The Effects of Suspended Particles on Opercula Beats and Cough Rates in *Oreochromis niloticus* (Bangkok Strain)

Olendi Robert
Department of Fisheries and Aquatic Sciences, University of Eldoret,
P.O. Box 1125 -30100, Eldoret, Kenya
rjolendi@yahoo.com

Abstract

A study on the effects of suspended particles on the opercula beats and cough rates in Oreochromis niloticus was conducted in aquaria tanks using different concentrations of algae, silt and sand particles. Microcytis aeruginosa cultured in the laboratory was used. Silt particles obtained from bottom mud of Airthrey Loch were used while sand particles used were sieved through a series of sieves down to 63µm. Three static 5-litre capacity experimental tanks maintained at 27^0C and vigorously aerated were set in the laboratory. Acclimatized O.niloticus of 7.50mg mean weight were put in each tank. Concentrations of 50mg/l and 150mg/l of algae and silt and algae and sand were added to experimental tanks. The results showed in 50mg/l of algae and silt mixture both the opercula beats ($P<0.000$) and cough rates ($P<0.000$) increased significantly compared to the control. In 50mg/l concentration of algae and sand there was significant increasein opercula beats ($P<0.000$) and cough rate ($P<0.000$).Between 50mg/l algae and sandand algae and silt, there was significant increase in opercula beats ($P<0.000$) and no difference in cough rates ($P<0.226$) In the 150mg/l concentration of algae and silt, the results showed both the opercula beats ($P<0.000$) increased significantly and cough rates ($P<0.000$). The implication of these results in light of breathing and coughing rates in O. niloticus are discussed.

Key Words: Silt, Sand, Breathing, Coughing, *Oreochromis niloticus*

INTRODUCTION

Suspended solids in water are normally defined as solid matter which is retained on a fine filter paper after filtration of water samples. Suspended solids in water bodies can originate from either external or internal water sources. In the tropics, the effect of suspended solids on fish in water bodies and ponds can be a problem following torrential rains accompanied by surface runoff. The actual effect on fauna would depend on the physical characteristics of the particle. For example, larger particles having greater angularity have generally been found to be more lethal than smaller and smoother particles (Appleby & Scarratt, 1989; Newcombe, 1994a). Smaller particles can also cause mechanical damage to gill tissue and are capable of stimulating mucous production in the gill epithelium (Newcombe, 1994).

Turbidity refers to the concentration of particulate organic and inorganic matter suspended in the water column of a pond. Most ponds in Africa are supplied from perennial streams and prolonged rainfall causes a considerable rise in turbidity due to clay particles (Okorie, 1975). Organic turbidity consists of plankton and fecal matter from culture organism. Inorganic turbidity usually consists of fine clay and silts which enter the ponds from surface runoff from rainfall and from pond bank erosion.

Fish that feed on bottom dwelling organisms and sedimented organic matter, such as the mud carp (*cirrhina molitorella*) and mrigal (*Cirrhina mrigal*) also stir up pond sediments (Havens, 1991; Riise & Roos, 1997). Suspended particles have been found to significantly affect growth rate in *sarotherodon galilaeus* (McNally, 1988). The same worker found increased opercula beat and cough rates with increased level of suspended particles. In order to meet the increased demand for oxygen by the tissues, opercula activity is enhanced but this too has a limit beyond which activity stops resulting in the death of fishes.

There are several reasons why inorganic turbidity should be avoided in culture ponds. Suspended particles absorb light radiation which would otherwise be available for algal photosynthesis. Clay particles readily absorb phosphorous and ammonia making them less available for algae nutrition. The settling of these particles may remove algae nutrients from the water column (Grobbelaar, 1983).

A part from the actual physical damage on fish, the suspended solids interfere with their natural habitat when deposition occurs rendering spawning grounds and shelters unavailable. Food available to fish becomes less due to reduced algae growth as a result of increased turbidity thereby limiting the light penetration in ponds (Alabaster & Llyd, 1982). There has been some benefit from increased suspended sediments in aquatic ecosystem. These include increased protection to prey fish predators (Bruton, 1985; Doan, 1941) as well as predators themselves (Gregory & Northcode, 1993).

In this study, the effects of suspended particles on opercula beats and cough rates in *O. niloticus* was investigated. Furthermore, the hypothesis that suspended particles has influence in opercula and cough rates was tested.

