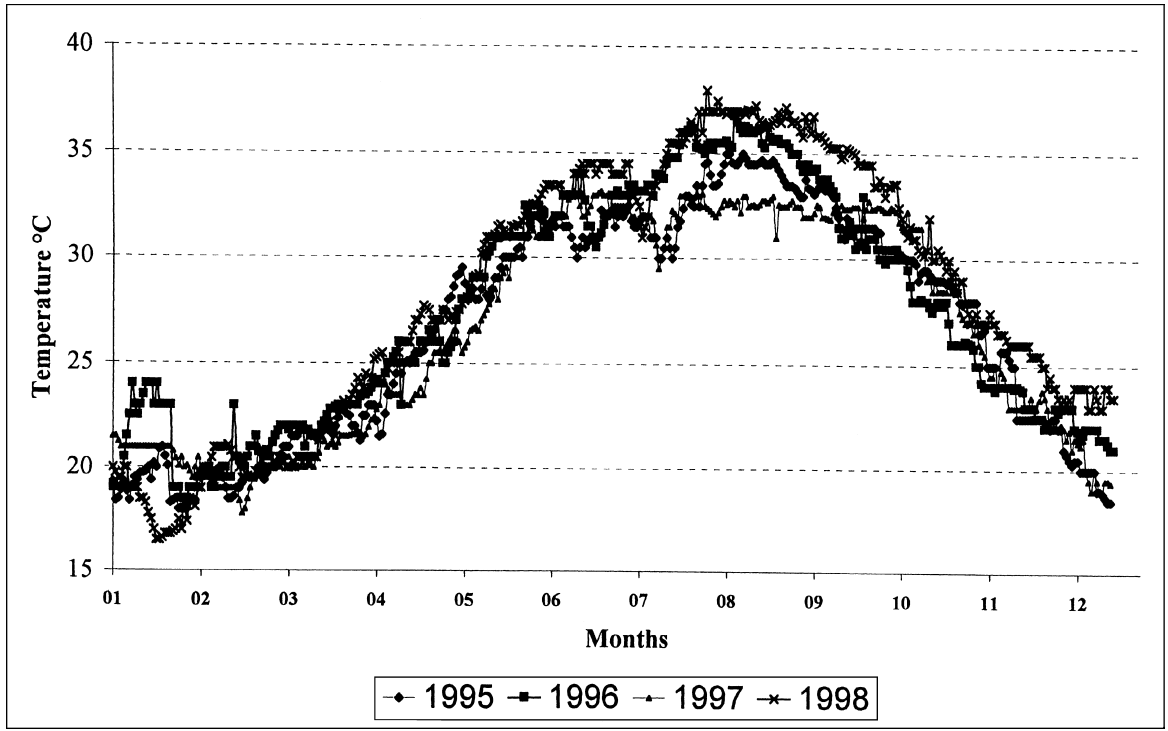

FIGURE 2a Annual variations of seawater temperatures recorded during 1995–1998.

