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Effect of Dissolved Oxygen on Physiology And Behaviour of Freshwater Fishes

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Abstract

Dissolved Oxygen (DO) is an important environmental factor which affect the fish population directly. Sometimes it is harmful and sometimes it is useful. It also depend on chemical composition of water body which is very variable, depending on season, time of day, place and depth. Of all the chemical substances in natural water, dissolved oxygen is one of the most significant. Dissolved oxygen changes very drastically in short period of time and sometimes cause loss of fisheries.

Fishes are important as a food source. Its production should increase with time. The requirement of dissolved oxygen is different for different fishes. Mostly it depend on the habitat of fish. The reduction in level of dissolved oxygen is an important criteria. As the dissolved oxygen reduces, the fish which is more tolerant survive well and populate the water.

This review shows various studies related to the effect of dissolved oxygen on growth and behavior of fish. It consolidate the data and aware us about different studies on this important aspects.

Keywords: *Dissolved Oxygen, Growth and fish behavior.*

Introduction

Dissolved Oxygen (DO) remains a key factor and it influences the healthy growth of fish in aquaculture. The DO content in water is an indicator of water quality. In the broader sense, it is considered as one of the important water quality variable in fish culture. Hence, dissolved oxygen concentration is more important than any other environmental variables because other factors that are beyond the range can be tolerated by fish and may not cause stress or death.

Dissolved oxygen concentration is important in intensive fish culture as it shows quick changes over a matter of hours, or sometimes even minutes, which can pass optimum level to become lethal to the fish, unlike other environmental variable factors in fish culture , this dynamic nature of Dissolved Oxygen may affect fish in many way. According to various studies reported, fish growth and differential behavioral responses are been reported from different parts of world, but they point out the same inference in response to the different dissolved oxygen concentration. With this review an attempt has been made to summarize various studies on this aspect.

Effect of different levels of Dissolved Oxygen on fish

Oxygen level is one of the key environmental factors that effects fish welfare and development. The relation of fishes to the oxygen is an important point of consideration for researchers. As it affect the fish life directly. Decreased level of dissolved oxygen is detrimental to the health of body of water, and the fishes that live in it, leading to the death of these fishes. (W.G. Moore, 1942) .

The oxygen present in air dissolves in water to meet the respiration needs of water animals. When the level of dissolved oxygen in water reduced and the oxygen consumption rate exceeds it leads to hypoxia. Certain level of oxygen is required for the life of all fishes. This level of requirement of oxygen is critical level, above and below it the fish does not survive. Reduction in dissolved oxygen occur in all waters and it affects the fish life. The effect of reduced oxygen on metabolism, development, growth and locomotion of fishes have been investigated.(Jones,1952; Fry,1960; Doudoroff & Warren,1965; Doudoroff and Shumway,1967).

Swingle (1969), developed a dissolved oxygen scale for warm water fish. According to this scale,

- Dissolved oxygen $\leq$ 0.3 mg/litre; fish die after short time exposure.
- Dissolved oxygen = 0.3 mg/litre to 1 mg/litre; lethal for long term exposure.
- Dissolved oxygen =1 mg/litre to 5 mg/litre ; fish survive but growth was slow for long term exposure.
- Dissolved oxygen = 5 mg/litre, minimum for warm water fish.(fast growth). Most of fresh water fish follow this scale.

Effect of low dissolved Oxygen on Growth and Development of fish

The different dissolved oxygen level affects different life stages of fish. Sometimes hatching of egg is accelerated by reduced oxygen and sometimes it is delayed. (P. doudroff and D.L. Shumway , 1970). Low DO effects the egg production and hatching period in fish. In Fathead minnows, the number of eggs reduced per female at 2.0 mg/l DO, Fry growth was reduced significantly at all concentration below the control (7.9 mg /l).Fry survival was reduced at 4.0 mg/l and lower dissolved oxygen concentration, 18% of the survivors at 4.0mg/l were deformed.(William A Brungs,1971) . Fathead minnows were exposed to constant dissolved oxygen concentrations (1.0-5.0 mg/liter) for 11 months.

