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Report of fish mass mortality from Lake Hashenge, Tigray, Northern Ethiopia and investigation of the possible causes of this event

T. Teame[1]*, P. Natarajan[2], H. Zebib[1] and G. Abay[1]

[1]Tigray Agricultural Research Institute (TARI), Tigray, Ethiopia.
[2]Biology Department, Ambo University, Ambo, Ethiopia.

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This study was intended to report the disastrous mass mortality of Nile tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio*) in Lake Hashenge, Tigray occurred in June, 12 to 15th, 2014 and to investigate the possible causes of this phenomenon. The dissolved oxygen (DO) of the water of the lake was 2.20 mg/L in the north part and 2.09 mg/L in the south west part of the lake with an average of 2.15 mg/L. The temperature was not out of the permeable range (18.05 to 24.30°C) which was 22.19°C and pH value was 7.67. Mass kills as well as respiratory distressed fish were seen along the lake. The disaster zone was so serious in the south western part of the lake when compared with the other parts of the lake, which were estimated at several thousands of Nile tilapia and common carp were dead. Clinically, the affected fish showed asphyxia with mouth wide opened and flared gills. Respiratory stressed fishes were smaller in size, while most of the mortalities were limited to large sized fishes. Previous record indicates that similar cases of mass kills have occurred 14 years ago in 2000, but the losses were much less. Laboratory analysis of water quality indicated that the low level of DO was the primary cause for the mass mortality of the fishes. The physico-chemical characteristics of water revealed the presence of abnormal water color, low level of DO (2.39 mg/L), low secchi disk reading, and slightly alkaline pH. So it was concluded that the turnover of the lake due to the mixing of the thermally layered water was the reason for the low DO, which causes mass kills of the fishes. The mass mortality was more severe in Nile tilapia as compared to mortality of common carp.

Key words: Common carp, Hashenge, low dissolved oxygen, mass mortality, Nile tilapia.

INTRODUCTION

The condition of mass mortalities of fish can be defined as a sudden death of a large number of fish 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 a million. The importance of oxygen to maintain life of fishes was explained by Diaz and Breitburg (2009) and its availability is one abiotic factor that can limit habitat quality, distribution, growth,

*Corresponding author. E-mail: tsegayteam331@yahoo.com.

reproduction, and survival of fishes (Kramer, 1987). All fishes require oxygen not only for survival, but also the physical properties of water (high viscosity, low oxygen content at saturation) make its uptake challenging for fishes even at high DO levels (Kramer, 1987).

Depletion of DO in water can lead to kill. Often low DO is due to the increased use of the DO in the water column by living organisms other than fish (e.g. aquatic plants, algae, bacteria); overcrowding of fish and the lake turnover will also deplete the dissolved oxygen levels in the water body. When the oxygen supply below the need of the organism or consumption exceeds the resupply, DO concentration can decline below the levels required by most animal's life.

The cause for low DO conditions can be due to natural conditions such as algal respiration, seasonal flooding, stratification and anthropogenic causes. Hypoxia occurs naturally in habitats characterized by low mixing or limited light, heavily vegetated swamps and backwaters that circulate poorly, stratify, and have large loads of terrestrial organic matter (Chapman et al., 1999). Wetzel (2001) reported that, levels of hypoxia are mainly determined by primary productivity, depth, and temperature of the aquatic body.

According to Chapman and McKenzie (2009), hypoxia is defined as the physiologically stressful for fish, shellfish, and invertebrates with prolonged exposure to anoxia being fatal to most aquatic fauna. When a fish exposure to hypoxia condition it can cause both lethal and sublethal effects. It can also lead to reduced feeding, reproductive, growth, metabolism, and slower reaction time. The effect of hypoxia on fish not only vary according to the fish species (Chapman and McKenzie, 2009), but also depend on the frequency, intensity, and duration of the hypoxic events (Diaz and Breitburg, 2009).

