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Limno-cultural studies of *Heterobranchus longifilis* within a water recirculation system in Kaduna, Nigeria

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Abstract

The physico-chemical indices dictating ecosystemic conditions in a simple recirculation aquaculture system were investigated with a view to ascertaining limnological trends in the commercial culture of *Heterobranchus longifilis* within concrete ponds size 5 x 1.5 x 1m. Temperature, pH, total dissolved solids and electrical conductivity were measured using a Hanna combo model. Dissolved oxygen, biochemical oxygen demand, dissolved carbon (iv) oxide, nitrate-nitrogen, phosphate-phosphorus were measured following standard methods of the American Public Health Association. The mean values of the physico-chemical parameters during the culture period were 6.45, 27.25°C, 39.32cm, 6.55mg/l and 12.05mg/l for pH, temperature, transparency, dissolved oxygen and dissolved carbon (iv) oxide respectively. Generally, over the culture period, total dissolved solids and electrical conductivity increased. A slight increase in nitrate-nitrogen was observed. While, transparency decreased over time. Other parameters remained relatively stable. The relative stability in temperature, pH and dissolved oxygen over the culture period could probably be attributed to the re-circulatory nature of the production system. The use of the water recirculation system in concrete built-up ponds for intensive fish culture is recommended in terms of maintenance of water quality.

Keywords: *Heterobranchus longifilis*, limnocultural, physico-chemical, recirculation
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Introduction

In the presence of environmental stress such as low dissolved oxygen, high temperature and high ammonia, the ability of organisms to maintain its internal environment (i.e. metabolism, catabolism and reproduction) is reduced (Ezra and Nwankwo, 2001). pH and temperature values ranging from 6.7 - 9.9 and 25 - 32°C, respectively are most suitable for tropical freshwater fish culture for maximum productivity (NAERLS, 1996). Water transparency is inversely proportional to the abundance of most plankton. An increase in plankton will avail ample food availability to fish for high productivity (Dhawan and Kaur, 2002). The maximum acceptable limit for total suspended solids for industrial and agricultural waste water recommended by the United States Evironmental Protection Agency is 30.0 mg/l (APHA, 1995). Electrical conductivity of a given sample is directly proportional to the given dissolved solids present in that same sample.

The amount of dissolved oxygen is a measure of the biological activity of the water masses. Phytoplankton and macroalgae present in the water mass produces oxygen by way of photosynthesis. Bacteria and eukaryotic organisms (zooplankton, algae and fish) consume this oxygen through respiration. The result of these two mechanisms determines the concentration of dissolved oxygen. Mean dissolved oxygen in earthen ponds ranged from 5 - 10.9mg/l (Ugwamba and Ugwamba, 1993). The difference between the physical concentration of oxygen in the water (or the theoretical concentration if there were no living organisms) and the actual concentration of oxygen is called the biological demand of oxygen. The maximum acceptable limit for biochemical oxygen demand for industrial and agricultural waste water recommended by the United States Environmental Protection Agency is 30.0 mg/l (APHA, 1995). Dissolved carbon (iv) oxide values ranging from 4.5 - 60mg/1 is acceptable for fish production (APHA, 1995). Nitrogen, one of the most commonly occurring elements in nature forms many inorganic ionic species, of which the most important are nitrate, nitrite and ammonium ions. The main anthropogenic sources of nitrates in the environment are municipal and industrial wastes and artificial fertilizers (Walna *et al*., 2004). Nitrites appear as intermediates in the nitrogen cycle. They are unstable and depending on conditions, are transformed into nitrates or ammonia. Nitrogen compounds enhance eutrophication of surface waters. Organic nitrogen compounds undergo biochemical decomposition into nitrites later oxidized to nitrates. An estimated daily dose of nitrates consumed by man reaches 75 - 100mg, of which 80 - 90% come from vegetables and 5 - 10% from water (Tannenbaum and Walstra, 2000). The admissible concentrations of nitrates and nitrites in drinking water are 50mg L^{-1} and 0.5mg L^{-1}, respectively (European Council Directive, 1998). Nitrates and nitrites do not have direct carcinogenic effects on humans, but in addition to eutrophication of water bodies, there are strong concerns as to whether nitrate can cause serious human diseases such as infantile methemoglobinemia (Powlson *et al*., 2008). Nitrate is an important environmental and human health analyte, and thus its detection and quantification are considered to be essential (Narayana and Sunil, 2009). Nitrates and phosphates in metabolic waste produced by fish are the origin of most dissolved nitrogen and phosphorus waste resulting from intensive aquaculture operations. The excess of these two elements in the effluents of aquaculture systems leads to eutrophication and a consequent change in aquatic ecosystem (Jahan *et al*., 2003).

