Global Fish Kills: Causes & Consequences

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Key points: *Fish kills event is an indicator that ecosystems health and water quality have been deteriorated, as a consequence water may have been contaminated with biotoxins or algal blooms or chemicals (pesticides/herbicides) or microbial pathogens, as a consequence, environmental water may be unsafe for beneficial water usage for a period of time*

Fish kills or mass mortalities of fish (*Figure 1*) can be defined as a sudden and significant death of fish. This is characterized by a large number of fish dying over a short period of time within the defined area. The number of fish killed in specific instances can range from a few thousands to more than one million (*Table 1*). For example, on 6 January 2011, 2 million fish died as a result of cold stress (Maryland, USA), and red tide was responsible for the death of 22 million fish alone in the Gulf of Mexico, USA in 1986. Red tide is a toxic algal bloom caused by certain marine algae (dinoflagellate, *Gymnodinium breve*) that turns the sea water red.

Globally fish kills is most frequently linked to natural causes such as ecological hypoxia (low dissolved oxygen) or anoxia (no or zero dissolved oxygen) (*Figure 2*), harmful algal blooms (toxic and non-toxic freshwater cyanobacteria, marine dinoflagellates), diseases, extreme or abrupt changes of temperature (e.g. winter fish kills, summer fish kills), salinity or turbidity; floods, black water events (flood events that give the water column a dark tea colour), overturns of lakes and upwelling of the oceans *(Table 1*, *Figure 2*). Minor and occasional natural causes of fish kills are volcanic eruptions, earthquakes, and meteorite.

Human activities are also responsible for a number of fish kills, for examples, accidental spills (e.g. oil), runoff and drainage discharge of pesticides and herbicides from agriculture farm lands into water bodies. In addition, mass killing in the name of recreational fishing (see Figure 3) may also responsible in significant fish death.

Figure 1: Natural cause such as cold water stress caused two million fish death in Chesapeake Bay, Maryland, USA on 6 January 2011. *Photo source: http://www.boncherry.com/blog/2011/01/06/two-million-fish-died-from-dropping-temperature-in-maryland/*

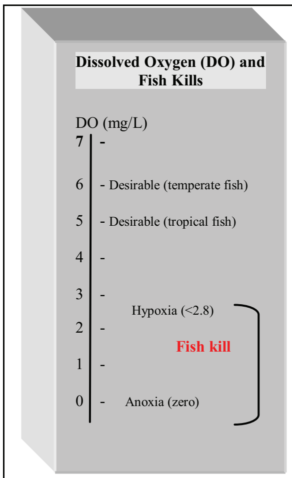

Figure 2: Dissolved oxygen level, ecological hypoxia and anoxia and fish kill. *Figure source: Golam Kibria 2011*

Figure 3: Recreational fishing or mass killing of fish in hoars of Bangladesh? Hundreds of fishers participate to catch wild fish refuges in haors. Haors (shallow wetland) are situated in Sunamganj, Kishorgang Netrokona, Habiganj, MoulviBazar. *Photo source: ICLARM Philippines (1992)*

Global reviews (*Table 1*) reveals that most fish kills are related to oxygen depletion or low level of oxygen in water (*Figure 2*). Water with low oxygen level could cause suffocation of fish resulting death. Oxygen depletion in water bodies can occur due to algae die-offs, weather related 'turnovers' of lakes water, surface run-off of organic materials into water bodies, disturbance of sediments containing large quantities of aquatic vegetation or with excess nutrient loads, low water levels, and high temperatures etc. Possible signs of fish kills due to oxygen depletion are fish gasping at the surface, sluggish movement, larger fish die earlier than smaller fish of the same species, kill occur at night or in the early morning. In marine environment, toxic algal blooms poison fish directly or indirectly via bioaccumulation through progressive trophic levels, whereas non toxic blooms cause fish mortalities through anoxia or hydrogen sulphide poisoning arising from algal decay.