MATERIALS AND METHODS

The study was conducted at the Institute of Aquaculture, University of Stirling, Scotland. *Microcystisaeruginosa* was cultured in BG11 Algal growth medium. Algae in suspension were introduced into flasks containing autoclaved BG II growth media. The initial culture was subcultured in a five liter autoclaved demijohn. The culture vessels on shelves were maintained at 28^0C and illuminated for 24 hours. The vessels were aerated and placed on Stuart SM4 magnetic stirrer. *O. niloticus* of 7.5gm mean weight fed on a micro-pelleted diet were reared in a re-cycle water system at 27^0-28^0C were selected for the experiment.

Silt particles were extracted from the mud of Airthrey Lock by sieving through a series of sieves down to 63µm. The resulting suspension was poured into 1 liter cylinder and left to settle for about 5 minutes and finer clay particles were then decanted. 100 ml of collected decanted material was re-suspended and poured into a tray placed in a drier set at 60^0C for 8-12 hours. The process was repeated until enough silt was obtained. Sand particles were obtained by sieving in series down to 68um and collected in a tray. The process was repeated until enough sand particles were collected.

Fish were transferred from rearing tank to holding tank and left for 24 hours without feeding. From the holding tanks 15 fish were taken and weighed after drying on absorbent tissue paper. Five fish of mean weight of 7.50gm were then put into three 5 liter experimental tanks with two replicates and control and left for 3 hours to acclimatize before experiment.

Two treatments of 50mg and 150mg of sand and silt were weighed separately on aluminium foil. Each of these were added algal suspension of 50mg and 150 mg dry weight. The experimental tanks were covered by black polythene with a small window on the side left for observation. The breathing and coughing rates were counted for one minute at five minutes interval. One way Anova calculated using minitab was used to determine opercula beats and cough rates.

RESULTS

The results of this work indicate that opercula beats and cough rates were highly variable over short time period. It was also seen that in general, both the opercula beats and cough rates increased with increased concentration of suspended particles. In low concentration tanks of 50mg/l of silt and algae mixtures and algae and sand there was significant increase of opercula beats ($F=15.17$, $P<0.000$) Fig.1 and cough rate ($F=65.56$, $P<0.0000$) (Fig. 2).

In high concentration tanks with 150mg/l silt and algae opercula beats ($F=1287.39$, $P=0.000$) and cough rate ($F=171.00$, $P=0.000$) both increased very significantly. In 150mg/l of silt and algae opercula beats ($F=155.68$, $P=0.000$) Fig.3 and cough rates ($F=68.69$, $p=0.000$) Fig. 4 both increased significantly.