The number of eggs produced per female was reduced at 2.0 mg/liter and no spawning occurred at 1.0 mg/liter. Fry survival was reduced at 4.0 mg/liter and lower dissolved oxygen concentrations. Eighteen percent of the survivors at 4.0 mg/liter were deformed. The time required for hatching was increased at successively lower oxygen concentrations by as much as 50%, from 5.0 days under control conditions to 7.8 days at 2.0 mg/liter. No effect on percent hatch was observed. Fry growth, therefore, was the most sensitive indicator. A continuous 12-month exposure of fathead minnows to elevated water temperatures (26-34 C) showed that reproduction was more sensitive than survival , growth, or egg hatchability in assessing the effect of temperature (Brungs 1971b). The number of eggs produced per female, the number of eggs per spawning, and the number of spawnings per female were each gradually reduced at successive temperatures above the control (23.5 C) . No spawning or mortality occurred at 32 C, which was the lowest temperature where growth was apparently reduced. Male secondary sexual characteristics were less developed at 30 C than at lower temperatures.

In 1974 Anthony.R.Carlson,Richard E.Siefert studied the effects of reduced oxygen on the embryos and larvae of lake trout(*Salvelinus namaycush*) and large mouth bass *Micropterus salmoides.* They found at 7 and 10 ºC lake trout development from fertilization through first feeding was initiated at all reduced oxygen saturations tested (50% and lower) survival was adversely affected at all reduced concentrations although only slightly at 50% saturation at 7ºC.At 20 and 23ºoxygen concentration as low as 35% saturation were adequate for large mouth bass survival. However even at the highest reduced oxygen saturation (70%) growth was reduced and at saturation of (50%) and below hatching was premature and first feeding was delayed.

Davis(1975) found that fish species differ widely in their ability to tolerate hypoxia.Even the survival of smolts of salmon *Salmo salar* reduced at low concentration of DO.(J.S.Alabaster and D.G.Shurben and M.J.Mallett,1979).

The variation in the range of lethal oxygen concentration studied by many workers on different species of fish. There are many studies on the dissolved oxygen requirements of salmonids or cold water fish((Salmon, Trout and Char) that are considered to be most sensitive group of fresh water fish specially at the time of hatching(modified from Alabastor & Lloyd,1980).

The survival mechanism of different fish change at low oxygen concentration. A great deal of work has been done by S. A .Klinger, J.J. Magnuson and G.W.Gallepp.in(1982)on Central mud minnow (*Umbra limi),*Fathead minnow (*Pimephales prumelas)*and brook stickleback(*Culacea inconstans).*

G. Singh & G. S. Virdi(1983) gave lethal oxygen concentration for some Indian fresh water fish.

In one more study by Tsadik and Kutty (1987) on the influence of ambient oxygen on feeding and growth in *Oreochromis niloticus.* In his experiments he performed different growth tests on high, medium and low level of dissolved oxygen and proved that the fastest rate of growth was at high dissolved oxygen and slowest growth in the low DO. The fish uses above different combinations for minimizing the cost of meeting their oxygen demands.

Diaz (2001), studied the effect of hypoxia on large coastal ecosystems around the world. He concluded that various human activities such as addition of nutrient to the water body leads to seasonal hypoxia in bottom water which affects growth of fish.

Even decreased oxygen also considered a major factor in determining food intake,low dissolved oxygen is a type of stress in fish farms with high fish densities. Here the food conversion ratio (FCR), which is the amount of fish food consumed to generate a given weight gain. It is the ratio between the weights gained in a given period to the total feed intake by the fish in the same period .It is the inverse of feed intake. The FCR ratio improved (lowered)at higher growth rates.(Mar Kore and Rorvik 2001, Crampton et al.2003, Norgarden et al.2003).

The results of the study done by Mallya et al in 2007 showed that oxygen saturation level had a positive effect on the growth and feed conversion ratio when it was set at 80% to 120 % saturation in Atlantic halibut. This study conclude that in case of Atlantic Halibut the growth rate is higher when oxygen level is between 80% and 120 %.The FCR ratio for halibut was lower at 120%oxygen saturation. These species appear more sensitive to oxygen saturation than Tilapia. More research is needed in order to know at which saturation point the growth is maximized.

Effect of low dissolved Oxygen on behavior of fish

Fish activity can increase or decrease at reduced oxygen concentration.The fish is able to detect low oxygen concentration in water and try to avoid it.In natural condition fish avoid lethal level successfully when oxygenated water is accessible. Upstream migration of adult salmonid has been reported at low dissolved oxygen.(Doudoroff and shumway,1970).