Fishes can compensate for hypoxic conditions by decreasing their need for oxygen, increasing the amount of oxygen available, or combining both strategies (Reardon and Chapman, 2010). Throughout the world, mass mortality of fish are most frequently linked to natural causes such as ecological hypoxia (low DO) or anoxia (no or zero DO), harmful algal bloom, disease extreme changes in temperature overturns of lakes. Many literature reviews reveal that mass fish mortality is linked to oxygen depletion or low levels of oxygen in the water. Water with a low oxygen level could cause suffocation of fish resulting in mortality. The decline of the concentration of DO in water bodies can occur due to algae die off, turnover of lake water, surface runoff of organic materials into water bodies, disturbance of sediments containing large quantities of aquatic vegetation or with excess nutrient loads, high temperature, etc. (Murithi et al., 2012).

Patterns of fish mortality due to physico-chemical factors were registered in many parts of the world, because of oxygen depletion, high un-ionized ammonia (Sargent and David, 2002) and an abrupt temperature fall (Economids and Vogiatzizs, 2009). The toxicity of ammonia is closely correlated with pH and to a lesser extent, with water temperature and DO. When the pH of the water become higher, the percentage of total ammonia converts to the toxic un-ionized form will increase. This means the water become more toxic. Wajsbrot et al. (1991) reported that ammonia toxicity may increase as a result of increasing ammonia levels and decreasing oxygen concentration following the death of phytoplankton populations in the water body. Moreover, under low concentration of DO level most of the mortality occurs within a few hours and this also cause the increase of toxic substances in the water body (Diana et al., 1997).

The study of respiratory organ color changes in fish has become an important tool for monitoring environmental exposure of fish to low dissolved oxygen in laboratory and field studies. The present study reports a mass mortality of fish in Lake Hashenge and determines the possible causes of this event.

MATERIALS AND METHODS

Study area

Lake Hashenge (Figure 1) is situated in Ofla Woreda Southern Tigray, about 628 km at North of Addis Ababa, Ethiopia. It is located at the coordinates of 12°34′50″N and 39°30′00″E and an elevation of 2440 m a.s.l. and it is one of the crater lakes in the country and not associated with the East African rift system; instead, it is the result of volcanism. This lake has no any outlet to drain its water. Hashenge Lake is 5 km long and 4 cm wide, with a surface area of 20 km^2. Its drainage area is 129 km^2 and has a maximum depth of 25 m. Nile tilapia and common carp are the dominant fish species in the lake.

Fish samples

The outbreak of the catastrophic mass mortalities has quickly triggered us to perform an emergency visit to the site. The emergency visit to the mortalities scene along the Lake Hashenge has enabled us to obtain the history of the problem, record fish kill patterns, determine the affected fish species and record clinical findings/abnormal behavioral changes in affected fishes. A total of 65 fishes (40 Nile tilapia and 25 common carp) with average weight between 100 and 1100 g was obtained from the lake and examined for external symptoms of disease. They were then brought to Abergelle Agricultural Research Center for further examination. Fish were examined for any abnormal external signs and internal and external parasites.

Water quality parameters

Physico-chemical parameters of the lake water were tested according to standard methods described by APHA (1995, 2005). The physical parameters, including color, odor, and transparency were measured. The pH and water temperature were detected using a waterproof digital pH meter and thermometer (CP-411, ELMETRON). DO concentrations and conductivity were measured using a waterproof digital, DO meter (conductivity/oxygen meter