Agricultural chemicals such as some herbicides and insecticides are highly toxic to fish and can enter into natural waters as spray drift, drainage discharges, spills, surface run-off and through leaching or soil dusts. Signs of fish kills associated with pesticide toxicity are convulsive, erratic swimming, sluggishness, smaller fish die earlier than larger fish of the same species, kills occur at any time. Pollutants such as suspended solids can prevent oxygen uptake by fish or can damage functioning of gills and thus may cause fish kills. Rapid fluctuations in temperatures can cause fish death. This is generally occurs in small water bodies that heat and cool rapidly. Flood associated mass mortality of fish is related to fish gills being clogged by suspended sediments, and osmoregulatory stress and reduced dissolved oxygen concentrations. Prolonged high temperatures period is harmful to cold water fish species; conversely prolonged cold water period is harmful to warm-water species. Fish affected by thermal stress (cold or warm temperatures shock) reduces its resistance to diseases thereby could be susceptible to bacterial and fungal infections that eventually kill them. Release of cooling water from electric/nuclear power generations reported to have caused some fish kills. Winter mass mortality of fish (e.g. North America and Europe) are related to winter hypoxia and physical disturbance (thermal stress due to long ice covers) etc.

Fish kills can also occur when water has a low pH. Acid spills, acid rain, runoff or industrial effluent, drainage of acid soils can lower pH of water. A pH below 4 is lethal. Nitrogen such as unionised ammonia (NH_3) is highly toxic to fish. Potential sources of ammonia are organic pollution, fertilisers, overcrowding of fish and industrial effluents. Weather related disturbances or turnovers could bring anoxic (lack of oxygen) bottom water and decaying materials of lakes into the water column and release large quantities of hydrogen sulphide (H_2S). Fish kills due to H_2S poisoning include lager fish and fish with brown/chocolate gill filaments. The possible signs of H_2S in water include an odour (rotten egg), black, decaying organic matter on the wind ward shore. *Table 1* provides an overview of fish kills in the worlds freshwaters, brackishwaters and marine waters.

Fish kills event is an indicator of environmental stress, a declining of aquatic ecosystems health, and water quality problems. Furthermore, fish kills events provide useful information on the spatial and temporal distributions of pollutants (e.g. nutrients) and problems (e.g. hypoxia) in aquatic environment. It is one of the most visible evidence that water quality has been degraded and as a consequence environmental water may be unsafe for beneficial usage for a period of time. Fish kills can severely reduce the recreational and commercial fisheries, as a result national economic losses could be substantial. For example, harmful algal blooms cost the US economy between 2.2 and 4.6 billion dollars per annum. Therefore, it is essential that scientific investigations are carried out so that causes of fish kills are established, future fish kills can be avoided, environmental factors relating to fish kills can be identified and water quality can be maintained or improved. It is important that public should be advised against the risk of consuming dead fish since fish killed due to biotoxins or pollutants/chemicals or diseases are harmful to humans.

Table 1: Some selected examples of global fish kills and their leading causes.