Different seasons have different dissolved oxygen concentration.In Winters the level of DO is high in flowing water and it is low in Summers. Due to low DO the fish move to habitable place. Other behavioral changes acquired by the fish due to low DO are change in activity of fish , increased use of air breathing, increased use of aquatic surface respiration and vertical or horizontal habitat change , (Kramer 1987, Tsadik and Kutty 1987).

Effect of low dissolved Oxygen on Movement, Respiration and Metabolism of fish

Swimming performance of the fish is reduced markedly at low DO .This study has been done by Michael L.Dahlberg (1968) on Juvenile Large mouth bass, (*Micropterus salmoides*).In this fish swimming performance of fish is reduced when oxygen concentration is below 5to 6 mg /l in tests at 25ºC in a tubular chamber.

Even the swimming performance of young Atlantic salmon *(Salmo salar)* affected by reduced oxygen.(modified by M.N.Kutty, R.L.Saunders, 1973).

Hypoxia result into stress increase, decrease of swimming activities and reduction in immunity to diseases. So there is need to maintain the level of dissolved oxygen. At saturation level ,the physiological

or metabolic activities are not affected. So to have high production in any culture system, the dissolved oxygen level should be maintain at saturation.(Wedemeyer,1996) .

Oxygen is important for respiration and metabolism processes in fish. The fish metabolic rate is affected by the availability of oxygen in rearing environment .As DO concentration decrease, respiration and feeding activities also decrease. As a result fish growth rate is decreased and possibility of disease attack is increased. At low dissolved oxygen fish is not able to assimilate the food consumed,(Tom,1998).

Studies on Tasmanian population of Atlantic salmon have the ability to regulate metabolic rate to low oxygen concentrations and show a relatively high degree of hypoxia tolerance. This is the first formal study to examine the effect of progressive hypoxia on individual Atlantic salmon and at a range of environmental temperature. (Robin barnes,2011).

Nimesh N (2012) found oxygen consumption rate of *Gambusia affinis, Clarias magur,Xiphophorus clemenciae* and *Labio rohita.* This study shows that smaller size fish has moderately high rate of dissolved oxygen consumption than the larger ones.

Elshout PM(2013) studied low oxygen tolerance of different life stages of three salmonids to create species sensitive distribution (SSD). The difference in lethal oxygen concentrations between adults and juveniles was largest for three salmonids .In addition lethal dissolved oxygen concentration were compared to oxygen concentration corresponding to maximum tolerable water temperature of the same species.

Claireaux G.(2016) revisited F.E.J Fry's concept and the effect of ambient oxygen availability upon fish metabolism and clarified the definitions of limiting, critical and incipient lethal oxygen levels. Finally how the cardiovascular system contributes to the capacity of fish to respond to reduced oxygen availability is considered.

CONCLUDING REMARKS

After reviewing the literature the authors have come to the conclusion that if we will be familiar with the effects of dissolved oxygen on fish, we can overcome them by adapting various new strategies. So, this area of research needs work to be done.

References.

Alabaster,J.S., D.G.Shurben , G.Knowles.1979: The effect of dissolved oxygen and salinity on the toxicity of ammonia to smolts of salmon,Salmo salar L.J.Fish.Biol.15,705-712.

Alabaster,J.S and R.Lloyd.1980: Water quality criteria for fresh water fish.Boston.MA:Butterworth.Inc.

Brungs,WA.1971: Chronic Effects of low Dissolved oxygen concentrations on the fathead minnow (Pimephales promelas).Journal of the Fisheries research Board of Canada. 28(8):1119-1123.

Barnes,R.(Katersky), H.king,Chris G Carter, 2011:Hypoxia tolerance and oxygen regulation in atlantic salmon,Salmo salar from Tasmanian population. Aquaculture 318 , 397-401.

Carlson, A.R. Richard E.Siefert. 1974: Effects of reduced oxygen on the embryos and larvae of lake trout (Salvelinus namaycush) and Largemouth Bass (Micropterus salmoides).Journal of the Fisheries research Board of Canada,31(8):1393-1396.

Crampton V.,A.Bergheim, M. Gausen, A.Naess, and P.M.Holland (2003). Effect of low oxygen on fish performance.(www.ewos.com).

Claireaux, G. ,D. Chabot: Responses by fishes to environmental hypoxia. 2016: integration through Fry's concept of aerobic metabolic scope. J.Fish Biol. Jan:88(1):232-51.

Doudoroff, P., and C. E. Warren.1965: Dissolved oxygen requirements of fishes. In: 1965 Biological problems in water pollution (Trans. 1962 Seminar). U. S. Publ. Hlth. Serv. Publ. 999-WP-25, p. 145-155.