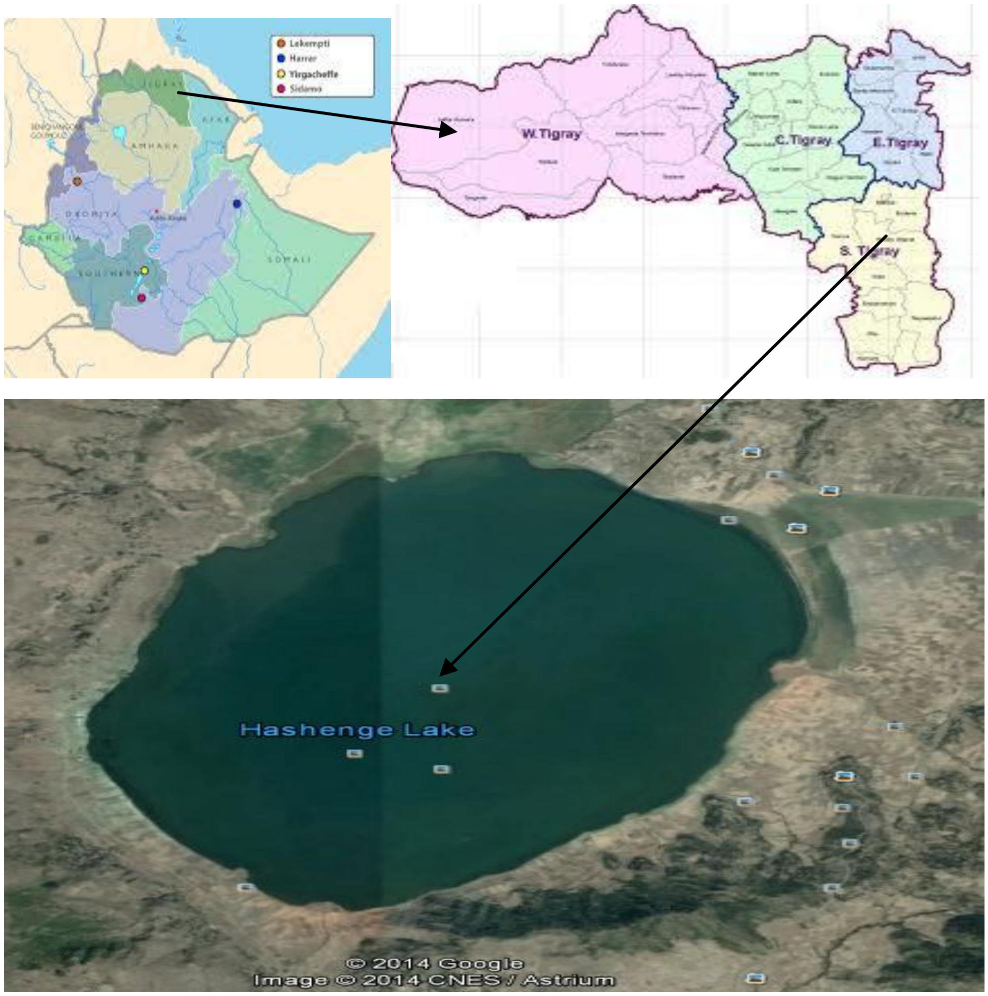

Figure 1. Map and location of Lake Hashenge.

CCO-401, ELMETRON). Transparency was measured using Secchi disc attached to graduated plastic rope.

RESULTS AND DISCUSSION

Field observation indicated the evidence of mortalities of fish in the lake. The lake water was brownish in color. The mortalities and signs were highly found in Nile tilapia when compared with the number of fish deaths of common carp as they showed signs of asphyxia, which include the accumulation of fish on the surface with gasping for air and increased opercular movements.

The signs of asphyxia was found in different sized of *O. niloticus* (fingerlings and large fish), while the mortalities were mostly limited to large sized fish. Further, the mortalities and signs of asphyxia among fishes were higher in the south western part of the lake. This part of the lake is deeper than the other parts of the lake. The total mortalities approached several thousands of fishes. The stressed fish shown symptoms, like opening of their month widely, their gills were flared and bent back head. The history revealed that this disaster has previously occurred in the year 2000, but on a small scale.

Dead and dying fishes were examined in the field for the evidence of disease symptoms as the presence of external parasite if any on the body surface. In the laboratory, they were examined for the evidence of diseases and parasites internally. Samples were also brought from the external and internal body of the fish to the laboratory of Abergelle agricultural research center for the examination of internal and external parasites of the fish and examination was done by hand lens for some large external and internal parasites and none of the external and internal parasites were recorded from the samples taken.