Country	Year and month	Location	Quantity	Species	Leading causes
Australia	2010 (Dec)	Murray River, Victoria	> 100 fish	Murray cod, silver perch, carp	Black water event and low dissolved oxygen
Australia	2004 (Jan)	Goulburn River, Victoria	-	Murray cod, minnows (*Galaxias* spp), trout cod, carp, red fin, gold fish, yabbies, small shrimp	Low dissolved oxygen and sulphide toxicity
Australia	1987 (Nov)	Donkey camp pool, Katherine River system	5000 fish, 200 prawn	Fish: *Arius graeffei, Lates calcarifer, Nematalosa erebi and* Prawn *Macrobrachium rosenbergii*	Black water event; low dissolved oxygen concentrations (1.2 mg/L); organic toxins (bark and leaf compounds)
Australia	1980 (Jan)	Billabong, Magela creek, NT	3465 fish	Salmontail catfish, barramundi, ord river mullet, black catfish	Natural acid water (pH 2-3)) and biotoxic aluminium (500 µg/L)
Bangladesh	2002 (Apr)	Fish ponds, Mymensigh	mass fish mortality	Silver carp, tilapia, catla and common carp	Oxygen deficiency, cyanobacterial/algal toxins released from *Aphanizomenon flos-aquae (major)* and *Microcystis aeruginosa (minor)*
Brazil	1970 (Jun)	Amazonian flood plain lake	Heavy fish kill	-	Cold front conditions; low dissolved oxygen (8-9% saturation); hydrogen sulphide (H_2S) toxicity
Canada	1969 (Apr)	North Sydney harbour, Nova Scotia	thousands	Herring (*Clupea harengus*)	Bioaccumulation of intermediate oil from coke ovens containing aromatic hydrocarbons
China	2011 (Jan)	Jiaxing Xiuzhou District	250,000 fish	Bream, carp, murrel, silver & grass carp	-
China	2010 (Jul)	Ting River, Fuijian	>1.000,000 fish	-	Mining effluents
Cocos Islands	2007-09 (Dec-Feb)	Indian Oceans, part of Australian Territory	592 fish (11 species)	Black-tip reef shark, blacktail snapper, silverbiddy, mullet, bonefish, pufferfish, others (octopus, crabs)	Low dissolved oxygen (1.4-1.8 mg/L), and high water temperature (33-35^0 C)
India	2001 (Aug)	Yamuna River, Panipat, Haryana	-	Barari, *Wallago attu*	Low dissolved oxygen (2.3 mg/L); higher concentrations of metals (chromium and copper); and pesticides (benzene hexachloride, endosulfan, DDT)
Denmark	1995-96 (Jan-Mar)	Lake	-	Roach	Winter fish kills due to oxygen depletion and long period of ice covers; temperature < 1^{o}C
Finland	1997 (Jun-Jul)	Brackish water lake, Lake Vargsundet	thousands of dead fish	Roach, bream, silver bream, rudd, bleak, carp, pike, perch, ruff, burbot, crayfish	Algal toxins and bloom of ichthyotoxic halophyte *Prymnesium spp.* And cyanobacterium *Planktothrix agardhii*
Germany	1986 (Jan)	Rhine river	500,000 fish	-	Spill from chemical warehouse
Germany	1969 (Jun)	Rhine river	40 million fish		Insecticide endosulfan
Hong Kong	1976 (Feb-Aug)-1977 (Oct-Mar)	Earthen Ponds fertlised with chicken manure	-	Summer kill- bighead, silver carp; Winter kill- Grey mullet, silver carp, bighead, common carp	Summer and winter fish kill, algal bloom, low dissolved oxygen and high ammonia concentration
Kenya	1984 (Sep)	Nyanza Gulf, Lake Victoria	40,000 fish (2400 tons)	Nile perch *(Lates niloticus)*, tilapia (*Oreochromis niloticus)*	Clogging of fish gills due to suspended materials (detritus and algae), low dissolved oxygen (3.2-4.8 mg/L)
Kuwait	2001 (Sep)	Kuwait Bay	> 2500 tons	Mullet, *Liza klunzingerii*	Bacterium, *Streptococcus agalactiae*
New Zealand	2010 (Jan)	Coromandel Peninsula	500	Snapper	Weather related
Philippines	2002 (Jan-Feb)	Aquaculture pens and cages, Bolinao, Pangasinan	Massive fish kill, loss US$120,000	Mainly milkfish *Chanos chanos;* others: reef fish, eels, octopus, urchins	Bloom and toxicity of algae *Procentrum minimum;* Lack of oxygen (1.95-2.25 mg/L)
Philippines	2002 (Feb)	Lingayen Gulf, Pangasinan, Luzon Island, Bolinao	Thousands kilo of milk fish; loss US$ 9 million	Milk fish	99% of bloom contained algae *Procentrum minimum* during fish kill; low dissolved oxygen (< 2 mg/L)
Italy	2005 (Feb)	Lake Averno, Campi Flegrei volcanic system	-	-	Lake overturn, higher concentrations of H_2S, CH_4
South Africa	1994 (Mar)	St Helena Bay	>1500 t (fish), 60 t (crayfish)	57 fish species, 90% fish killed was hardier *Liza richardsonni* , others sharks, bottom dwelling fish	Non-toxic red tide (*Procentrum micans*, *Ceratium furca*), anoxic water condition, hydrogen sulphide poisoning and black tide event
Oman	2008-09 (Aug-May)	Arabian Gulf, Gulf of Oman	Thousands tons of fish dead	-	Ichthyotoxic dinoflagellate/red tides (*Cochlodinium polykrikoides*)
UK	2004-05 (187 fish kills) (Apr-Jun)	Recreational lakes (England and Wales)	> 1500 kg	66% Carp (main), roach and common bream (9%) rainbow trout (1%)	Bacterial & parasitic infections: ulcerative disease by *Aeromonas salmonicida, Pseudomonas* and parasites *Icthyophthirius multifilis, Chilodenella spp. And Icthybodo nectar, Argulus spp.*
UK	2002 (Jul)	River Dee	100,000 fish	Salmon, trout, roach, perch	Release of whey into River
USA	2011 (Jan)	Chesapeake Bay	2 million	Drum fish	Cold water stress
USA	1951-2006 (55 years)	Coastal areas of Texas	383 million fish (55 yrs)	Gulf menhaden (*Brevoortia patronus*) (77%), Finescale menhaden (*B.* gunteri)	Low dissolved oxygen, golden alga *Prymnesium parvum*
USA	2004 (Sep)	Neuse River, North Carolina	1,900,000 fish	Menhaden	Natural upwelling, hydrogen sulphide
USA	2001 (May-Jul)	Saline lake, Salton sea, California	3.54 million fish	-	Wind induced upwelling events
USA	1997-1998	Texas coast	21,000,000 fish	-	Bloom of *Karenia brevis*
USA	1996 (Oct)	Indian River, Florida	-	Common snook, striped mullet, hardhead catfish, red rum, sheep's head, black drum	Alga, *Gymnodinium pulchellum*
USA	1992 (Apr-Aug)	Missouri River	9770 fish	37% common carp (*Cyprinus carpio)*; 34% *Ameiurus melas*; 3% *Ictiobus cyprinellus*	Low Dissolved oxygen or anoxia (0.1-3.7 mg/L); high unionised ammonia (upto 2418 µg/L)
USA	1986	Gulf of Mexico	22 million fish	Gulf menhaden, striped mullet and other species	Red tide (*Gymnodinium breve*)
USA	1972 (Jan)	Oyster creek, New Jersey	-	Menhaden (major), anchovies (minor)	Thermal shock
USA	1935	Gulf of Mexico (Corpus Christi)	22 million fish	Massive fish kill	Red tide (*Gymnodinium breve*)