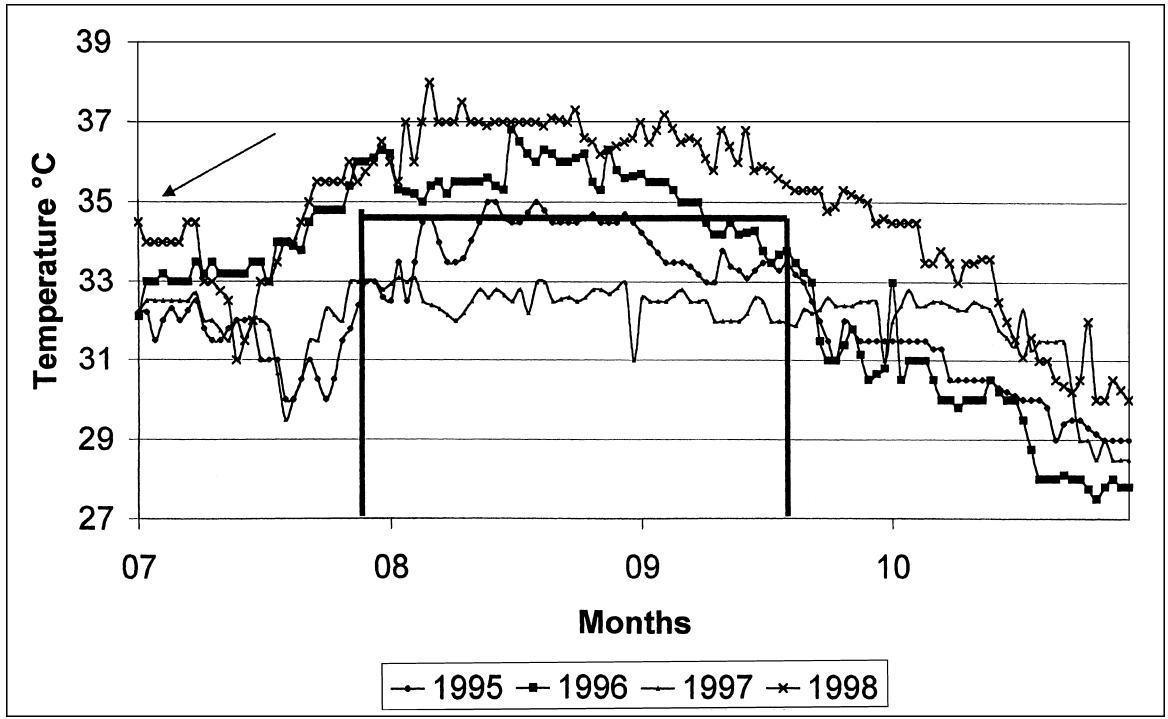

FIGURE 2b Seawater temperature daily variations during summer 1995–98.

blooms were proven to cause on Kuwaiti as well as Iranian coasts fish mortality, while a temperature rise ($>35°C$) caused the same phenomena along the Qatari coast. Tables I and II showed that water and sediment quality parameters along the Kuwaiti beaches, especially nutrients, paved the conditions for toxic bloom and consequently fish-kill. Water temperatures along the Kuwaiti coast during fish-kills were 29.6 (1997), 33.8 (1998) and 28.4 (1999)°C. Accumulation of metals in fish samples was higher in Kuwaiti fish, *i.e.*, 0.11 – 0.44 μg/g Cd, nd – 33.52 μg/g Cu, 0.02 – 0.231 μg/g Hg, nd – 0.66 μg/g V (KEPA, 1999), compared to 0.05 – 0.1 μg/g Cd, nd – 4.5μg/g Cu, nd – 0.05 μg/g Hg and nd – 0.23 μg/g V observed for the Qatari fish [11, 12]. A temperature rise causes a metabolic rate increase. Such increase is non-linear and could eventually level off at an increasing temperature. Some fish can acclimatize and tolerate a temperature rise by becoming sluggish and lethargic, while others are radically affected by a temperature rise turning hyperactive and then die. Despite the low levels of most pollutants, the possibility that the mortality was caused by the combination of high temperature and pollution cannot be discounted since elevated temperature may have made fish more sensitive to pollutants levels. Chemicals exposure or accumulation may be enhanced by temperature stress. However, the forementioned experiment demonstrated that temperature alone is sufficient to cause fish deaths.

MEASURES TO OVERCOME THE FISH MORTALITY PHENOMENA

Such natural phenomena cannot be controlled but their effect could be minimized. Its natural cycle is only few days, sometimes weeks if conditions permit. The following are some measures to be undertaken in the future to overcome the fish-kill phenomena.

a. Study the establishment of an early alarm system to monitor red tide phenomena through recording any unnatural variations occurring in the marine environment.
b. Continuous check of temperature, chlorine, ammonia and urea opposite to the industrial outfalls.

c. Deployment of mini-Seamon continuous recording thermometers for monitoring temperature variations in different locations along the Qatari coast.
d. Use remote sensing images to follow up temperature changes and chlorophyll *a* blooms along the Qatari coast.
e. Intensify beach and territorial water surveillance.
f. Increase surveillance on oil tankers spilling ballast water along the EEZ of Qatar.
g. Control and monitor water discharge in the Doha harbour.
h. Prepare a contingency plan to deal with fish mortality phenomena.
i. Promote regional co-operation between Gulf countries in identifying, reporting and combating marine mortalities.
j. Urge Universities and Research Institutes in the Gulf region to enhance their studies on fishery life cycles.
k. Issue necessary rules and regulations for the conservation and sustainable use of fishery resources.
l. Adopt stricter regulations for the control of landbased as well as seabased sources of pollution.
m. Develop a programme for "Temperature and Red Tide Watch" in the Gulf region.
n. Promote environmental awareness and educational campaigns on marine mortalities.

CONCLUSION

Our investigation revealed that:

(i) Temperature is the main cause of excessive fish mortality around Qatar during summer.
(ii) The concentrations of tested pollutants during summer time are insufficient to explain the increased mortality.
(iii) The most sensitive fish to a temperature rise are Siganidae, Lethrinidae, Carangidae and Coral reef fishes.
(iv) The 35°C limit is the threshold beyond which fish-kill phenomena appear.
(v) Thermal pollution and chlorine discharge around Qatar are not suspects.

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