The number and size groups of fishes collected from the lake are presented in Table 1. The fish constitutes mostly the larger sized fish of the length group of 26 to 30 cm in Nile tilapia and 36 to 40 cm in common carp. The catch consisted of more number of larger sized fish mainly because the fishermen of the area uses larger

Table 1. The size group of the fishes collected randomly from the lake for further examination.

Fish species and number	Size groups				
Nile tilapia (cm)	10-15	16-20	20-25	26-30	>31
No. of fishes	3	7	8	17	5
Common carp (cm)	20-25	26-30	31-35	36-40	>41
No. of fishes	0	2	5	12	6

Table 2. Water quality characteristics of Lake Hashenge during mass mortality.

Site No.	Physical characters		Physico-chemical of the water					
	Color	Odor	DO (mg/L)	Temp (°C)	pH	Transparency (cm)	TDS (g/L)	Cond(mS/cm)
1*	Dark brown	Rotten egg	2.09	22.20	7.60	22.00	11.40	5.06
2**	Dark brown	Rotten egg	2.20	22.17	7.74	23.00	10.62	5.14
mean	-	-	2.15	22.19	7.67	22.50	11.01	5.10

*Northern part of the lake (shallower). **South western part of the lake (deeper).

mesh sized to catch larger sized fish for commercial purpose. The relationship between water quality parameters and fish mortality is presented in Tables 2 and 3.

Relationship between water quality characteristics and fish mortality

Water quality parameters

The monthly physical and chemical parameters of Lake Hashenge were reported as shown in Table 3.

Temperature and oxygen

The monthly variation in water temperature of the lake ranged between 16.10 and 24.20°C. The highest water temperature was reported in April and lowest in December. The monthly variations in dissolved oxygen ranged from 2.15 to 6.18 mg/L. An inverse relationship of oxygen and temperature has been reported by Tiwari and Ranga (2012) and Sinha and Biswas (2011).

From the results observed, it is seen that both temperature and oxygen have contributed a significant role in fish kills. The fish kills occurred in the month of June 2014 when the temperature was found to be 20.15°C and it was 24.30°C in May, lowering of the temperature may cause the turnover of the lake during June when oxygen was found to be the minimum (2.15 mg/L). The increased temperature and the consequent reduction in oxygen level may be one of the factors responsible for mass kills in the lake. Further, the sudden temperature drop of 20.15°C in June after a gradual increase of temperature from December 2013 (18.05°C) to May 2014 (24.30°C) has caused turnover of the lake which may cause oxygen depletion in the lake. More similar phenomena of oxygen depletion and increased toxic levels of NH_3 as a function of temperature drop and fish kills have been reported by Moyo (1997) in Lake Chivero in Zimbawe in March 1996. The exposure of fish to low dissolved oxygen (<5 mg/L) for a long period of time has direct consequences for the survival of fish and other aquatic animals as DO reduction elicit physiological regulatory mechanisms involved in the maintenance of the oxygen gradient of water in tissues which is essential to maintain the metabolic aerobic pathways (Adeogun, 2012).

Common carp seems more resistant to low dissolved oxygen than Nile tilapia; this might be due to the adaptation of common carp to turbid water and their feeding nature of the fish species that is why higher mass mortalities was observed in Nile tilapia, especially in the larger fisher during the present study. Signs of asphyxia have been presented by different sized fishes, while the mortalities were mostly limited to large sized fish. The earlier history revealed that an incidence of fish kills occurred in the lake in the year of 2000 when compared with the present report is much smaller.

Transparency and DO

When the water has high transparency, there is high photosynthesis releasing high oxygen by the plants to the water. The low values of transparency recorded during the rainy season probably due to the entrance of silt from adjoining catchment area through rain water in to the lake. High value of transparency occurs during the dry

Table 3. Monthly physico- chemical characters of Hashenge Lake water.