In a 5-month culture study carried out on female *H. bidorsalis* and male *C. gariepinus* hybrid in concrete tanks in Nsukka, physico-chemical parameters recorded from first to fifth month were 35.1 to 22.23, 6.70 to 7.73, 4.09 to 4.87, 0.0024 to 0.0015 and 0.0003 to 0.0005, for temperature (°C), pH, dissolved oxygen concentration (mg/l), ammonia concentration (mg/l) and nitrate level in concrete ponds at stocking density of 21 juveniles per square metre (Oguguah *et al*., 2011).

Materials and Methods

The Fish Farm Complex

The study was conducted on the Sama Farm, Mando, Kaduna. Mando is situated in Igabi Local Government Area of Kaduna, Kaduna State which falls between latitude 10º 49'06"N and longitude 6º 42' 00" E. The fish farm complex consisted of ; an indoor hatchery with four 1m by 1.2m rectangular plastic breeding troughs with a water depth of 60cm, an indoor nursery with six 5 by 1.5m dug-out rectangular concrete ponds with a water depth of 1m, sixteen 5 by 2.5m enclosed built-up rectangular concrete grow-out ponds with a water depth of 1m, and three 5 by 1.5m enclosed rectangular broodstock ponds with a water depth of 1m, a functional bore-hole, four water wells, a 5 by 4 built-up concrete reservoir, six 2,000 litres plastic water storage tanks, the sedimentation, biofiltration and ultra violet treatment chambers, various aeration units. The different sections were systematically connected in a water recirculation management system at a flow rate of 3-5 liter/minute of water. The constant flow of water and daily cleaning ensured the prevention of fouling and resultant shortage in dissolved oxygen by uneaten foods and other metabolites.

Heterobranchus longifilis Production

Induced breeding activities were carried out in the rainy seasons in July, 2012 following methods described by De Graaf and Janssen (1996). Triplicate crosses each consisting of 2 females and a male of morphometrically similar broodfish from the same genetic pool, were carried out. The synthetic hormone ovaprim was administered intramuscularly at the rate of 0.5ml/kg. Breeding indices were noted. Fishes were raised within built-up concrete ponds in a water recirculation system. They were fed decysted artemia and various pellet sizes of the durante superior fish concentrate basically containing 45% crude protein. The growth and survival rates of the F1 were calculated following recommended methods of Madu *et al*. (2003) and Fagbenro (1996), respectively over a period of 24 weeks. Cogent physico-chemical parameters were determined.

Physico-chemical Parameters

Physico-chemical parameters were determined forth-nightly, over a 22-week culture period. Hydrogen ion concentration (pH) was taken on field with a Hanna meter model HI 98107 pHep. Water temperature, Total Dissolved Solids (TDS) and Electrical Conductivity (EC) were taken on field with a HM digital Hanna combo meter, model TDS-3. Dissolved Oxygen content of the water was determined in the Hydrobiology Laboratory, Department of Biological Sciences, Ahmadu Bello University, Zaria by Winkler's tetrimetry method (APHA, 1998). Samples of water were taken in a 250ml bottle and fixed on field for oxygen by adding 1ml each of $MnSO_4$ and alkaline iodide solutions respectively. The biochemical oxygen demand was determined by difference of DO on day 1 and DO from water samples incubated in the dark for 5 days at 20°C after treatment with 1ml manganous sulphate ($MnS0_4$), 2ml alkaline iodide-azide solution and 2ml concentrated H_2SO_4, stoppering and shaking well according to approved methods by APHA (1998). The dissolved carbon (iv) oxide was calculated on titration with 0.0454N sodium carbonate (Na_2CO_3) solution. The phenoldisulphonic acid method as described by APHA (1998) was used to determine nitrate-nitrogen. Phosphate-phosphorus was determined using the Deniges method (APHA, 1995). Water transparency was measured with the aid of a weighted secchi disc of 25cm in diameter, painted in alternative black and white colours as described by Carballo *et al*. (2008).

Results

Physico-chemical Trends over the Culture Period

The pattern of fluctuations in the physico-chemical values obtained for the culture water over time is depicted in Figure 1. Generally, over the culture period, as the fish grew from of 0.9 to 1029.1 (mean weight in gram), total dissolved solids and electrical conductivity were observed to increase. A slight increase in nitrate-nitrogen was observed. Transparency was observed to decrease over time. Other parameters remained relatively stable. The mean values of the physico-chemical parameters during the culture period were 6.45, 27.25°C, 39.32cm, 6.55mg/l and 12.05mg/l for pH, temperature, transparency, dissolved oxygen and dissolved carbon (iv) oxide respectively.