Doudoroff, P., and D. L. Shumway,1967: Dissolved oxygen requirements for the protection 1967 of fish, In: A symposium on water quality criteria to protect aquatic life (E. L. Cooper, ed.). Spec. Publ. No. 4, Am. Fish. Soc. (Suppl. to Vol. 96, No. 1, Trans, Am. Fish. Soc.), pp.13-19.

Doudroff, P. D.L.Shumway.1970: Dissolved oxygen requirement of fresh water fish.FAO Fish.Tech.Pap.,86:1-291.

Davis,J.C.1975:Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian Species. A review.J.Fish.Res.Board can,32;2295-2332.

Diaz,R.J.2001: Overview of Hypoxia around the world. Journal of environmental Quality .Vol .30. March-April.275-281

Dahlberg, M. L.,Shumway,D.L.,Doudoroff ,P.1968 :Influence of Dissolved oxygen and carbon dioxide on swimming performance of Largemouth Bass and Coho Salmon.Journal of fisheries Research Board of Canada,1968,25(1):49-70.

Elshout,P.M., L.M.Dionisio Pires, R.S.,Leuven ,Wendelaar Bonga . 2013: Low oxygen tolerance of different life stages of temperate freshwater fish species.J.Fish.Biol. Jul;83(1):190-206.

Fry, F. E. J. 1960. The oxygen requirements of fish. In: Biological problems in 1960 water pollution (Trans. 1959 Seminar). Tech. Rep. W60-3, Robert A. Taft Sanitary Engng. Center, U. S. Publ. Hlth. Serv., p. 106109.

Jones, J. R. E. 1952. The reaction of fish to water of low oxygen concentration. J. Exp. Biol., 29(3): 403-415.

Kutty,M.N., R.L.Saunders, 1973:Swimming performance of young Atlantic Salmon (Salmo salar) as affected by reduced ambient oxygen concentration .Journal of fisheries research board of Canada.,1973,30(2):223-227.

Klinger,S.A., J.J.Magnuson, G.W. Gallepp. 1982: Survival mechanisms of the central mudminnow (Umbra limi),fathead minnow (Pimephales promelas) and brook stickleback(Culacea inconstans) for low oxygen in winter. Environ. Biol.Fish.7: 113-120.

Kramer,D.L 1987:Dissolved oxygen and fish behavior: Environmental Biology of fishes Vol18.No.2,pp81-92.

Morkore,T.and K.A. Rorvik.,2001:Seasonal variations in growth, feed utilization and product quality of farmed Atlantic Salmon(Salmo salar L.)transferred to sea water as 0+ smolts or1+smolts.Aquaculture,199,145-158.

Mallaya,.Y.J. 2007: The Effect of dissolved oxygen on fish growth in aquaculture. Project. Kingolwira National Fish Farming centre, Fisheries Division, Ministry of Natural Resources and Tourism, Tanzania.

Norgarden,U., F.Oppedal, G.L.Taranger, G.I.Hemre and T. Hansen. 2003:Seasonally changing metabolism in Atlantic salmon (Salmo salar L.).Aquac.Nutr.9:287-289.

Nimesh,N., G.S,Virdi, S.Jain.2012 : Evaluation of oxygen tolerance in fresh water fishes. Voyager Vol.lll.Dec. 49-61.

Moore ,W.G.1942:Field studies on the oxygen requirements of certain fresh water fishes.Ecology23;319-329.

Swingle,H.S.1969:Methods of analysis for water,organic matter and pond bottom soils used in fisheries research.Auburn:AL:Auburn University.

Singh,G.and G.S.Virdi.1983:Lethal oxygen concentration for some Indian fresh water fishes.Indian journal of forestry.vol.6(1),83-84.

Tom L.1998,Nutritional and feeding of fish. Kluwer Academic Publishers. Second Edition

Tsadik Gagma ,M.N Kutty.1987. Influence of ambient oxygen on feeding and growth of tilapia,Oreochromis niloticus ARAC/87/WP/10. United Nation Development Programme.Food and agriculture organization of United Nations, Nigerian institute for oceanography and marine research project RAF/87/009.

Wedemeyer,G.A.1996:Physiology of fish in Intensive culture systems. Chapman&Hall,115 Fifth Avenue,New York,NY.10003,U.S.A.