Billabong=lagoon & small permanent water body or waterholes; Upwelling= an oceanographic phenomenon that involves wind-driven motion of dense, cooler, and usually nutrient-rich water towards the ocean surface, replacing the warmer, replacing the warmer, usually nutrient depleted surface water.

Key references

Azanza R.V., Fukuyo, Y., Yap, L.G. and Takayama, H. 2005. *Procentrum minimum* bloom and its possible link to a massive fish kill in Bolinao, Pangasinan, Northern Philippines. Harmful Algae. 4: 519-524.

Brown et al. 1983. Report of a large fish kill resulting from natural acid water conditions in Australia. J. Fish Biology 22: 335-350.

Caliro, S., Chiodini, G., Izzo, G., Minopoli, C., Signorini, A., Avino, R. and Granieri, D. 2008. Geochemical and biochemical evidence of lake overturn and fish kill at Lake Averno, Italy. Journal of Volcanology and Geothermal Research. 178: 305-316.

Gilbert, P.M., Landsberg, J.H., Evans, J.J., Al-Sarawi, M.A., Faraj, M et al. 2002. A fish kill of massive proportion in Kuwait bay, Arabian Gulf, 2001. the roles of bacterial disease, harmful algae, and eutrophication. Harmful Algae. 1: 215-231.