Correlation between mean physico-chemical indices of water sample is shown in Table 1. Significant ($p \leq 0.05$) perfectly positive correlation was observed between total dissolved solids and electrical conductivity ($r = 1.00$), positive correlation between; temperature and dissolved oxygen ($r = 0.94$), electrical conductivity and nitrate-nitrogen ($r = 0.91$), electrical conductivity and phosphate-phosphorus ($r = 0.92$). Significant negative correlation ($p \leq 0.05$) was observed between temperature and nitrate-nitrogen ($r = -0.97$), total dissolved solids and dissolved oxygen ($r = -0.72$), dissolved oxygen and phosphate-phosphorus ($r = -0.73$).

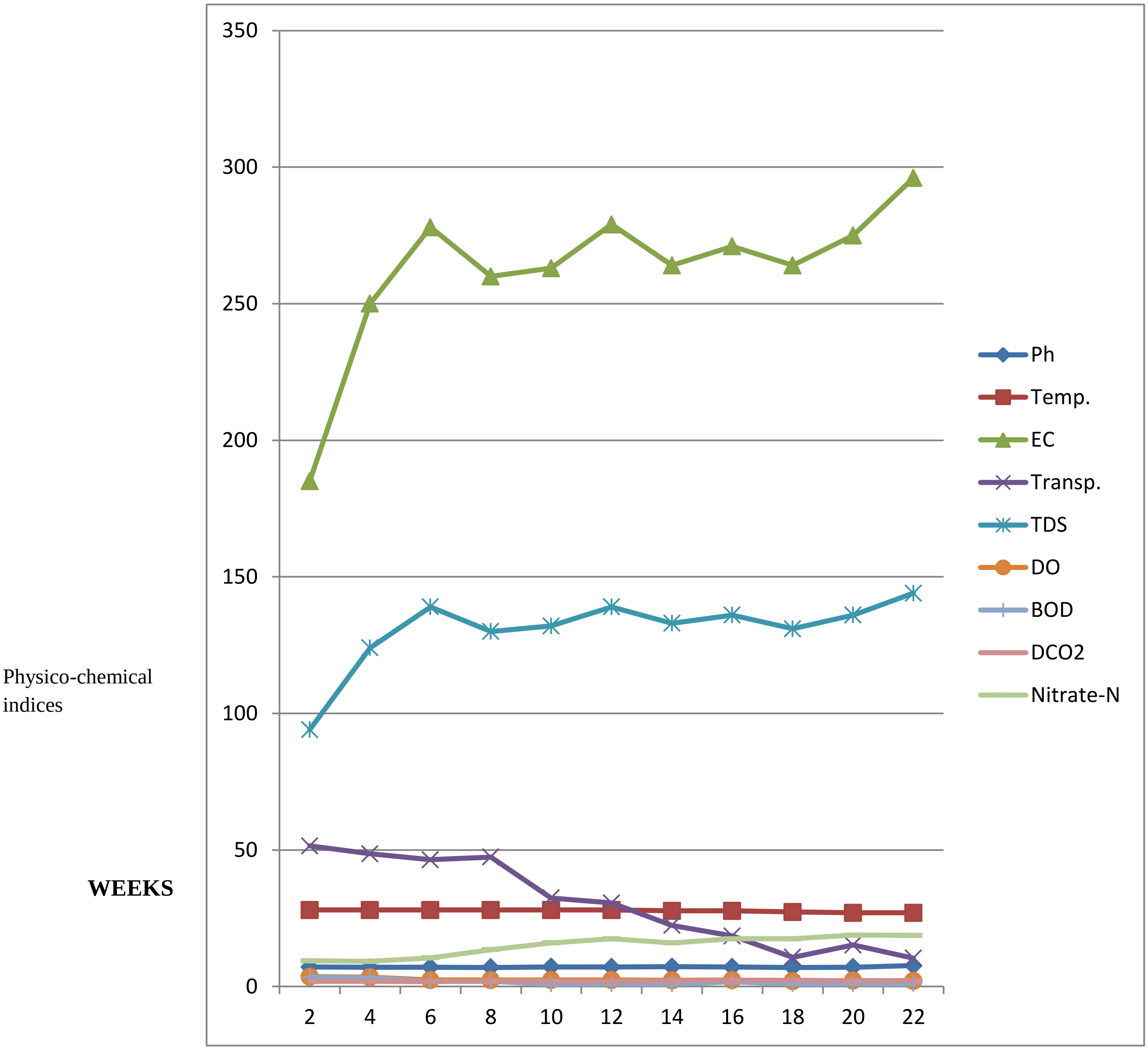

Figure 1: Fluctuations in Physico-chemical Indices through the Culture Period

Legend:

pH – Hydrogen Ion Concentration
EC (µS/cm) – Electrical Conductivity
TDS (ppm) – Total Dissolved Solids
BOD (mg/l) – Biochemical Oxygen Demand
Nitrate-N (mg/l) – Nitrate-nitrogen