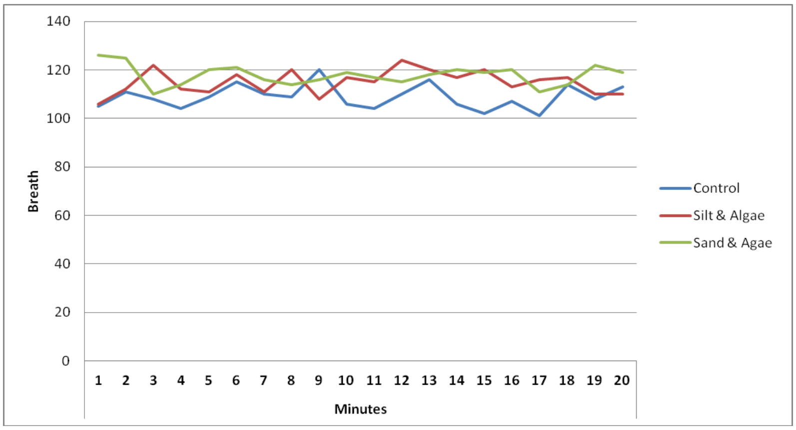

Figure 1. Opercula beats in 50mg/liter of treatments

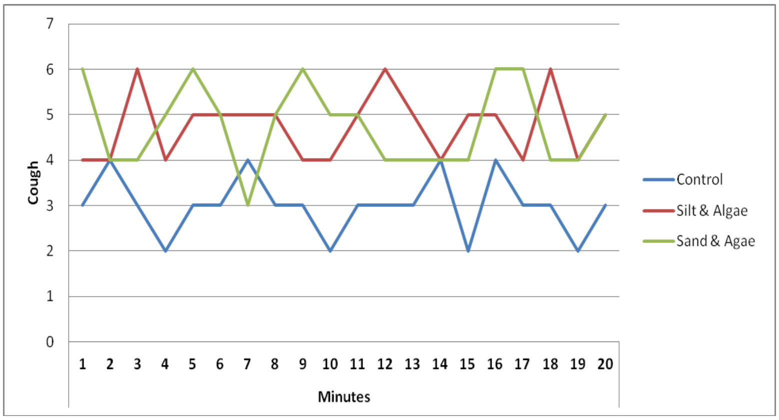

Figure 2. Cough rates in 50mg/liter of treatment

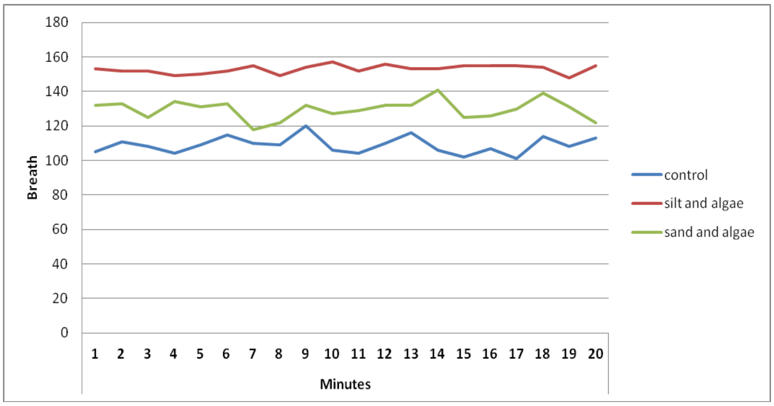

Figure 3. Opercula beats in 150mg/liter of treatments

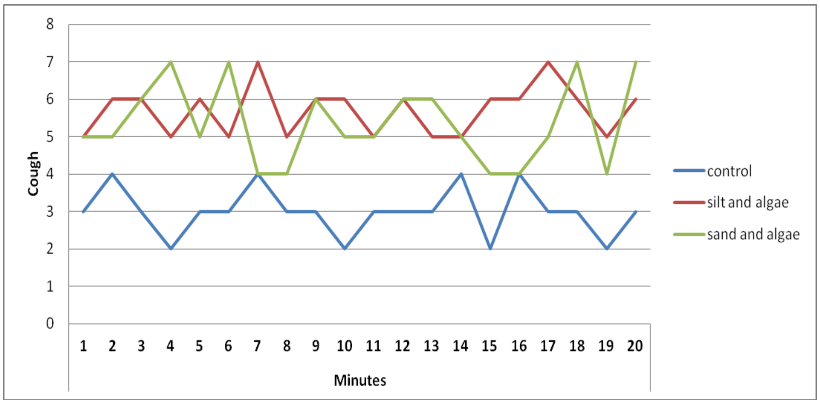

Figure 4. Cough rates in 150mg/liter of treatments

DISCUSSIONS

Several species of fish have been found to be relatively tolerant of high suspended sediments concentrations (Petticord, 1976). Fish can tolerate short episodes of extremely high levels of suspended sediments by exuding a protective mucus on the skin and gills. Avoidance is the primary fish behavioral response to locally turbid water. Avoiding areas with elevated Total Suspended Solids (TSS) or turbidity may lead to fishless reaches in natural systems (DeVore *et al.*, 1980; Birtwell *et al.*, 1984; Scannel, 1988). Excessive levels of silt clog opercula cavities and irritate gills leading to respiratory difficulties and poor health (Philips, 1971). At very high turbidities, sediment-clogged gills cease to function as oxygen exchange sites and the fish dies from a combination of anoxemia and carbon dioxide retention (Ritchie, 1972). In a study with green sunfish, Hokel and Pearson (1976) found that ventilation rates increased under highly turbid conditions to compensate for reduced respiratory efficiency while maintaining a constant oxygen uptake.