Month 2013/14	Water physico-chemical parameters of the lake						
	DO (mg/L)	DO (%)	Temp (°C)	pH	Transparency (cm)	TDS (g/L)	Cond (ms)
June (2013)	4.70	67.00	21.30	8.10	23.00	10.6	5.34
July (2013)	4.51	65.30	21.85	8.23	26.00	9.96	3.34
August (2013)	5.12	63.00	19.90	7.88	20.00	8.45	8.29
September(2013)	5.90	74.40	17.90	8.56	48.00	11.56	14.20
October (2013)	5.76	73.40	16.73	8.40	57.00	8.34	12.33
November (2013)	5.80	72.00	17.22	8.90	51.00	9.75	14.20
December (2013)	6.18	82.50	16.10	9.12	60.00	8.33	14.80
January (2014)	5.33	78.78	18.05	8.70	52.00	9.80	10.70
February (2014)	5.85	81.00	20.14	9.56	58.00	8.41	10.90
March (2014)	5.64	79.00	22.32	9.10	65.00	8.09	10.89
April (2014)	4.21	75.00	24.20	8.30	57.00	9.60	12.00
May (2014)	4.40	67.00	24.30	8.67	61.00	8.10	12.33
June (2014)***	2.15	54.00	20.15	7.74	22.50	11.01	5.20
Average	5.04	71.72	20.01	8.56	46.19	9.38	10.35

*****Mass fish kills occurred.

season may be due to gradual settlement of suspended particles. Similar trend of increasing values for transparency during winter and decreasing during rainy season was noted by Thirupathaiah et al. (2012). Araoye (1997) reported that runoff water to the lakes during rainy season brought suspended solids and dissolved salts. This also causes negative correlation of DO concentration with total dissolved solids (TDS) and conductivity. DO depletion and reductions of transparency also occurred due to the high concentration of dissolve salts and suspended solids in Lake Kainji (Imevbore, 1975).

DO and pH

The result of the pH reading of the Tekeze reservoir surface water confirmed that it was slightly alkaline. The highest pH values of 9.56 were recorded in February while pH dropped to 7.74 in June (2014). This drop in pH from 9.56 to 7.74 could be due to the turnover of the lake which causes the mixing of the bottom of acidic water with the surface slightly alkaline water. Decomposition of dead organisms declined the concentration of DO in the water, while it causes increase in the amount of carbon dioxide in the water body. This fact leads to conclude that dissolved oxygen and pH has positive correlation. Egborge (1977) and Adeniji (1991) reported similar observations in Lake Asejire and Jebba in Nigeria, respectively.

The highest value of DO concentration (6.18 mg/L) recorded in December could be due to the high transparency and this causes an enhanced photosynthetic activities during the dry season. The decline of dissolved oxygen concentration to 2.15 mg/L in June 2014 was probably due to the vertical mixing and the decrease of surface water temperatures. The vertical mixing of the lower and higher layers formed due to temperature difference of water brought the bottom deposits to the water surface resulting in reduction of transparency and DO concentration in the water.

Araoye (2007) reported that the vertical mixing of the water layer of lake due to temperature changes resulted in over turn of the lake. Similar observation was reported by Vander-Heide (1982) who reported similar observation in Lake Brokopondo. The mixing of the lake water vertically results in depletion of dissolved oxygen and very low concentration of dissolved oxygen could be disastrous to fish species like the Tilapines (Araoye, 2009). This may be the result for less mortality of common carp when it is compared with Nile Tilapia.

Kaul and Handoo (1980) revealed that increased pH value of surface water is due to increased metabolic activities of autotrophs, because they utilize the carbon dioxide and release oxygen, thus reducing H+ ions. Table 3 shows that low pH was recorded in June 2014 during the mass fish kill. This may be due to the liberation of acids from decomposition of organic matter during the turnover of the lake.

Conclusion

It could be concluded that the cause of the mass fish mortality was oxygen depletion, since there was no other factors associated with the fish kill from the investigation. Oxygen depletion occurred probably due to the fall turnover of the lake. The Secchi disc reading of the water was low and the color of the water was brown and rotten egg. These phenomena of the water of the lake were indicators of the turnover. Since at that time there was no rain, heavy wind, and storm that cause those conditions. The turnover may have occurred due to the slightly decrease of the surface water temperature.

Conflict of Interests

The authors have not declared any conflict of interests.

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