Temp. (°C) – Temperature
Transp. (cm) – Transparency
DO (mg/l) – Dissolved Oxygen
DCO_2 (mg/l) – Total Dissolved Carbon (iv) oxide

Table 1: Correlation between Mean Physico-chemical Indices of Water Samples through the Period of Growth Studies of *Heterobranchus longifilis*

Para meter	Means	Std.Dev.	pH	Temp. (C)	EC (µS/cm)	Transp. (cm)	TDS (ppm)	DO (mg/l)	BOD (mg/l)	$TDCO_2$ (mg/l)	NO_3-N (mg/l)	PO_4-P (mg/l)
pH	6.4467	0.1420	1.0000									
Temp. (°C)	27.2500	1.1382	-0.4951	1.0000								
EC (µS/cm)	300.2500	133.5774	0.4833	-0.9171	1.0000							
Transp. (cm)	39.3200	15.9694	-0.43544	0.8382	-0.5866	1.0000						
TDS (ppm)	150.4167	66.7634	0.4859	-0.9178	0.9999	-0.5671	1.0000					
DO (mg/l)	6.5467	1.7010	-0.4726	0.9438	-0.9227	0.7593	-0.9227	1.0000				
BOD (mg/l)	12.8417	1.0991	-0.2169	0.5504	-0.6041	0.7731	-0.6027	0.7880	1.0000			
$TDCO_2$ (mg/l)	12.0508	0.6882	0.5093	-0.8966	0.7985	-0.7893	0.8001	-0.7165	-0.1459	1.0000		
NO_3-N (mg/l)	0.03	0.0001	0.4863	-0.9669	0.9131	-0.9114	0.9133	-0.9918	-0.7357	0.7635	1.0000	
PO_4-P (mg/l)	7.200	0.2344	0.4432	-0.8383	0.9174	-0.9372	0.9181	-0.7311	-0.2597	0.8894	0.7408	1.0000

Note: Mean of triplicate determination
Significant at 95% confidence limit
Legend:
pH – Hydrogen Ion Concentration, Temp. – Temperature,EC – Electrical Conductivity,Transp. – Transparency,TDS – Total Dissolved Solids,DO – Dissolved Oxygen
BOD – Biochemical Oxygen Demand, NO_3-N – Nitrate-nitrogen, PO_4-P – Phosphate- phosphorus,$TDCO_2$ – Total Dissolved Carbon (iv) oxide

Discussion

The pH and dissolved oxygen values in this study fall within the ranges of 6.7 – 9.9 and $\geq$ 5.0mg/l, respectively reported by NAERLS (1996) as desirable for the culture of warm water fishes. The values in this study are comparable to those reported by Adeogun *et al*. (2005), with respect to temperature (25 - 30°C), transparency (0.45 – 0.57m), biochemical oxygen demand (0.66 – 48.34), dissolved oxygen (3.0 – 10.9) and dissolved carbon (iv) oxide (5.46 to 28.3) from production ponds on six farms in Lagos and Ibadan. The mean nitrate and phosphate levels of 0.03 and 7.2 mg/l in this study are comparable with the 0.03 and 6.50 respectively reported by (Nwadukwe and Nawa, 2000) for 'Heteroclarias'.

Over the culture period as the fishes grew, the biomass of the system increased resulting in an increase in the metabolic and feed wastes generated evidenced by the slight increase in nitrate-nitrogen; an increase in total dissolved solids and electrical conductivity and a corresponding decrease in transparency, observed in this study. The relative stability in temperature, pH and dissolved oxygen over the culture period could probably be attributed to the recirculatory nature of the production system. Dissolved oxygen concentration within the water body increased with increase in temperature probably as a result of increasing photosynthetic activity resulting in a concomitant increase in dissolved oxygen (by-product of photosynthesis). Nitrate-nitrogen and phosphate-phosphorus are by-products of metabolic wastes and excess feed within production systems (Jahan *et al*., 2003) therefore resulting in increased dissolved solids, invariably increasing turbidity and reducing light penetration for photosynthetic activity resulting in lower levels of dissolved oxygen. The corresponding increase in Electrical conductivity with increasing total dissolved solids observed in this study is in tandem with the strong significant linear relationship reported by Uwidia and Ukulu (2013) for both parameters.

Conclusions

Nitrate-nitrogen increases with an increase in the biomass of the system as a result of increased metabolic activities evidenced by growth. Water transparency is inversely proportional to the total dissolved solids and electrical conductivity. The relative stability in temperature, pH and dissolved oxygen over the culture period could probably be attributed to the re-circulatory nature of the production system. The study suggests use of the water re-circulation system in concrete built-up ponds for intensive fish culture for the maintenance of water quality.

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