In most cases, elevated suspended sediments have sub-lethal effects. These may include increased fin rot and body abrasion (Herbert & Merkens, 1961; Ritchie, 1972). Paler coloration (Mc Leay *et al.*, 1984), delayed maturation (Reynolds et al, 1988) elevated cough frequency (Servizi & Artens, 1992), elevated micro-hematocrit (packed red blood cells volume hemoglobin concentration and red blood cell counts (Appleby & Scarratt, 1989; Redding *et al.*, 1987). The tolerance to high concentration of suspended solids varies from species to species. Tilapia, carps, and catfish can tolerate greater than 10,000 mg/l.

There was a considerable increase in opercula beat rate in silt suspension compared with levels recorded in sand suspension (McNally, 1988). He argued that the physical characteristics of the sediments such as angularity and shape may enhance the clogging of the gill surfaces, thus reducing respiratory areas, followed by increased breathing rate. He also found that cough rates increased proportionally to the suspended silt and sand particles up to a concentration of 250 mg/l. Increased breathing rate and coughing rate was seen in *Oreochromis aureus* when subjected to high densities of algae (Briggs,1985). Of key importance in considering the effects of TSS on fish are the frequency and the duration of the exposure, not just the concentration (Newcombe & Jensen, 1996). They further stated that diverse effects can become more pronounced with increased TSS concentrations and longer exposure durations in aquatic systems where elevated TSS conditions occur infrequently.

Impacts are based on intensity which is defined as the product of concentration of suspended sediments multiplied by the duration (hours) of exposure of the organism (Newcombe, 1996). Model on fish and aquatic life indicate that Severity of ill effect (SEV 5) caused minor physiological stress, increase in rate of coughing and increased respiration rate. Additional behavioral effects include gill flaring and coughing responses. These responses increase in frequency at higher concentrations (30 to 60 Nephlometric Turbidity Units (NTU), Berg and Northcode, (1985) and 230 mg/l TSS Servizi and Martems (1992) While the effects of chronic exposures to increased turbidity are evident, there is evidence that short exposures to very high turbidity (100,000ppm) have no lasting effects (Rowe *et al.,* 2003).

In this study, it can be concluded that breathing and coughing rates increased or fastened with increased concentration of suspended particles in *O.niloticus*. It can be generalized that although both trials of silt and sand showed increased breathing and coughing rates,silt particles had more effect. Using density of 106 cells/ml of algae (Briggs, 1985), andusing 500mg/l of silt and sand, McNally (1988) observed increased opercula beats andcough rates. This can be supported by the fact that silt and algae were trapped in the gills. The rate increased to compensate for the deficiency for oxygen as a result of the reduced respiratory surface. Coughing action on the other hand was an activity that necessitated the removal of irritants and perhaps larger particles such as sand which could damage the delicate gill apparatus a part from orienting the gathered particles for subsequent swallowing into the esophagus by the action of the pharyngeal pads. Although *O. niloticus* can tolerate high concentration of suspended particles in water column, very high turbidity could be avoided as it has profound effects on the behavioral and physical aspects of fish including natural habitat. Where necessary settling ponds can be constructed above the inlet to allow sedimentation before inflow into ponds

ACKNOWLEDGEMENT

I am obliged to sincerely thank Prof. Malcolm Beveridge for his support and guidance during the study. I am also grateful to the British government through the British Council for the sponsorship and Kenya government for granting me the opportunity to study.

REFERENCES

Alabaster, J., & Llyod, (1982). *Water quality criteria for freshwater fish* (2nd ed.). London: FAO Butterworth publishers.

Appleby, J. P., &Scarratt, D. J. (1989). Physical effects of suspended solids on marine and estuarine fish and shellfish with special reference to ocean dumping: A literature review. *Canadian Technical Report of Fisheries and Aquatic Sciences* No. 1681.

Birtwell, I.K., Hartman, G.F., Anderson, B., McLeay, D.J., & Malick, J.G. (1984). A brief Investigation of Arctic Grayling (*Thymallus arcticus*) and Aquatic Invertebrates in the Minto Creek Drainage, Mayo, Yukon Territory: An Area Subjected to Placer Mining. *Canadian Technical Report of Fisheries and Aquatic Sciences 1287.*

Briggs, M.R.P. (1985). *The structure and function of Tilapiine microbranchiospine with special reference to filter feeding*. M.sc Thesis, Institute of Aquaculture, University of Stirling.

Bruton, M. N. (1985). The effects of suspensoids on fish. *Hydrobiologia*, 125, 221-241.