Henrikson, J.C., Gharefeh, M.S., Easton, A.C., Easton, J.D et al. 2010. Reassessing the ichthyotoxin profile of cultured *Prymnesium parvum* (golden algae) and comparing it to samples collected from recent freshwater bloom and fish kill events in North America. Toxicon 55: 1396-1404.

Hewlett, J.R., Snow, J., and Britton, J.R. 2009. The role of management practices in fish kills in recreational lake fisheries in England and Wales. Fisheries Management and Ecology 16: 248-254.

Howitt, J.A., Baldwin, D.S., Rees, G.N. and Williams, J.L. 2007. Modelling blackwater: Predicting water quality during flooding of lowland river forests. Ecological Modelling

Hobbs, J-P.A and McDonald, C.A. 2010. Increased seawater temperature and decreased dissolved oxygen trigger fish kill at the Cocos (Keeling) Islands, Indian Ocean. Journal of Fish Biology 77: 1219-1229.

Hurst, T.P. 2007. Causes and consequences of winter mortality in fishes. Journal of Fish Biology. 71: 315-345.

Jewel M.A.S., Affan, M.A., Khan, S. 2003. Fish mortality due to cyanobacterial bloom in an aquaculture pond in Bangladesh. Pakistan Journal of Biological Sciences. 6(12): 1046-1050.

Lamberth, S.J., Branch, G.M. and Clark, B.M 2010. Estuarine refugia and fish response to a large anoxic, hydrogen sulphide, "black tide" event in the adjacent marine environment. Estuarine, Coastal and Shelf Science 86: 203-215.

Lidholm et al. 1999. Toxic algae and fish mortality in a brackish-water lake in Aland, SW Finland Hydrobiologia 397: 109-120.

Marti-Cardona, B., Steissberg, T.E., Schladow, S.G. and Hook, S.J. 2008. relating fish kills to upwellings and wind patterns in the Salton Sea. Hydrobiologia. 604: 85-95.

Ochumba, P.B.O. 1990. Massive fish kills within the Nyanza Gulf of Lake Victoria, Kenya. Hydrobiologia. 208: 93-99.

Richlen, M.L., Morton, S.L., Jamali, E.A., Rajan, A and Anderson, D.M. 2010. The catastrophic 2008-2009 red tide in the Arabian Gulf region, with observations on the Identification and phylogeny of the fish-killing dinoflagellate *Cochlodinium polykrikoides*. Harmful Algae. 9: 163-172.

Thronson, A and Quigg, A. 2008. Fifty-five years of fish kills in coastal Texas. Estuaries and Coasts. 31: 802-813

Sargent, J.C. and Galat, D.L. 2002. Fish mortality and physicochemistry in a manged floodplain wetland. Wetlands Ecology and Management. 10: 115-121.

San Diego-McGlone, M.L., Azanza, R.V., Villanoy, C.L. and Jacinto, G.S. 2008. Eutrophic waters, algal bloom and fish kill in fish farming areas in Bolinao, Pangasinan, Philippines. Marine Pollution Bulletin. 57: 295-301.

Steidinger, K.A., K.A., Landsberg, J.H., Truby, E.W. and Roberts, B.S. 1998. First report of *Gymnodinium pulchellum* (Dinophyceae) in North America and associated fish kills in the Indian River, Florida. Journal of Phycology. 34: 431-437.

Townsend, S.A., Boland, K.T. and Wrigley, T.J. 1992. Factors contributing to a fish kill in the Australian wet/dry tropics. Water Research. 26(8): 1039-1044.

Wai_ching Sin, A and Tak-Lun Chiu, M. 1982. summer and winter kills in fish ponds of Hong Kong and their possible prediction. Aquaculture 29: 125-135.

Zitko, V and Tibbo, S.N. 1971. Fish kill caused by an intermediate oil from coke ovens. Bulletin of environmental Contamination and Toxicology. 6(1): 24-25.

Website:File://F:\fish_kill.htm-22 Jan 2011

Note