DeVore, P.W., Brooke, L.T., & Swenson, W.A. (1980). *The Effects of Red Clay Turbidity and Sedimentation on Aquatic Life in the Nemadji River System. Impacts of Nonpoint Pollution Control on Western Lake Superior*. S.C. Andrews, R.G. Christensen, and C.D. Wilson. Washington D.C., U.S. Environmental Protection Agency, EPA Report 905/9-79-002-B,1980.

Doan, K. H. (1941). Relation of sauger catch to turbidity in Lake Erie. *Ohio J. Science*, 41(6), 449-452.

Gregory, R. S. & Northcote, T. G. (1993). Surface, planktonic and benthic foraging by juvenile Chinook salmon, *Oncorhynchus tshawytscha,* in turbid laboratory conditions. *Canadian J. Fisheries Aquatic Sciences*, 50, 233-240.

Grobbelaar, J.V. (1983). Availability of algae of N and P absorbed on suspended solids in turbid waters of the Amazon River Arch. *Hybrobiol*, 96, 302 – 316.

Havens, C.A.S., & Moll, R. (1991). Fish induced Sediment resuspension. Effects on Phytoplankton biomass and community structure in a shallow hypereutrophic lake. *J. Plankton Res*. 13(6), 1163 – 1171.

Herbert, D. W. M., & Merkens, J. C. (1961). The effect of suspended mineral solids on the survival of trout. *International J. Air and Water Pollution*, 5, 46-55.

Horkel, J. D., & Pearson, W. D. (1976). Effects of turbidity on ventilation rates and oxygen consumption of green sunfish, *Lepomis cyanellus. Transactions American Fisheries Society*, 105(1), 107-113.

McLeay, D. J., Ennis, G. L. Birtwell, I. K., & Hartman, G. F. (1984). Effects on Arctic grayling, *Thymallus arcticus*, of prolonged exposure to Yukon placer mining sediment: A laboratory study. *Canadian Technical Report of Fisheries and Aquatic Sciences* No. 1241, 96 p.

McNally, J., (1988). *The effects of suspended silt and sand particles on growth of the phytoplankton feeding tilapia,* sarotherodongalilaeus, M.sc Thesis Institute of Aquaculture, University of Stirling.

Newcombe, C. P. (1994a). *Suspended sediments in aquatic ecosystems: Ill effects as a function of concentration and duration of exposure.* Habitat Protection Branch, British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia. 298 p.

Newcombe, C.P., & J.O.T. Jensen, (1996). Channel Suspended Sediment and Fisheries. A Synthesis for Quantitative Assessment of Risk and Impact. *North American Fisheries Management* 16, 693-727.

Okorie, O.O (1975). *Environmental Constraints to Aquaculture development in Africa.* FAO/CIFA Symp. On Aquaculture in Africa, Accra, Ghana CIFA/7S/SE:1.

Petticord, R. K., (1976). *Biological impacts of suspensions of dredged material*. p. 605-615 In Proceedings of Dredging Environmental Effects and Technology.

Phillips, R. W., (1971). Effects of sediment on the gravel environment and fish production. *In* J.K. Krygier and J.D. Hall [eds.], *Forest Land Uses and the Stream Environment.* p. 64-74 Corvallis, Oregon: Oregon State University

Redding, J.M., Schreck, C.B., & Everest, F.H. (1987). Physiological Effects on Coho Salmon and Steelhead of Exposure to Suspended Solids. *Transactions of the American Fisheries Society* 116,737-744

Riise, J.C., & Roos, N. (1997). Benthic Metabolism and the effects of bioturbation in a fertilized polyculture fish pond in northeast Thailand. *Aquaculture*, 150, 45-62.

Ritchie, J. C. (1972). Sediment, fish and fish habitat. *J. Soil and Water Conservation*, 27(3), 124-125.

Scannell, P.O. (1988). *Effects of Elevated Sediment Levels from Placer Mining on Survival and Behavior of Immature Arctic Grayling.* Alaska Cooperative Fisheries Unit, University of Alaska, Unit Contribution 27.

Servize, J.A., & Martens, D.W (1992). Sublethal Responses of Coho Salmon (Oncorhynchus kisutch) to Suspended Sediments. *Canadian Journal of Fisheries and Aquatic Sciences* 49,1389-1395.